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Introduction of Agile, Green, Lean, and Resilient Elements to Flexible Systems: State of the New Age Trends of Manufacturing in India

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Abstract. The global manufacturing industry is entering a new age. Brought along are the challenges of complementing the supply and demand needs in the markets. Another hurdle faced by the manufacturing industry is the challenge of rapidly changing climate and environment conditions that call for corrective measures. The global concern is equally shared by India. In this regard, the flexible systems have contributed to resolve the challenges to a certain extent. The paper intends to research the advent of emerging technology that deals with these challenges. The focus remains on the Indian manufacturing industry and the advancements in it. The work presented also gives a perception of the state of research and identifies the potential of relatively new introduced elements to manufacturing.

Keywords. Flexible systems, Indian manufacturing sector, lean, agile, green, advanced manufacturing

1. Introduction

Activities of manufacturing are the foundational support to all the global economies. These industries have proved to be a facilitator of sustainability and welfare of the community by generating quality products, the output of greater worth [1]. The initial focus of the manufacturing technology was tunneled on the qualitative aspects, and capacity, however, the focus later incorporated much valued objectives of enhanced flexibility [2]. It also made relevant the possibility of progressing towards an enhanced sustainability, and new technologies. The advent of information technology also resulted in performance enhancement, overall flexibility, and adaptive control capabilities [3].

An important objective of the advancements flexibility in the hindsight was to provide a differentiating alternative to the emerging global economies concentrated especially in the east [2]. Though countries like India were limited in capabilities and steadily progressing as compared to the growing and leading west, it contributed to the

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requirement of workforce of the manufacturing industries [4]. The Indian industries currently are of greater significance than in the past, however, they lag behind in the new technological advancements prowess. It is very difficult to envisage economic and manufacturing gains without future generation capabilities [5].

Lean forms the basis for collective activities that deminute the least worthy of processes for a state of market ready production [6]. Agility is supportive to such lean systems that enables the organizations to react at unprecedented rates to survive the dynamic environment. A new notion, the idea of green manufacturing focuses on the environmental implications of flexible manufacturing by employing environment friendly materials and techniques [7,8]. Green manufacturing optimizes energy use by methods including reuse of critical fluids, optimized pathways and parameters, deactivation of non-productive components, performance enhancement, etcetera.

Indian GDP stands at 694.93 billion USD. It is pertinent to mention the impetus of India's manufacturing sector to reach 1 trillion USD by the year 2025. The promising metrics are indicative of the need to address such concerns and look for sustainable approaches [9]. Currently, the state-of-the-art flexible manufacturing capabilities are largely out of reach of the majorly present MSMEs, constituting more than 95% of the total strength, and generating highest employment, where manufacturing is still by the conventional methods, skewing the total impact towards the lower side [9,10].

The diverse range of instruments in the Indian landscape makes it even more challenging to introduce relevant technologies. The interaction of new age elements is the principal need given that these industries are involved in contributing exports. It can be said that the weaker links of the manufacturing chain are the aspects of economics, ecology, and social responsibility.

2. Literature Review

Lean and green practices are successful methods to increase the profitability prospects of any organization. It adds to the capability of flexible systems to efficiently utilize the resources with minimum wastages. The emissions and heedless use of resources are concerning and going green is a viable solution. The rapid changes in customer's expectation from the organization to deliver the right product, at the right time and place makes it a complex case for conventional flexibility [11]. Hence, the component of agility is integrated. To carry work in the manufacturing industry regardless of the interferences, the need for developing resilience so as to swiftly revert to pre interference levels is desired. The addition of resilient along lean, green, and agile manufacturing techniques finds mention in the research by Rafique et al. [12] and Harikannan et al. [9] further talks about such essential integration.

The earliest applications of lean were achieved by the production system of Toyota [13, 14]. Seven types of wastages are identified along with the lean's objective of diminution of waste, optimization of inventories, and attainment of quality standards of manufacturing to meet the customer expectations [15, 12]. The integration of lean is also talked about by Rafique et al. [12] stating the changes at cultural level and process level are a necessity.

It is pertinent to mention that the advent of green has impacted the capability of the industry to enhance performance with the only use of present resources as highlighted by Sagnak et al. [16]. Recent years have posed uncontrolled waste being released in the environment as highlighted by Thanki et al. [17]. The occurrence puts at risk the growth

of many economies. GRI therefore talks about the adoption of 34 important green indicators that have become a part of global manufacturing, as presented by Goyal et al. [18]. Similar green indicators have been incorporated into industries globally on the advice of the ISO. The Indian industry has only seen limited adoption of green parameters due to the cost and effort associated with bearing the change.

The agile strategy is the choice for maintaining and enhancing the relationship. Sindhwani et al. [19] highlights the progress from the earlier model of exclusive lean strategies while suggesting the transition to agile manufacturing systems. For dynamic scenarios of manufacturing, Moradlou et al. [20,21,22] suggests that agile and integration of data backed and information technology infrastructure is the need of future manufacturing. Rad et al. [14] also registers a newer form of lean, green, and agile that is in conjunction with the digital ecosystem of information and technology. Such a strategy and its acceptance are the future of Indian industry as highlighted by Ganvir et al. [23].

The Indian manufacturing sector is contributor to the multi-billion-dollar global manufacturing industry as indicated by Gartner research [24]. A report issued by the WEF positions India 31st as the driver of production along the advanced economies. Despite the global manufacturing industry embracing new age elements, a multitude of factors including issues pertaining to flexible capacity, capital expenditure on new elements of technology, and others concern the Indian manufacturing sector as identified by Sharma et al. [24]. The manufacturing entities in India remain fragmented to an extent that integration of technologies achieve limited benefits. Lack of technical knowledge, stakeholder support, complex systems, standards, frameworks and necessary models as identified by Luthra et al. [25] are recognized as major challenges to manufacturing.

3. Methodology

The integration of new age technologies is complex and demands high expenditure. A measured approach needs to be applied to realize the state of advancements of the Indian manufacturing sector. The synergies of new elements have also been studied in the Indian landscape. The method paves a way for the successful integration by being mindful of the adversities in the adoption. Together, all data elements form a basis for greater knowledge and understanding. It also possesses the potential to answer certain observed challenges that have arisen in the current technological state of the Indian manufacturing sector.

4. Lean, Green, and Agile- State of New Age Trends in India

Agility paradigm is new for the Indian manufacturing sector as opposed to the other parts of the world [10]. The Indian government realizes the criticality of agile flexible systems. A supportive initiative therefore, that follows the idea of incentivization is the Production Linked Incentive that promotes the new age elements into the current manufacturing technologies of indigenous units. It is also in line with the industry 4.0's expectations creating manufacturing potential. An amount of more than 25 billion USD has so been laid for thirteen major sectors.

The ecosystem for development of lean technology as a foundational component for future growth trends includes Ministry of MSMEs' supporting initiatives like Lean

Manufacturing Competitiveness Scheme under the National Manufacturing Competitiveness programme. The scheme backs the enhancement of manufacturing volumes and waste diminution. The number of enterprises that availed the benefit and identify as lean units of manufacturing since the implementation totals to 3,732 till the year 2017 with a total expenditure in excess of 48 crores. However, the identified challenges include less optimal performance due to high randomness in techniques adopted, obsolescence, inefficient resources at hand, and lack of expenditure capacity

Green manufacturing has been more than a factual indication as we progress towards the cost optimizing, investment friendly, environmentally sound initiatives enhancing the contribution from manufacturing to 25%. The development takes over several areas of green energy sources, goods, and manufacturing. The challenges associated include lack of a framework and approach to focus on the change, meeting expectations of Indian policy regulators, and addressing costs of change. Data shows that the growth of carbon dioxide emissions in India was more than 150% over a period of eighteen years and the creation of 400 crore kgs of hazardous waste from the Indian sector. The restriction of hazardous materials by Indian manufacturing units in the process of carrying out manufacturing of EVs is a positive move along with the revision of the portfolio of high resource consumption units. The Department of Industrial Promotion & Policy is a key facilitator of green. Such support is instrumental in further developing synergies between lean and green.

On the consumer side, the increasing consciousness amongst the citizens about environment friendly manufacturing demands green. However, lack of presence of desired products leads customers to alternatives outside, which has a negative impact on the Indian manufacturing sector. Allied initiatives that have a positive impact on the green landscape include the government's Solar Mission which when extended to the manufacturing sector promotes integration. The losses mounted further by the unnecessary movement of resources on manufacturing is a void and against the objectives that are facilitated by lean and green. Hence, efforts are required to be concentrated on going green within the transportation sector due to its closeness with manufacturing.

Decisions backed by relevant, accurate, and precise data are the backbone of advanced manufacturing technologies worldwide [20,21,22]. However, the Indian systems still rely a lot on the manual processes that govern decisions having not more than 5% of units utilizing data to advantage. With progression towards newer age technologies now, India has started witnessing adoption of information and technology based and data driven initiatives including some from the private players for research and development. More than 80% of the sector is yet to attain recognizable transformation. The push from the government to develop such an ecosystem within India has been non evident so far. As a result, the conventional practices are considerably prevalent in the Indian sector.

5. Results and Discussions

There is much need for the implementation of corrective measures including significant capital expenditure on material, equipment, resources, and the upskilling of the workforce. MSMEs constitute the larger of the Indian sector and have serious constraints. Their limited economic capacity, low risk-taking potential, semiskilled and non-standard

workforce, access to the market exposure delays the prospects of new age flexible systems.

The Indian sector is in the foundational stage of accepting technologies like IoT, data intelligence, advanced computing, 3D manufacturing, cloud technology, AI, and cyber systems. These developments are leading to lean due to inhibition of unintelligent overuse of manufacturing systems, green due to reduced ecological footprints, agile due to real time realization and satisfaction of customer expectations, and resilient due to resistance potential to any adverse events affecting manufacturing. Furthermore, environmental policy support by the government comes in the form of environment, air and water pollution prevention and control act, and extended producer responsibility. The labor and workforce rights are being enforced with diligence. Standardization with regulating agencies have been the planned approach by government stakeholders for quality. Overall, the research conveys the positive sentiment for the introduction of lean, green, agile, and resilient elements.

6. Conclusion

It emerges that new elements are essential for sustainability. Less than half of the Indian sector has introduced new age elements to the flexible systems. Strong push from stakeholders, adoption of policy measures, knowledge of models and frameworks of new age technologies, high production process standards, capital expenditure, access to materials and resources, upskilling, enhancing risk capacity, and creating an IT and data backed confident manufacturing environment have been identified as necessary conditions for creating the desired ecosystem of manufacturing in India.

Significant opportunities also exist in India for the integration of new elements in the Indian ecosystem. In the future, the cultivation of sustainable practices in the Indian sector is identified as promising with the introduction of new age elements.

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