A Ph. D. Synopsis

ADOPTION OF FLEXIBLE MANUFACTURING SYSTEM IN INDUSTRY

Submitted to
Gujarat Technological University, Ahmedabad

Name of Student : S.H.SUNDARANI
Enrollment No. : 119997119013
Branch : Mechanical Engineering

Supervisor:
Dr. M. N. Qureshi
Associate Professor-Mechanical Engineering Department,
Faculty of Technology & Engineering,
The M. S. University of Baroda,
Vadodara, Gujarat, INDIA.

Co-Supervisor:
Dr. Sanjeev Khanna.
Associate Professor,
University of Missouri,
USA.

Doctoral Progress Committee Experts:
Dr. G. D. Acharya
Principal,
Atmiya Institute of Technology and Science, Rajkot, Gujarat, INDIA.

Dr. Mangal G. Bhatt
Principal,
S. S.Govt.Engg. College,
Bhavnagar, Gujarat, INDIA.
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1. Abstract:

Manufacturing companies face a challenge of technological innovation in competitive markets. Rapid changes in technology produce product and process with short product life cycles, short lead times with continuously changing consumer preferences with high the uncertainty that demands enhanced manufacturing flexibility not only for productivity enhancement but for survival too. The higher manufacturing flexibility offers more spare time to feed the customers with a higher product range and variety of options with high quality product and competitive price. Dynamic changes and competitive market may be captured through adoption of flexible manufacturing system.

This research is focused on the study of the adoption of flexible manufacturing system in industries by studying various barriers and intensity of barriers for adoption of FMS. These study industries which are found for willing to accept modification in present manufacturing system.

Mathematical modeling with the help of Multiple Criteria Decision Making (MCDM) like AHP or TOPSIS can be used by any industry by just finding the value of barriers. Once this is done, industry can be assessed, how they can adopt flexible manufacturing system, which are the most significant barriers for the adoption of FMS. And what will be effect on their performance indicators like financial performance, market share etc by adoption FMS. The major outcome of this research is adoption assessment and intensity of barriers assessment for successful implementation of Flexible Manufacturing System. Also to find framework for adopting FMS, that is crucial for the organization looking for the selection of FMS setup as per their main determinants of the FMS system. This procedure can be used for both old as well as new industry.

2. Brief description on the state of the art of the research topic

The Liberalization,Privatization and Globalization (LPG) of Indian economy dates back to 1991. This LPG model introduced referred three terms mainly (i) Liberalization (making the business world less complex by loosening the business norms i.e. changing investment policies, inviting foreign direct investment (FDI) in India. Removing the cap on
manufacturing, Removing licensing etc.), (ii) Privatization (Handing over of business controlled by the government to private companies), and (iii) Globalization (removal of geographical barriers for the business world). The LPG effect arising from this move has changed the business dynamics in India and throughout the globe. Under the new business regime, more cut-throat competition is seen. Business has shifted towards unstable and predictable range. Manufacturers have to devise new strategies to be on the safer side. The manufacturers still relying on conventional machining are under the greater threat because of not meeting the challenge of 4R (Right quality, Right quantity, Right cost, and Right time,).

Nowadays, Flexibility and agility in manufacturing system are highly desirable in the manufacturing system. Flexibility in manufacturing can be obtained by Flexible manufacturing system. The adoption of FMS will accrue the following benefits to manufacturers:

- Reduction in manufacturing time thus reducing lead time to meet the delivery targets
- Provides flexibility in manufacturing to reduce the risk in the uncertain business environment
- Reducing headcount, to reduce the manufacturing cost to become more competitive
- FMS would provide machine flexibility and routing flexibility to accomplish required production and productivity
- Improving customer service

Therefore, the need of the hour is to have FMS in manufacturing to overcome the manufacturing problems.

The present study is a step forward to study the present status of manufacturing industries in Gujarat, India. The present study is aimed at addressing the adoption of FMS and its related issues in manufacturing. The study is also aimed to develop various models identifying the barriers responsible for hindering the adoption of FMS.
3. Definition of the problem Research gap

Although various manufacturing philosophy like Lean manufacturing, Agile manufacturing and FMS are widely used across world. But still today adoption of FMS in industry is very low although first step for adoption of FMS is programmable machine tools (CNC) and programmable production satiation are now widely used in industry but full FMS is not adopted in industry. The gap is identified that there is no statistical measure and decision making model to compute the intensity of various barriers and frame work for adoption of FMS in industry. Despite the significant amount of work that has promoted the use of Flexible manufacturing system model building, the gap that requires further investigation to identify various barriers as per literature review and intensity of barriers for adoption of FMS, decision making modeling and frame work for adoption of FMS.

The present research pertaining to adoption of a FMS in industry also attempts to bridge the gap existing in the body of knowledge. An exhaustive and comprehensive literature review has been conducted to identify the gaps pertaining to adoption of FMS. Many barriers have been identified that are responsible for obstructing the adoption of FMS. The present research also studies the present status of manufacturing system prevailing in the Gujarat region of India and tries to collect the most needed information for upgrading the manufacturing systems.

A questionnaire based empirical study has been conducted to gauge the prevailing status of the manufacturing systems adopted in manufacturing industries and probable adoption of flexible manufacturing system. An attempt has also been made to study various barriers responsible in adopting FMS. A structured questionnaire covering hard and soft issues has been designed administered to get the insight of adopting the FMS in industry. An Analytic hierarchy process based model has been designed and applied to select the FMS system. A two-phase AHP and Group decision making (GDM) based model has been designed for the performance evaluation of Flexible Manufacturing System.

4. Objective and Scope of work

The objectives of the present research are:

- To identify and classify the key barriers in the adoption of Flexible Manufacturing System (FMS) in industry.
• To carry out a questionnaire based methodology for empirical studies leading to the adoption of the Flexible Manufacturing System.

• To compute a statistical measure for various barriers and performance indicator of adoption of FMS and to make Structural Equation Modelling (SEM) and Confirmatory Factor Analysis (CFA) Model for Adoption of FMS.

• To compute a statistical measure of various barriers and to make decision making model (MCDM) as per the intensity of various barriers for adoption of Flexible Manufacturing System.

• To develop a decision making model for the selection of the potential FMS using Analytic Hierarchy Process (AHP) by considering the various barriers for adoption of Flexible Manufacturing System.

• To make a framework for the adoption of FMS in industry. Selection of FMS setup as per their main determinants of the FMS system with the help of AHP-TOPSIS analysis.

    The research focused on identifying the existing manufacturing facility willing to upgrade for adopt FMS.

    The challenge this research attempts to address is how to improve the ability of the manufacturing industry to make a more effective decision and view for the adoption of flexible manufacturing systems (FMS).

5. Original contribution by the thesis

    The main contribution of this research is given below:

    • An extensive and comprehensive literature review is undertaken in order to identify the research gaps and research issues in the adoption of Flexible Manufacturing System in industry.

    • The detailed literature review also provides a solid platform to explore the future related research in the area of Flexible Manufacturing System.
• Statistical measure for various barriers and performance indicator of adoption of FMS and to make Structural Equation Modelling (SEM) and Confirmatory Factor Analysis (CFA) Model for Adoption of Flexible Manufacturing System.

• An AHP model has been built and applied to a case study problem for adoption of Flexible Manufacturing System.

• An AHP along with group decisions making has been introduced to gauge the performance evaluation of FMS systems.

• A IBM SPSS V22.0 based empirical analysis has been conducted to investigate the various barriers responsible to construct the adoption of Flexible Manufacturing System.

• The Structural Equation Modelling (SEM), Confirmatory Factor Analysis (CFA) and Multiple Regression Analysis (MRA) have also been conducted to derive the models for adoption of Flexible Manufacturing System.

6. Methodology of Research, Results / Comparisons

The research methodologies used in the present work are:

• Questionnaire based Survey: The survey based methodology has been employed to gain the insight for the adoption flexible manufacturing system (FMS) in industry.

• To develop Structural Equation Modelling (SEM) and Confirmatory Factor Analysis (CFA) to develop model for Adoption of FMS using IBM SPSS statistics software package version 22.0.

• Analytic Hierarchy Process (AHP) has been adopted for the selection of the potential FMS by considering the various barriers for adoption of Flexible Manufacturing System.

• To prepare two-phase AHP-TOPSIS methodology for the FMS selection has been applied to develop a model for the selection of the FMS by considering the various criteria.
This research is unique and original since similar work has not been carried out previously. This research will help manufacturing industries in three ways as shown in figure.

A questionnaire survey was conducted in person with various industries of Gujarat also questionnaire were emailed to industries also Google doc was created and the link was emailed and personal visit to manufacturing industries. After continuous follow up 172 usable responses were collected from 198 manufacturing industries and used for further analysis. Gujarat is one of the leading Indian states, in terms of highly populated mechanical industries with core expertise of machining using FMS. Considering the fast industrial development, installations of number of FMS setups and its increasing potential users, it is ideal choice to study the research objectives.

Data analysis consists of various descriptive statistics as below.

- Frequency and percentages.
- Analysis of Variance (ANOVA)
- Confirmatory Factor analysis (CFA)
- Multiple Regression analysis (MRA)
Adoption barriers for FMS are grouped into seven major categories. To identify intensity of barriers and sub-barriers in the path of adoption of FMS. All sub-barriers are quantified on linear scale as per intensity in path for adoption of FMS. Also to check reliability of data collected through questionnaire survey, reliability test carried out and found satisfactory as shown in Table 1 value of cronbach's alpha is showing reliability of data.

### Statistical analysis

**Reliability Analysis**

- **Multiple Regression Analysis**

- **IBM SPSS** Statistics is a software package used for logical batched statistical analysis for present research work.

- **IBM SPSS** Statistics is an integrated family of analysis software with capabilities to help to address every stage of the analytical process.

### Table -1

<table>
<thead>
<tr>
<th>Adoption barriers for FMS</th>
<th>No of items</th>
<th>Cronbach’s Alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human Resources Behavior barriers</td>
<td>06</td>
<td>0.782</td>
</tr>
<tr>
<td>Technological barriers</td>
<td>06</td>
<td>0.859</td>
</tr>
<tr>
<td>Operational barriers</td>
<td>06</td>
<td>0.765</td>
</tr>
<tr>
<td>Investment and Financial resources barriers</td>
<td>05</td>
<td>0.712</td>
</tr>
<tr>
<td>Strategic and planning barriers</td>
<td>06</td>
<td>0.878</td>
</tr>
<tr>
<td>Supply chain and Logistic barriers</td>
<td>04</td>
<td>0.715</td>
</tr>
<tr>
<td>Miscellaneous barriers</td>
<td>04</td>
<td>0.706</td>
</tr>
</tbody>
</table>
Table -2

<table>
<thead>
<tr>
<th>Performance indicator for FMS</th>
<th>No of items</th>
<th>Cronbach’s Alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Financial</td>
<td>04</td>
<td>0.763</td>
</tr>
<tr>
<td>Customers/Market Measure</td>
<td>11</td>
<td>0.898</td>
</tr>
<tr>
<td>Process</td>
<td>12</td>
<td>0.912</td>
</tr>
<tr>
<td>People</td>
<td>03</td>
<td>0.756</td>
</tr>
<tr>
<td>Future</td>
<td>03</td>
<td>0.712</td>
</tr>
</tbody>
</table>

Identification and categorization of barriers

<table>
<thead>
<tr>
<th></th>
<th>Human resources Behaviour barriers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Uncertainty and fear of failure</td>
</tr>
<tr>
<td>Mean</td>
<td>3.72</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>0.84</td>
</tr>
<tr>
<td>Intensity of barriers</td>
<td>Very High</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Technological barriers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Difficulty in the use of high tech-equipment like AGVs, robots, AS/RSs etc.</td>
</tr>
<tr>
<td>Mean</td>
<td>2.44</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>0.94</td>
</tr>
<tr>
<td>Intensity of barriers</td>
<td>Moderate</td>
</tr>
<tr>
<td>Operational barriers</td>
<td>Resource failures</td>
</tr>
<tr>
<td>--------------------------------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>Mean</td>
<td>2.33</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>1.04</td>
</tr>
<tr>
<td>Intensity of barriers</td>
<td>Moderate</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Investment and Financial resources barriers</th>
<th>High cost of FMSs</th>
<th>Non-availability of funds</th>
<th>High taxes like sales tax, excise duty etc.</th>
<th>Poor rate of return over investment</th>
<th>Long payback period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>3.59</td>
<td>3.58</td>
<td>3.14</td>
<td>3.34</td>
<td>3.09</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>0.99</td>
<td>0.98</td>
<td>0.99</td>
<td>0.97</td>
<td>1.04</td>
</tr>
<tr>
<td>Intensity of barriers</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>High</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Strategic and Planning barriers</th>
<th>FMS planning problems</th>
<th>Low throughput time</th>
<th>Unfavourable government polices</th>
<th>Flexibility measurement problems</th>
<th>Non-availability of good vendors</th>
<th>Failure to carry out feasibility studies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>2.31</td>
<td>2.27</td>
<td>2.25</td>
<td>2.36</td>
<td>2.55</td>
<td>2.55</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>0.88</td>
<td>0.84</td>
<td>0.93</td>
<td>0.82</td>
<td>0.84</td>
<td>0.98</td>
</tr>
<tr>
<td>Intensity of barriers</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
</tbody>
</table>
## Logistical and supply chain barriers

<table>
<thead>
<tr>
<th></th>
<th>Vendor selection problems in the supply of high-tech equipment</th>
<th>Big losses of market share during transition periods</th>
<th>Lack of supply chain planning and coordination</th>
<th>Demand uncertainties</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean</strong></td>
<td>2.48</td>
<td>2.40</td>
<td>2.28</td>
<td>2.47</td>
</tr>
<tr>
<td><strong>Standard Deviation</strong></td>
<td>0.96</td>
<td>0.78</td>
<td>0.76</td>
<td>0.89</td>
</tr>
<tr>
<td><strong>Intensity of barriers</strong></td>
<td>Moderate</td>
<td>Moderate</td>
<td>Low</td>
<td>Moderate</td>
</tr>
</tbody>
</table>

### Miscellaneous barriers

<table>
<thead>
<tr>
<th></th>
<th>Energy Cost</th>
<th>Cost of upgrading of systems</th>
<th>Cost of recycling/refurbishing of machine systems</th>
<th>Location and geographical sub barriers</th>
<th>Price sensitivity and customer support for high quality products</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean</strong></td>
<td>2.37</td>
<td>2.38</td>
<td>2.43</td>
<td>2.35</td>
<td>2.17</td>
</tr>
<tr>
<td><strong>Standard Deviation</strong></td>
<td>0.95</td>
<td>0.92</td>
<td>0.89</td>
<td>0.85</td>
<td>0.76</td>
</tr>
<tr>
<td><strong>Intensity of barriers</strong></td>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Low</td>
</tr>
</tbody>
</table>

Various descriptive statistics such as Frequency and Percentage, Mean, Standard deviation, Minimum value and Maximum value are calculated with the help of Statistical Package for social Sciences (SPSS). SPSS Statistics is a software package used for logical batched statistical analysis for present research work. IBM SPSS Statistics is an integrated family of analysis software with capabilities to help to address every stage of the analytical process.

Various Multivariate Data Analysis techniques such as Confirmatory Factor Analysis (CFA), Structural Equation Modelling (SEM) and Multiple Regression Analysis were performed.

Confirmatory Factor Analysis (CFA) was performed to confirm two proposed models. First Model was proposed after confirming individual constructs of Flexible
Manufacturing System Barriers. Second Model was proposed for Performance indicators of Flexible Manufacturing System. Both Proposed models were tested by using First Order Confirmatory Factor Analysis. After confirming both models, Researcher tested a Model representing relationship between Barriers of FMS and Performance indicators of FMS by using Structural Equation Modelling (SEM). The relationship between Flexible Manufacturing System and Performance of the organization was then tested with the help of Multiple Regression Analysis.

Structural Equation Modelling (SEM) shows that statistical measure for various barriers and performance indicator of adoption of FMS are very much correlated. Confirmatory Factor Analysis (CFA) shows that all performance indicator of adoption of FMS are having direct effect with changes in barriers of FMS. Multiple Regression Analysis for Performance Indicator for adoption of FMS with barriers shows that adoption of Flexible manufacturing system has a significant positive impact on all performance Indicator.

Confirmatory Factor Analysis model for adoption barriers of FMS fitted data well. Based on three types of Fit measures (Absolute, Relative and Parsimonious) it was concluded that the Data fits the Model. From Human Resource Barrier, The barrier H3 has highest factor loading indicating highest contribution in terms of variance for Human Resource Barrier. In terms of Technological Barrier T2 is having highest factor loading indicating highest contributing in terms of variance of Technological Barrier. Similarly it can be interpreted for OP3 for operation barrier, IF2 for Information Technology barrier, SP3 for Supply Chain Barrier, LS2 for Logistics Barrier and MS1 for miscellaneous Barrier.

Similarly for Performance indicator Model, based on three types of measure, it can be concluded that the data fits the model. For financial Performance, FP2 is having highest loading, indicating highest contribution in terms of explaining variance for financial Performance. Similarly it can be concluded that CP2 is contributing highest amount of variance for Customer Performance, PP6 is contributing highest amount of variance for Process performance, PEP3 is contributing highest variance for People performance and FTP 3 is explain highest amount of variance for Future performance.

The SEM model developed to study the relationship between Barriers and Performance indicators for Flexible Manufacturing System is also found to be fitted well. The majority
of the standardized regression coefficients were found to be negative indicating negative relationship between barriers and performance indicators. Hence it can be concluded that as the barrier for adoption decreases, the performance in the area of Finance, market or Customer, People, Process and Future increases. The Unstandardized coefficients are tested for its significance. Majority of the relationships are found significant.

**Multiple Regression Analysis:**

This technique was used to predict the dependent variables performance indicator of FMS (Performance Measurement factors) from independent variables i.e. adoption barriers for FMS (Success Factors). The factor scores were used to run the analysis. Each model predicts the performance factors from the factor scores of success factors.

**Model : 1**

**Dependent Variable: Y= Financial Performance**

**Independent variables:**

X1= Human resources behaviour barriers  
X2= Technological barriers  
X3= Operational barriers  
X4= Investment and Financial resources barriers  
X5=Strategic and planning barriers  
X6= Logistical and Supply Chain barriers  
X7= Miscellaneous barriers

**Similarly**

**Model : 2**  
**Dependent Variable: Y= Customer Performance**

**Model : 3**  
**Dependent Variable: Y= Process Performance**

**Model : 4**  
**Dependent Variable: Y= People Performance**

**Model : 5**  
**Dependent Variable: Y= Future Performance with...**
X7= Miscellaneous barriers

With 

\[ Y'_1 = b_0 + b_1X_{1i} + b_2X_{2i} + b_3X_{3i} + b_4X_{4i} + b_5X_{5i} + b_6X_{6i} + b_7X_{7i} + \varepsilon \]

Carried out and found satisfactory ,The R^2 for all the model were above recommended value and p value were also found significant for all the five model

**Structural Equation Modeling:**

Confirmatory Factor Analysis Performance factors and Linking Barriers with Performance Factors by using Structural Equation Modelling was carried out. the developed model were tested by using SEM with the help of IBM® SPSS® Amos the test statistics was found above recommended values and the model was found significant

**T- Test and ANOVA analysis:**

Linking Structural Details with Barriers and Performance factors by using t test and ANOVA carried out

T test and ANOVA analysis was performed to find about significance difference in Performance factors.

**Mathematical modeling by the Analytic Hierarchy Process (AHP)**

The adoption of Flexible Manufacturing System (FMS) in industry faces the challenges of many barriers. These barriers possess varied the influence ranging from minor to major for the adoption of FMS in industries. It has been of great significance to the manufacturing managers, if the influences of such barriers are completely understood before adopting the FMS in industries. In this chapter all barriers discussed in previous chapters are modeled using Analytic Hierarchy Process (AHP). AHP helps in quantifying the influence of such barriers that pose hindrance in the adoption of FMS.

After the synthesis of AHP pairwise comparison of each decision matrix, the local and final weightages are obtained. On Arranging the global weightages in descending order the final ranking of all the 35 barriers are obtained. In order to understand the main influence of
the barriers, the main barriers are prioritized and ranking is shown in Figure 5.4. The prioritized main barriers are ranked in the descending order of Investment & Financial barriers (0.2644), Human Resources Behavior barriers (0.1853), Technological barriers (0.1472), Operational barriers (0.1363), Supply chain and Logistic barriers (0.1152), Strategic and planning barriers (0.0858), and Miscellaneous barriers (0.0719). This shows that an Investment & Financial barrier has a significant effect on the adoption of FMS in the industry and it is quantified as 26.44%. The least effect found to be of Miscellaneous barriers and it is quantified as is 6.57%. The sub-barriers are also ranked and are shown in Figure

![Main Barriers for Adoption of FMS](image)

**Framework for adopting FMS**

Framework for adopting FMS is crucial for the organization looking for the selection of FMS setup. The selection involves set of attributes which must be included in decision support system. Any attributes missing may cost profoundly to the organization. A systematic framework is very crucial to meet the need of organizations looking FMS setup for their specific need.

Before actual implementation of FMS, simulating and modeling practices which are widely used in FMS evaluation may be applied virtually. Thus saving time, cost with
flexibility in accommodating additional features may be added if required.

An organization may face technical as well as a managerial problem while installing FMS setup. Technical problem may come up with the degree of complexity and the selection alternatives available whereas the resistance to change could be the strongest managerial problem mostly envisaged globally. The organization must comply with the required infrastructure to make an ideal fit between FMS setup and infrastructure requirement. An organization may fine tune their FMS requirements to ease out FMS configuration. Management plays a decisive role in realizing the FMS need. Precaution must be taken at every stage as the selection decision could be costly and may be misleading.

**Procedural steps for establishing best FMS setup**

1. Establishing FMS needs
   Production Qty, Processing Time

2. Decision Support System for
   M/C Tool, Layout, Material Handling
   System(AS/RS), Inspection / Work
   Station, Human Involvement

3. Simulating for attaining desired objectives

4. Establishing best FMS Setup

Before actual implementation of FMS simulating and modeling practices which are widely used in FMS evaluation may be employed virtually. Thus saving in time, cost with flexibility in accommodating additional features is realized

Organization may face technical as well as managerial problem while installing FMS setup. Technical problem may come up with the degree of complexity and the selection alternatives available whereas the resistance to change could be the strongest managerial
problem mostly envisaged globally. Organization must comply with the required infrastructure to make an ideal fit between FMS setup and infrastructure requirement. Organization may fine tune their FMS requirements to ease out FMS configuration. Management plays a decisive role in realizing the FMS need. Precaution must be taken at every stage as the selection decision could be costly and might be wrong one as well.

A two-phase AHP-TOPSIS methodology concerning the FMS selection problem is developed which is illustrated using a case problem. Later on, evaluation and comparison of various FMS has been carried out using two-phase AHP-TOPSIS methodology.

7. Achievements with respect to objectives

This work may provide important managerial implications with general result which are summarized below:

• The work reveals state-of-the-art practices and related issues of adoptions of flexible manufacturing system in manufacturing industries. This information may provide a great insight to practitioners i.e. manufacturing managers.
• FMS essentially enhances firm’s competitiveness thus boost its position in competitive market. The present framework work will help organization to make correct decision in selecting suitable FMS system in a holistic way
• An AHP based mathematical model is derived for selection of flexible manufacturing system in manufacturing industries outsourcing relationship could prove to be a vital tool for enhancing the productivity and competitiveness of manufacturing industries.
• A two-phase Analytic Hierarchy Process and Group Decision Making (GDM) based model may give sufficient choice to manufacturing managers to select feasible adoption of flexible manufacturing system in manufacturing industries.

The major outcome of this research is adoption assessment, intensity of barriers and performance improvement indicators for successful implementation of Flexible Manufacturing System. The procedure can be adopted for both old and new industry.
8. Limitations and future scope of study

Apart from several benefits, the present research has few limitations as well. The following summary of limitations pertaining to this present research may provide clear insight and understanding in adopting Flexible Manufacturing System in industry. The limitations may be considered by the researchers in this field to carry out further work.

The questionnaire based study reflect the opinion of respondent manufacturing managers, engineers, experts etc. hence the opinion expressed represent the opinion of key factors in the adoption of Flexible Manufacturing System.

The research related to Flexible Manufacturing System in the Gujarat region is scarce. Hence the status of Flexible Manufacturing System may be relatively new in this region. Hence the ongoing practices adopted for the adoption of flexible manufacturing system, selection of FMS, Performance evaluation of FMS are incorporated using various modeling may not be generalized in larger interest.

9. Conclusion

A modest attempt has been made to help the manufacturing managers, industrialist in selecting various criteria, for the selection of flexible manufacturing system, in crisp and fuzzy environments based on various approaches. Looking at the merits and demerits of each approach manufacturing managers may employ a suitable model to meet their different needs. It is hoped that the research work presented will be fruitfully used by the manufacturing managers and the future researchers in this area. It is further anticipated that the present work will provide a strong basis for the adoption of Flexible Manufacturing System in Industry.

10. Copies of papers published and a list of all publications arising from the thesis

Following papers are published/presented at national/international level journals/conferences.

1. Sundarani,S.H. Mohsin Khan, Qureshi,M.N. (2010), Adoption of Flexible Manufacturing System (FMS) in Industry, National Conference On Advances in Mechanical Engineering (NCAME-10) Aligarh Muslim University, Aligarh-202002, U.P., India


**Patents (if any)**

Not applied for any patent.

11. **References**


Chen, I., 2006. manufacturing systems.


Raj, T. et al., 2010. A graph-theoretic approach to evaluate the intensity of barriers in the


