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Journal of Analytical Research

Vol 1 - Issue 2, Jun-Dec 2021
www.rsya.org/jar

Design and Development of Flexible Manufacturing System (FMS)

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Abstract

However, there is evidence that the deployment of flexible manufacturing systems (FMS) might be a challenge. As a consequence, FMS is being implemented at a considerably slower pace than anticipated. The purpose of this study is to examine several methods for developing an FMS. Work done so far on the design of an FMS is reviewed in the areas of facility design; material handling system; control system design; and scheduling. Research and development problems are outlined in each case The lack of an integrated design process for FMS may be shown by reviewing the tools and methodologies utilised to create these four stages. It is difficult to find tools that are precisely adapted to FMS and its unique integrated form. In the absence of integration, it is necessary to build an FMS by considering each of the four phases separately, even if choices made in one area influence the effectiveness of the other areas.

Keyword FMS, AGV, Manufacturing,

1. Introduction

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 [1]. The manufacturers still relying on conventional machining are under the greater threat because of not meeting the challenge of 4R (Right quantity, Right quality, Right time and Right cost,). Nowadays, Flexibility and agility in manufacturing system are highly desirable in the manufacturing system [2]. 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.

2. Manufacturing System

It is possible to describe a manufacturing system as an organised organisation and operation of fundamental resources such as equipment and tools as well as material and personnel. A steady stream of information about products or services that have added value and may be used to calculate the final product's cost and its manufacturing or service cost. Basic resources i.e. 7Ms (Management, Manpower, Machine, Material, Method, Money, Matrix) are always scarce. The optimized use of basic resources may provide the required competitive advantages to remain in the market and beat the fierce competition [3-5]. Manufacturing is depicted in Figure 1 requires the use of automation in manufacturing practices that covers the use of Automated machines (Computer Numerical Controlled machines), Automatic Storage and Automatic Retrieval System (AS/RS), Automated Material Handling System like Automated Guided Vehicles (AGV), Robots.

2.1 Introduction to Flexible Manufacturing System

Automated machine cells with a collection of processing workstations linked to an automated material handling and storage system comprise the Flexible Manufacturing System.

• Work orders, production schedules, component programmes, and tooling for various parts families may all be accommodated by the FMS programmable machining system design [6].

• A manufacturing system must be able to do the following three things:

Identification and differentiation of incoming product or component styles, Quick changeover of operating instructions, Quick changeover of the physical set-up of the machine

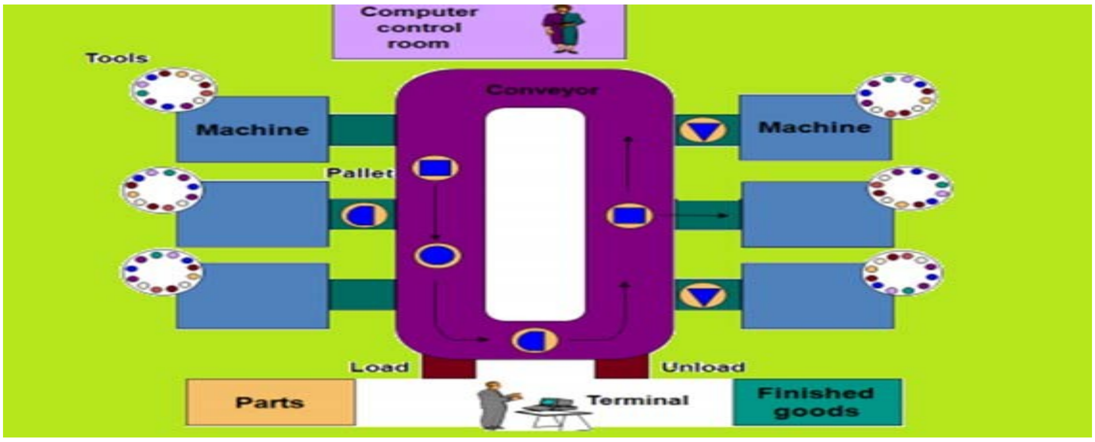

Figure 1: Typical Flexible Manufacturing System

Figure 2 shows the typical Flexible manufacturing system. In the FMS, the raw materials are entered into the system and loaded on the CNC machine tool with the help of pick and place robot. The loaded part is machined and processed completely on the machine. The loading and unloading are completed using robots and transferred to next machine using automated conveyor provided in the system [7]. The machining process is accomplished using CNC program. The raw material is being transferred from one station to another workstation using dedicated pallet. CNC machines tools are equipped with Automated Tool Changers (ATC) comprising of tool magazine to cover the wide range of manufacturing process required. Automated guided vehicles (AGV) are incorporated in the system to transfer the machined components from workstations to warehouses [8]. The AGV are driverless computer operated vehicles handles the material transfer related activities effectively and efficiently. Finished parts later on stored in automatic storage and retrieval system (AS/RS). The basic components of the Flexible manufacturing system are shown in Figure 1.3 and described as follows:

(i) In a production system, workstations are simply CNC machines that are used to conduct machining operations on different components [9].

(ii) Moving components from one processing station to another is part of an automated material handling and storage system. It may also be connected with a storage system.

(iii) In a flexible manufacturing system, the computer control system is employed to coordinate the processing stations and material management.

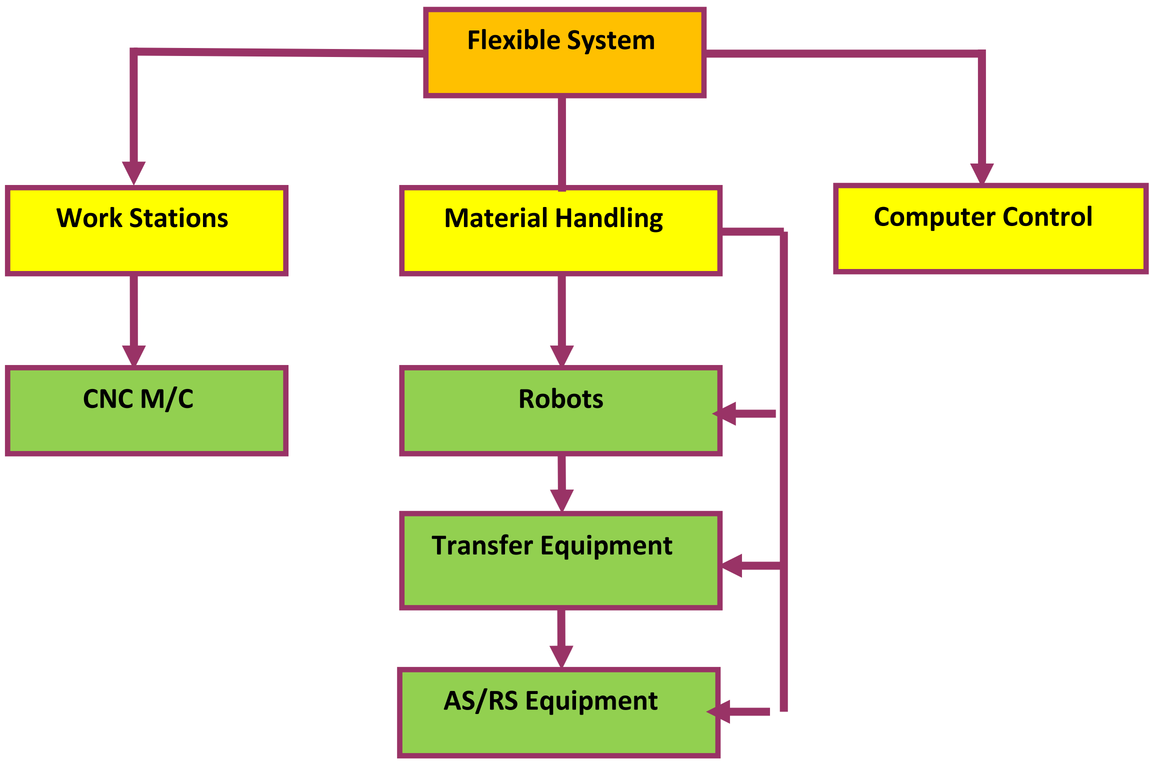

Figure 2: Various Elements of Flexible Manufacturing System

2.2 Future Trends in Flexible Manufacturing System

Cost-effective production systems are constantly in demand in the face of severe competition in order to remain competitive in the face of often updated and altered products. Conventional DMSs may be tailored to match the specific needs of the industrial process. A common complaint with DMS is that they are expensive and only useful in a small number of situations. Furthermore, it will not be able to respond quickly enough. As a result, an FMS is built to handle a wider range of production needs [10]. Reconfigurable Manufacturing Systems (RMS) were developed as a new production paradigm to solve the difficulties of cost-effective machine tools and responsive manufacturing systems. Customizable flexibility and cost-effectiveness make the RMS superior than the FMS in terms of meeting unique production needs. RMS is able to meet all of your production needs in terms of cost-effectiveness, robustness, and customization. An important benefit of RMS is its ability to adapt quickly to changing production demands [11-12]. RMS is being hailed as the most demanding and beneficial technology because of its broad range of capacity modifications, ability to accommodate a wider range of products, and faster changeover time. The modular nature of RMS makes it simple to integrate with other production systems, so it can communicate with them without encountering any difficulties. To be an independent modular machine with open-architecture controls, RMS will need further research and development, as well as the necessary expertise and staff training.

3. Literature Review

The present chapter deals with the Flexible Manufacturing System related issues like brief scenario, various components of FMS and future trends in FMS. It also includes motivation for the research and comprehensive review of literature. The literature encompassing various issues related to FMS like definition, classification of available literature, various enablers, barriers, advantages, disadvantages and success of FMS is presented. For the current study, the literature review serves as a firm basis, and it may also be useful for future research endeavours. To compete in today's market, contemporary manufacturing companies must be able to produce customised, high-quality goods in small batches with short lead times due to increased worldwide competition. This is the common problem faced by all modern manufacturing companies [13-14]. The main aim behind installing the FMS setup is to prepare variety of components at low to medium volumes efficiently. Several activities including manufacturing, controlling tool wear, transferring parts from work center to another work center, incorporating setup, quality control through inspection, tool installation and adjustment, incorporating material handling, implementing scheduling and dispatching are embedded automatically with the application of computer.

FMS is a manufacturing setup possessing numerically controlled machine tools and material handling equipment, which are centrally controlled. Selection of an appropriate FMS is complex in nature and requires comprehensive considerations as it involves huge capital investment. Because of fierce competition all over the world, it is very important to select the right machine setup to meet the challenges. Many alternatives are being considered before coming to the final decision. The selection of final alternative candidate is fixed on the basis of many criteria. These criteria may be of tangible or intangible in nature.

As a result, a search technique was devised to assist with the data collection procedure. Data sources and keywords were identified in order to concentrate on a broad range of databases, conference proceedings, books, libraries, and [15] articles from online journals as the primary sources of information. For the review, the search was limited to articles that were published between 1980 and 2016.

3.1 An Overview of Definitions of Flexible Manufacturing System

An automated material handling system connects a large number of programmed machine tools, allowing the system to create an immense number of different goods. Many sectors cannot afford conventional FMS, which are big, complicated, and costly production facilities in which computers operate all of the machinery that finish the process. As a result, flexible manufacturing cells, which are smaller variants of FMS, are becoming more popular. Many CNC machines are now designated a Flexible Manufacturing Cell (FMC), and a Flexible Manufacturing System (FMS) is a collection of multiple cells. CNC machine tools, networked by an automated material handling system with the capabilities of Automated Storage/Retrieval Systems (ASRS), are part of a flexible manufacturing system. Customers' needs and specifications for every product are always shifting in today's industry. A manufacturing system's ability to compete in the market depends heavily on its ability to swiftly adapt to these changes. A Flexible Manufacturing System has been defined by many researchers from time to time. FMS can accomplish production flexibility as well as high productivity to meet customer demand in the fierce competitive market [16]. FMS is a manufacturing system consisting of computer-controlled machine tools along with material handling equipment which are working in coordination with the highly efficient production system involving medium size production volume involving medium size variety. Looking to these definitions it has been found that most of them are defining the manufacturing system involving automated tools and material handling system normally integrated with computer. These definitions also hint towards production volume and product variety which is very important aspect in modern production system. It has also been understood from various definitions that such system provides higher production efficiency. Generally, the literature may be classified according to the focus area. Some of these focus area are Factors pertaining to FMS, Decision problem in FMS, Decision problem in scheduling, FMS performance related studies , Miscellaneous studies in FMS and Review based studies in FMS. A comprehensive review is presented on Flexible Manufacturing System covering various aspects referred in various literatures available on FMS. Literature has been suitable classified and presented under separate heading in order to provide up-to-date information of that section of FMS. It covers various definitions, Production system, Modeling, Performance analysis, current state and future trends in FMS. Later part of the review refers to the research methodology adopted in the present work [17]. Literature review plays an important role in evaluating the literature of a particular area. Lists limits of ideas and points of view assist the reader in examining and finding gaps in current knowledge that are present in the text. There are several ways to describe how research is conducted, but the most common is that it begins with an examination of prior studies [18]. When doing research, it is essential to conduct a literature review. This chapter provides a comprehensive review of the literature on FMS modelling. Modeling flexible manufacturing systems may be done in a variety of ways, and the literature reflects this. An introduction and a review of many papers relating to mathematical, knowledge-based, and hybrid methods are provided in order to harness the potential of these approaches in the area of FMS research. Here are a few of the modelling strategies evaluated and provided to help researchers in the subject of FMS modelling: mathematical programming models, multi criteria decision making models, hierarchical models, artificial intelligence models and petri net models [19]. There was a literature study on FMS by Sundarani and Qureshi that emphasised the various implementation strategies. In addition, the research focused on the implementation of FMS in industries and the challenges they encounter. Additionally, the authors outlined a number of potential applications for FMS. A review of the most recent scheduling studies revealed a number of issues. Scheduling in job shop systems is a difficult issue to solve when the goal of the manufacturing system is to minimise the makes pan and waiting times in production [20-21]. Kusiak presents FMS design and operation issues in an organised manner. FMS's automated storage and computer-aided design system are also shown, which illustrates a model of the integration of the fabrication, machining, and assembly systems. The various steps of the part's production. The first step was to pick the components that will be produced, and then to develop a numeric control programme [22-23].

4. FMS Selection

A systematic in-depth literature review has been carried out to identify the various criteria for FMS selection problem. Many researchers have conducted the various studies in the field of FMS selection. Various methodologies and modeling approaches have been put forwards for the FMS selection wherein various criteria have been considered and subsequently used for a selection process. For an example, FMS selection could be based on the various aspects like FMS productivity, FMS advantages, FMS enablers, FMS barriers. Various criteria for affecting, the FMS productivity are People, Quality, Machine and Flexibility Based on the major criteria of Line Efficiency, Performance, Process, Volume and Configuration Control, FMS assessment may be carried out. Economic cost, production flexibility, and organisational response are all influenced by FMS considerations. Machine utilisation is a subcategory of these primary criteria. Set-up time, labour, etc. are all reduced. Criteria of Prime Importance Part Mix, Design Change Accommodation, and Scheduling and Control are all examples of processes that may be categorised as performance. With regard to Configuration Control (DC), it is possible to classify Delivered Accuracy (DA), Manufacturing Precision (MP), and Design Complexity (DC).

All of the FMS selection criteria and sub-criteria have been analysed. It has been decided to seek the advice of three senior executives from multinational corporations (MNCs). After consulting with experts, the primary criteria and sub-criteria for the selection of an FMS have been determined.

4.1 Main Criteria

a) **Line Efficiency:** The ratio of total workstation time to the product of cycle time and the number of available workstations may be described as line efficiency. Line efficiency is governed by Machine utilization, Direct and in-direct labour to operate the machine and set up time between the jobs.

b) **Performance:** The efficiency of FMS is a critical aspect in increasing output and productivity. The performance is influenced by Production lead time and In-process inventory.

c) **Process:** FMS process is a significant aspect as it influences its utility in a big way. It is influenced by many sub-criteria such as Part mix, Design change accommodation, Scheduling and control, Ease of operation, Routing Flexibility etc.

d) **Volume:** Volume of production largely influence the profit earned on such production thus justifies the FMS usage. The volume of FMS production is influenced by installed Production capacity and Capacity growth cover

e) **Configuration control:** The FMS configuration control contributes overall functioning of FMS unit. It delivers the required machined components meeting the required specification in terms of accuracy and design. The FMS configuration control is governed by sub- criteria such as Delivered accuracy, Manufacturing precision, and Design complexity.

5. The application of proposed method

Step 1: Decomposition: Structuring the decision issue into a hierarchy with the use of decision makers, group decision or survey approach.

In this stage, the main-criteria and sub-criteria of the FMS decision issue are identified. The choice issue was broken into three level hierarchy containing Goal, Main criterion, Sub-criteria, and Alternatives. In the level 1, the major main-criteria of FMS selection have been determined. Line Efficiency (LE), Performance (PER), Process (PRO), Volume (VOL) and Configuration Control (CC) are regarded as major criteria. Level 2 covers the sub-criteria of each major requirement. The Line Efficiency (LE) contains three sub-criteria including Machine Utilization. Reduced Labour and Set-up time. Main Criteria Performance (PER) may be defined as In-process inventory and Production Lead Time, Process (PRO) may be classified as Part Mix, Design Change Accommodation and Scheduling and Control. The Volume (VOL) may be defined as Production capacity and Capacity Growth while Configuration Control (CC) may be classified as Delivered Accuracy, Manufacturing Precision, and Design Complexity. At the level 3, three FMS alternatives are designated as FMS1, FMS2 and FMS3.

Step 2: Comparative Judgments: The different matrixes are created using pair-wise comparisons by evaluating the interactions of all main-criteria and sub-criteria with regard to each main-criterion and sub-criteria. Similarly, pair wise comparison of sub-criteria may be carried out. The relevant weights computed for each main- criteria are presented in final column. Later on, these weights thus acquired are further utilised together with weightages of sub-criteria of each major –criterion.

Step 3: Consistency Check: For the validity of AHP, each decision matrix has been reviewed for consistency to validate the decision makers' judgments. The computed values are determined to be within the permissible limit.

Since 0.0864< 0.10; Pair-wise comparison is permitted (Saaty,1994) (Saaty,1994). Similarly, all other judgmental matrixes are examined for consistency ratio.

Step 4: Synthesis of Priorities: All the pair-wise matrices give weightages of each main-criterion, sub-criteria with relation to the FMS selection. The relative weights of the major criterion and sub-criteria were derived by pair-wise comparisons with Task Force committee.

Step 5: Calculation of the normalised decision matrix: The relative weightages of FMS options without considering the acquired weightage (OW) are given in Table 6.4. The normalised value rij for the FMS alternative is obtained using equation (6.8). (6.8). The normalised decision matrix for the FMS selection is shown in Table 6.5.

Step 6: Calculation of the weighted normalised decision matrix: The weighted normalised decision matrix for the FMS options may be derived.

Step 7: Determination of the ideal and negative-ideal solution: To get the ideal (A*) and ideal-negative (A-) solutions,

Step 8. Calculation of the distances to be separated: It is essential that the PIS be located within the optimal Euclidean distance for the benefitting criterion. Non-benefiting criteria or cost criteria must also be far from the PIS or close to the NIS. the different separation lengths for each FMS option that may be calculated using the as shown.

Calculation of the Closeness Coefficient, which measures how near a solution is to the ideal one (CC). Equation (14) may be used to calculate the proximity coefficient of different FMS options. In certain cases, the FMS option with the higher CC value may be the better choice.

Awareness about FMS: When asked about the awareness about the Flexible Manufacturing System. 86.86 percent of the respondents were aware regarding the FMS. 172 Organization have awareness about the Flexible Manufacturing System) from 198 manufacturing industries surveyed and these 172 industries used for further analysis. Please indicate your preference level for adopting Future Manufacturing System: When asked about the preference of adoption, CNC machine is on top list with a mean of 4.04, Flexible Manufacturing System is second preference with mean of 3.99, conventional machines and special purpose machines are the last two choices with a mean of 2.69 and 2.00 respectively. From data it shows organization giving preference to CNC Machines and Flexible Manufacturing System.

Table 1: Preference level for adopting Future Manufacturing System

Preference of Technology	N	Minimum	Maximum	Mean	Std. Deviation
Conventional Machines	172	1.00	5.00	2.6919	.87415
CNC Machines	172	2.00	5.00	4.0465	.71585
Special purpose machines	172	1.00	4.00	2.0058	.80566
Flexible Manufacturing System	172	2.00	5.00	3.9942	.71326

Please indicate the present competency level of your organization in the following areas: The highest competency is found in constantly reinventing and reengineering the organization followed by capable to handle capacity and volume fluctuations and the lowest competency is found in capable to change mixes of products in manufacturing.

Operational Barrier: Maintenance Failure is the highest affecting barrier followed by resource failures and difficulty in handling the scheduling problems of FMS.

Investment and Financial resources barriers: High cost of FMS is highest ranked investment and financial resource barrier followed by non-availability of funds. Long payback period is given last importance.

Table 2: Statistical Analysis for Investment and Financial ResourcesBarriers for Implementing FMS

Investment and Financial Resources Barriers					
Sub Barriers	**High Cost of FMS (IF1)**	**Non-Availability of Funds (IF2)**	**High Taxes Like Sales Tax, Excise Duty Etc. (IF3)**	**Poor Rate of Return Over Investment (IF4)**	**Long Payback Period (IF5)**
Mean	3.59	3.58	3.14	3.34	3.09
Standard Deviation	0.99	0.98	0.99	0.97	1.04
Intensity of Barriers	High	High	High	High	High

Strategic and Planning barriers: Non availability of good vendor is given highest importance followed by failure to carry out feasibility studies and flexibility measurement problem. Unfavourable government policies are least affecting strategic and planning barrier.

Miscellaneous barriers: Cost of recycling/refurbishing of machine systems is given highest importance among the miscellaneous barriers. The second important barrier is Cost of upgrading of systems.

4.2 Structural Equation Modelling Adoption Barriers of FMS:

In order to perform SEM (Structural Equation Modelling) and Confirmatory factor analysis, a single factor model for each of the barriers and performance factors for adoption of Flexible Manufacturing System have been analyzed. Explain the procedure for SEM modelling for adoption of Flexible Manufacturing System. SEM modelling is divided in two parts first Structural Equation Modelling for adoption barriers of FMS which further divided for all seven construct adoption barriers for adoption of FMS. Second part is Structural Equation Modelling for Performance indicator of FMS which further divided in five individual construct for Performance indicator of FMS. Thus with the help of SEM we will find relationship between adoption barriers of FMS andPerformance indicator of FMS.

5. Conclusion:

- An extensive and comprehensive literature review in order to identify the research gaps and research issues in the adoption of Flexible Manufacturing System in industry and to provide solid platform to explore the future related research.

- Statistical measure for various barriers and performance indicator of adoption of FMS and to make Structural Equation Modelling and Confirmatory Factor Analysis Model for Adoption of FMS.

o An Analytic Hierarchy Process based multi-criteria mathematical modelling has been carried out for the selection of FMS system.

o Frame work 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.

o A two-phase Analytic Hierarchy Process multi-criteria based mathematical modeling along with Group Decision Making has been carried out and applied in the potential selection of FMS system for the given industrial case problem.

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