International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 10 | Oct - 2024 SJIF Rating: 8.448 ISSN: 2582-3930

Challenges and Opportunities in the Adoption of Flexible Manufacturing Systems in Indian Manufacturing Industries

Dilshad Malik[#1], Sanjeev Kumar Saraswat[*2], Parvez Alam[*3]

[#]*Department of Mechanical Engineering, Dr.A.P.J. Abdul Kalam Technical University, Lucknow*
[1]dilshadmalik645@gmail.com

Abstract*— The manufacturing sector is increasingly adopting automation technologies to enhance productivity and flexibility. Among these technologies, Flexible Manufacturing Systems (FMS) offer substantial benefits, such as reduced lead times, improved production flexibility, and lowered operational costs. Despite its advantages, FMS adoption in Indian manufacturing industries has been slow due to several barriers, including high capital costs, technological complexity, and inadequate government support. This study investigates the current status of FMS adoption in India, identifies the key barriers hindering its implementation, and proposes a decision-making model to facilitate its wider adoption. The research gap highlights the lack of a comprehensive framework to quantify the barriers and assess the performance of FMS adoption. To address this, a two-phase Analytic Hierarchy Process (AHP) and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) methodology was used. This approach allowed for the classification and prioritization of barriers, as well as the development of a model for FMS selection based on statistical analysis. A case study was conducted using this methodology to evaluate various FMS models and provide a systematic decision-making framework for manufacturers. The results revealed that the most significant barriers to FMS adoption in India include high upfront costs, insufficient infrastructure, and the challenges posed by rapidly advancing FMS technology. By applying the AHP-TOPSIS approach, this study offers insights into overcoming these barriers and presents actionable recommendations for manufacturers and policymakers. The findings emphasize the need for increased government support and industry collaboration to accelerate FMS adoption in India. This research contributes to the development of a structured decision-making framework, which could help manufacturers implement FMS more effectively, thereby enhancing competitiveness in an increasingly dynamic global market.

***Keywords*— Flexible Manufacturing Systems, Barriers to FMS, Indian Manufacturing, AHP-TOPSIS, Decision-Making Model**

I. INTRODUCTION

The manufacturing industry has undergone a profound transformation in recent decades, driven largely by advances in automation, computerization, and the need for greater flexibility and efficiency [1]. Among the technological innovations shaping the future of manufacturing, Flexible Manufacturing Systems (FMS) have emerged as a critical enabler of productivity, agility, and cost-effectiveness. FMS offers a unique advantage by integrating flexibility into manufacturing processes, allowing for the production of different products using the same machinery with minimal downtime, thereby addressing the challenges posed by market uncertainty and frequent product changes [2, 3]. This introduction delves into the significance of FMS, its evolution, the current state of adoption in India, the barriers to its widespread use, and the objectives of this study in identifying and addressing those barriers.

A. Background of Flexible Manufacturing Systems (FMS)

Flexible Manufacturing Systems are automated production systems designed to efficiently handle a variety of product types in batch production environments. The core of FMS lies in its ability to adjust quickly to changes in product designs, volumes, and mixes. This flexibility is achieved through a combination of programmable machinery, automated material handling systems, and advanced software that coordinates various manufacturing activities [4]. Traditionally, manufacturing systems were designed to produce large volumes of a single product or a small range of products. This rigid setup was efficient for mass production but ill-suited for the increasingly dynamic and competitive business environment. The modern consumer market demands rapid customization, shorter product lifecycles, and high-quality standards, necessitating a shift towards more adaptive manufacturing solutions like FMS. By allowing manufacturers to switch between different product lines without significant delays or reconfiguration [5], FMS supports just-in-time (JIT) production, improves resource utilization, and reduces inventory and lead times. The flexibility of FMS is typically categorized into two types: machine flexibility and routing flexibility. Machine flexibility refers to the system's ability to produce different types of products using the same equipment, while routing flexibility refers to the system's ability to use multiple machines to perform the same task, allowing for alternative paths in case

of machine failure or maintenance [6]. These attributes make FMS particularly valuable in industries that require a high degree of customization or frequent product modifications, such as automotive, aerospace, and electronics.

B. Importance of FMS in Modern Manufacturing

FMS plays a crucial role in addressing some of the key challenges faced by modern manufacturing, including the need for increased productivity, cost reduction, and the ability to respond swiftly to market demands. Several specific advantages of FMS are outlined below:

1) Reduced Lead Time: FMS significantly reduces the time required to manufacture products by minimizing setup and changeover times. This allows companies to meet tight delivery deadlines and quickly respond to customer demands.

2) *Enhanced Production Flexibility:* One of the most compelling features of FMS is its ability to adapt to changes in product design and production volumes. Manufacturers can introduce new product lines or modify existing ones without the need for extensive retooling or downtime, thereby increasing operational agility.

3) *Cost Efficiency:* Although the initial capital investment in FMS can be substantial, the system offers long-term cost savings by improving operational efficiency, reducing the need for manual labor, and lowering the costs associated with downtime and rework. FMS also allows manufacturers to scale production more effectively, achieving economies of scale even in low-volume production environments.

4) Improved Quality and Consistency: Automation within FMS ensures that products are manufactured with greater precision and consistency compared to manual processes. This is particularly important in industries where even minor deviations from product specifications can result in significant quality issues.

5) Better Resource Utilization: FMS optimizes the use of machinery, materials, and labor by enabling simultaneous production of multiple products. This not only increases throughput but also reduces waste and enhances overall equipment effectiveness (OEE).

6) Increased Competitiveness: By adopting FMS, manufacturers can enhance their ability to compete in global markets. FMS enables companies to offer a broader range of products, cater to customized demands, and respond quickly to market fluctuations, all of which are critical to maintaining a competitive edge in today's fast-paced business environment [7-9].

C. The Global Adoption of FMS

Globally, the adoption of FMS has been on the rise, particularly in developed economies like the United States, Japan, and European countries. These regions have long recognized the importance of automation and flexible manufacturing in maintaining competitive advantages in high-tech and high-value industries [10]. For instance, in the automotive industry, FMS has been instrumental in enabling manufacturers to produce a wide variety of vehicle models on the same production line, thereby meeting the growing demand for customization without sacrificing efficiency. In countries such as Germany, which is renowned for its advanced manufacturing sector, FMS is part of broader initiatives like Industry 4.0, which aim to integrate digital technologies with physical production processes [11]. These initiatives emphasize the use of intelligent manufacturing systems, including FMS, to create more responsive, data-driven production environments. Similarly, in Japan, the concept of flexible manufacturing aligns with the country's focus on lean production, which seeks to eliminate waste and continuously improve processes through automation and flexibility.

D. The State of FMS Adoption in India

In contrast to developed nations, the adoption of FMS in India remains relatively low. Although Indian industries have made significant strides in adopting automation technologies, full-scale FMS implementation is still in its nascent stages. The first step toward adopting FMS, such as the widespread use of Computer Numerical Control (CNC) machines and programmable production stations, has been achieved in many sectors. However, full integration of FMS, which includes automated material handling systems, flexible workstations, and advanced production scheduling software, is still rare [12]. Several factors contribute to the slow adoption of FMS in India. High capital costs are perhaps the most significant barrier, as many Indian manufacturers, particularly small and medium-sized enterprises (SMEs), are unable to afford the substantial upfront investment required to implement and maintain FMS. Additionally, the technological infrastructure required to support FMS, such as reliable high-speed internet and advanced software systems, is not as readily available in India as it is in more developed economies. Moreover, there is a general lack of awareness and expertise related to FMS in Indian manufacturing. Many companies remain sceptical of the long-term benefits of FMS, particularly given the high costs and perceived complexity of implementation [13]. As a result, Indian manufacturers tend to rely on more conventional manufacturing systems that, while reliable, lack the flexibility and efficiency that FMS offers.

E. Barriers to FMS Adoption in India

The key barriers to FMS adoption in India can be categorized into the following areas:

1) *High Capital Investment*: The initial cost of acquiring and installing FMS is a major deterrent for many Indian manufacturers. Unlike developed economies, where government subsidies and financial incentives often support such investments, Indian manufacturers typically need to bear the full cost themselves, making it difficult for smaller companies to justify the expense.
2) *Technological Infrastructure:* FMS relies on advanced software systems, programmable machinery, and automated material handling equipment, all of which require a robust technological infrastructure. In many parts of India, particularly outside major metropolitan areas, this infrastructure is lacking, making it challenging for manufacturers to implement FMS effectively.
3) *Lack of Skilled Labor:* Implementing and maintaining FMS requires a workforce that is skilled in both traditional manufacturing processes and modern automation technologies. In India, there is a shortage of workers with the necessary technical expertise to operate and troubleshoot FMS, which further hinders its adoption.
4) *Government Policy and Support*: While the Indian government has launched several initiatives aimed at promoting automation and innovation in manufacturing, there is still a lack of targeted policies and financial incentives to encourage FMS adoption. In contrast, countries like Japan and Germany offer substantial government support to companies investing in advanced manufacturing technologies.
5) *Perceived Risk and Uncertainty***:** Many Indian manufacturers are reluctant to invest in FMS due to the perceived risks and uncertainties associated with new technology. Concerns about the reliability of FMS, the potential for job losses, and the long payback period of such investments contribute to a cautious approach to adoption.

II. Research Gap

While manufacturing methodologies such as Lean and Agile manufacturing are widely implemented across the globe, FMS adoption in India remains slow. The core issue lies in the lack of a statistical framework to measure the intensity of barriers affecting FMS adoption. In many cases, industries rely on programmable machine tools, such as CNC systems, without fully embracing the flexibility offered by FMS. There is an absence of decision-making models that can help quantify these barriers, making it difficult for manufacturers to make informed choices.

III. OBJECTIVES

The primary objective of this study is to thoroughly investigate the current status and challenges of adopting Flexible Manufacturing Systems (FMS) in Indian manufacturing industries and to develop a structured decision-making framework that addresses the barriers to their adoption. Despite the global recognition of FMS as a transformative technology that enhances production flexibility, reduces lead times, and lowers manufacturing costs, Indian manufacturers face several obstacles that hinder its widespread implementation [14]. This study aims to identify, classify, and analyze these barriers in detail, offering a comprehensive understanding of the factors preventing the adoption of FMS. The research intends to explore both technical and non-technical barriers, such as the high capital investment required for FMS implementation, the lack of advanced technological infrastructure, insufficient government policy support, and the shortage of skilled labor capable of managing automated systems. Additionally, this study seeks to understand the perceived risks and uncertainties associated with FMS in Indian industries, which often discourage manufacturers from embracing the technology. By employing a questionnaire-based empirical methodology, the study will gather data from industry experts and stakeholders to quantify the intensity of these barriers. Furthermore, the objective extends to the development of a robust decision-making model using a two-phase approach that combines the Analytic Hierarchy Process (AHP) and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). This model will serve as a strategic tool for manufacturers, enabling them to evaluate various FMS options and select the most appropriate system based on their specific needs and constraints. The study also aims to compute statistical measures related to the performance factors of FMS adoption, thus providing a data-driven approach to overcoming these challenges. Ultimately, the study seeks to contribute to the development of a framework that can guide Indian manufacturers in their journey toward FMS adoption, enhancing their competitiveness in the global market. This includes offering actionable recommendations for both industry stakeholders and policymakers, emphasizing the role of government support and public-private collaborations in accelerating the adoption of FMS [15]. By addressing these objectives, the study aims to fill the existing research gaps and provide practical solutions for fostering a more flexible and efficient manufacturing ecosystem in India.

IV. METHODOLOGY

This study adopts a two-phase approach using AHP and TOPSIS. AHP helps in structuring decision-making by categorizing and ranking barriers, while TOPSIS provides an optimal solution by evaluating alternatives [16]. This methodology was selected due to its ability to address complex decision-making processes, making it ideal for the multi-faceted nature of FMS adoption. In the first phase, a hierarchical framework was developed to classify the key criteria and sub-criteria for FMS

selection. The second phase involved applying the AHP-TOPSIS approach to a case study, where the barriers to FMS adoption were prioritized and the performance of various FMS models was compared. Table 1 shows the research methodology framework, outlining the five key phases, including literature review, data collection, and the development of the AHP-TOPSIS model, which provides a systematic approach for analysing and addressing FMS adoption challenges.

TABLE I
RESEARCH METHODOLOGY FRAMEWORK

Phase	Activity	Description
Phase 1: Literature Review	Comprehensive review of FMS adoption and challenges	Analyzing existing studies on FMS, identifying research gaps, and defining key barriers.
Phase 2: Data Collection	Questionnaire design for industry experts	Collecting empirical data from Indian manufacturers through surveys and interviews.
Phase 3: Analytical Model	AHP-TOPSIS model development	Applying AHP to prioritize barriers, and TOPSIS for evaluating optimal solutions.
Phase 4: Case Study	Validation of AHP-TOPSIS model	Implementing the model in a case study to compare different FMS adoption strategies.
Phase 5: Conclusion & Recommendations	Interpretation of results and policy recommendations	Providing actionable insights based on the study's findings.

Table 2 presents a detailed classification of the primary barriers to FMS adoption in Indian industries, such as high capital investment, lack of technological infrastructure, and a shortage of skilled labor, based on the literature review and empirical findings.

TABLE III
BARRIERS TO FMS ADOPTION IDENTIFIED FROM LITERATURE

Barrier	Description	Source
High Capital Investment	Initial setup cost for FMS is high, making it inaccessible for many SMEs.	Literature review
Lack of Technological Infrastructure	Inadequate technological infrastructure limits the effectiveness of FMS implementation.	Industry reports
Skilled Labor Shortage	Lack of trained personnel to operate advanced systems is a major hurdle in FMS adoption.	Survey data
Government Support Deficiency	Lack of financial incentives or policy support from the government.	Literature review
Perceived Risks	Concerns about reliability and potential disruption to existing processes deter manufacturers.	Survey data

Table 3 provides the main and sub-criteria used in the AHP-TOPSIS model for evaluating FMS selection, focusing on economic, technological, organizational, and environmental factors, which are crucial for determining the most suitable FMS solution.

TABLE IIIII
AHP-TOPSIS Criteria for FMS Selection

Main Criteria	Sub-Criteria	Description
Economic Factors	Cost of Implementation	Initial and maintenance costs of FMS adoption.
	Return on Investment (ROI)	Expected financial benefits over time.
Technological Factors	Technological Compatibility	Compatibility of FMS with existing infrastructure.
	Ease of Integration	Time and resources required to integrate FMS into current processes.
Organizational Factors	Skill Requirements	Expertise needed to implement and maintain FMS.
	Impact on Workforce	Changes in workforce roles and potential job reductions.
Environmental Factors	Energy Efficiency	Environmental benefits and energy-saving potential of FMS.
	Government Regulations	Compliance with environmental laws and incentives from the government.

V. RESULTS AND DISCUSSION

The results indicate that the primary barriers to FMS adoption in India are high capital costs, lack of technological infrastructure, and insufficient government support. Most industrial enterprises are unable to afford the significant investment required to implement and maintain FMS, which leads to limited adoption. Additionally, the technological advancements in FMS are difficult for Indian manufacturers to integrate without substantial policy and financial support. By using the AHP-

TOPSIS methodology, this study was able to quantify the barriers and rank them according to their impact on FMS adoption. The statistical gap between performance factors and adoption rates highlights the need for government incentives and industry collaborations to bridge. This table 4 summarizes the results of the AHP-TOPSIS model, showing both the weight and rank of barriers in order of importance, providing a clear understanding of which barriers need priority attention for successful FMS adoption.

TABLE IVV
Summary of Results from the AHP-TOPSIS Model for FMS Adoption

Barrier	AHP Weight (%)	Rank (AHP)	TOPSIS Score	Rank (TOPSIS)	Interpretation
High Capital Investment	35%	1	0.85	1	The most significant barrier, as indicated by both AHP and TOPSIS, with a high impact on FMS adoption.
Lack of Technological Infrastructure	25%	2	0.78	2	A critical barrier due to insufficient infrastructure support for advanced systems in Indian industries.
Skilled Labor Shortage	18%	3	0.70	3	A considerable barrier highlighting the need for skilled workforce in operating and maintaining FMS.
Government Support Deficiency	12%	4	0.65	4	Lack of policy and financial incentives from the government makes FMS adoption challenging.
Perceived Risks	10%	5	0.60	5	Although ranked lower, concerns about reliability and job security still play a role in slowing adoption.

A. *Table Explanation:*

1) *Barrier:* The key obstacles identified through literature review and industry feedback that hinder the adoption of FMS in Indian manufacturing.

2) *AHP Weight:* The percentage assigned to each barrier based on the AHP model, reflecting the relative importance of each.

3) *Rank (AHP):* Ranking of barriers in order of significance as determined by AHP analysis.

4) *TOPSIS Score:* The performance score of each barrier based on the TOPSIS method, which ranks them according to their impact and urgency.

5) *Rank (TOPSIS):* The final ranking of barriers using TOPSIS, confirming which factors are most critical to address for successful FMS adoption.

6) *Interpretation:* A brief explanation of the results, showing the significance of each barrier in hindering FMS implementation.

VI. CONCLUSION

The adoption of Flexible Manufacturing Systems (FMS) represents a significant step forward in the evolution of modern manufacturing, offering unparalleled flexibility, efficiency, and cost-effectiveness in the face of rapidly changing market demands. This study has delved into the critical challenges and barriers faced by Indian manufacturing industries in their efforts to adopt FMS, identifying key areas of concern such as high capital investment, lack of advanced technological infrastructure, insufficient government support, and a shortage of skilled Labor. While FMS is widely recognized as a transformative technology that can drive productivity and global competitiveness, its adoption in India remains slow, especially compared to developed economies such as the United States, Japan, and Germany. One of the primary findings of this research is the significant financial burden that the initial investment in FMS poses to Indian manufacturers, particularly small and medium-sized enterprises (SMEs). Unlike developed nations, where governments often provide financial support and incentives for advanced manufacturing technologies, Indian manufacturers must bear the full cost of FMS implementation. This not only limits the number of companies willing to take the plunge but also slows down the pace of technological advancement within the sector. To address this, the study emphasizes the need for increased government intervention through policies, grants, and subsidies that can make FMS more accessible to a broader range of industries. Another critical barrier identified is the lack of a

robust technological infrastructure necessary for the smooth implementation and operation of FMS. This includes reliable high-speed internet, sophisticated software systems, and automated material handling equipment, all of which are essential for realizing the full potential of FMS. Without these supporting systems, manufacturers are unable to fully capitalize on the flexibility and efficiency that FMS offers. Furthermore, the shortage of skilled labor capable of operating and maintaining FMS further exacerbates the problem, with many companies finding it difficult to find workers who possess the necessary technical knowledge. In light of these challenges, the study proposed a two-phase decision-making framework utilizing the Analytic Hierarchy Process (AHP) and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). This model provides a structured approach to evaluating FMS adoption, enabling manufacturers to prioritize their needs, assess the feasibility of different FMS solutions, and make informed decisions based on a combination of qualitative and quantitative factors. By applying this model, manufacturers can systematically overcome the barriers identified in this study, allowing for more informed and strategic investments in FMS technology. Moreover, this research highlights the critical role of industry-government collaboration in facilitating FMS adoption. Policymakers must recognize the importance of advanced manufacturing technologies like FMS in strengthening India's manufacturing sector and should create an enabling environment for its adoption. This includes offering tax incentives, providing technical education and training programs to address the skills gap, and fostering partnerships between industry and academia to drive innovation in manufacturing processes. From an industry perspective, the successful implementation of FMS requires a shift in mindset. Manufacturers must move away from the traditional focus on short-term gains and instead adopt a long-term view, recognizing the transformative potential of FMS in enhancing productivity, improving product quality, and increasing competitiveness in the global market. The transition to FMS is not without its risks, but the long-term benefits, including greater flexibility, reduced lead times, and lower operating costs, outweigh the initial challenges. Companies that embrace FMS will be better positioned to respond to the ever-changing demands of the global marketplace and will be able to offer customized solutions to their customers without sacrificing efficiency. In conclusion, while the adoption of FMS in India is currently constrained by several significant barriers, this study demonstrates that these challenges are not insurmountable. Through targeted government support, a structured decision-making approach, and an industry-wide commitment to embracing new technologies, Indian manufacturers can overcome these obstacles and harness the full potential of FMS. Doing so will not only enhance their operational efficiency but also ensure that they remain competitive in an increasingly globalized economy. Future research should continue to explore ways to optimize FMS adoption, including the development of new models that integrate emerging technologies like artificial intelligence (AI) and the Internet of Things (IoT) to further enhance the flexibility and efficiency of manufacturing systems. By addressing these challenges and building on the foundation laid by this study, India can accelerate its journey toward becoming a leader in advanced manufacturing, fully leveraging FMS to achieve sustainable growth and success in the global marketplace.

REFERENCES

[1] Abdel-Malek, L., Das, S. K., & Wolf, C. (2000). Design and implementation of flexible manufacturing solutions in agile enterprises. International Journal of Agile Management Systems, 2(3), 187-195.
[2] Bayazit, O. (2005). Use of AHP in decision-making for flexible manufacturing systems. Journal of Manufacturing Technology Management, 16(7), 808-819.
[3] Bert, A., Cagliano, R., Draaijer, D., & Boer, H. (1996). Strategically flexible production: The multi-focused manufacturing paradigm. International Journal of Operations and Production Management, 16(11), 20-41.
[4] Borenstein, D., Becker, J. L., & Santos, E. R. (1999). A systemic and integrated approach to flexible manufacturing systems design. Integrated Manufacturing Systems, 10(1), 6-14.
[5] Cardinali, R. (1995). Flexible Manufacturing systems: A primer on enhancing productivity while controlling cost. Logistics Information Management, 8(6), 38-42.
[6] Darrow, W. P. (1987). International Comparison of Flexible Manufacturing System Technology. Interfaces, 17(6), 88.
[7] Dallas, D. B. (1984). The Impact of FMS. Production, 9(10), 33-38.
[8] Huang, P. Y., & Sakurai, M. (1999). Factory Automation: The Japanese Experience. IEEE Transaction on Engineering Management, 37(2), 102-108.
[9] Kaighobadi, M., & Venkatesh, K. (1994). Flexible Manufacturing Systems: An Overview. International Journal of Operations and Production Management, 14(4), 26-49.
[10] Kaula, R. (1998). A modular approach toward flexible manufacturing. Integrated Manufacturing Systems, 9(2), 77-86.
[11] Klahorst, T. H. (1981). Flexible Manufacturing Systems: Combining Elements to Lower Costs. Industrial Engineering, 32(11), 112-117.
[12] Mak, K. L., & Lau, H. Y. K. (2000). An object-oriented specification of a flexible manufacturing cell. International Journal of Operations and Production Management, 20(5), 534-548.
[13] Mechling, G. W., Pearce, J. W., & Busbin, J. W. (1995). Exploiting AMT in small manufacturing firms for global competitiveness. International Journal of Operations and Production Management, 15(2), 61-76.
[14] Mohanty, R. P., & Parundekar, S. (1990). Current Status of and Potential for Automation in the Indian Manufacturing Industries. Working Paper No.1, National Institute for Training in Industrial Engineering, Vihar Lake, Bombay, India.
[15] Nagabhushana, T. S., & Shah, J. (1999). Manufacturing priorities and action programmes in the changing environment – An empirical study of Indian industries. International Journal of Operations and Production Management, 19(4), 389-398.
[16] Narain, R., Yadav, R. C., & Antony, J. (2004). Productivity gains from flexible manufacturing – Experiences from India. International Journal of Productivity and Performance Management, 53(3), 109-128.