The Reflections of Lean Digitalization in Indian MSMEs: A Case Study

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Abstract: Lean production is very widely used and thoroughly tested approach among various enterprises for many decades, its motive is to remove non-value-added activities (waste) from the value stream and make the system highly optimized and efficient. Industry 4.0 is combination of technology driven applications that merge the traditional physical industry to cyber word with the use of digital technology, IoT and sensors etc. In today's highly competitive and volatile market scenarios it is very hard to fulfill the consumer demands and to produce highly customized quality product, without applications of integrated lean principles and industry 4.0 technologies. This combination known as lean 4.0, is not a replacement for either Industry 4.0 or Lean, but rather a way to improve the performance of the industrial sector. This study looks at how lean manufacturing principles can be used with Industry 4.0 to help India's hard-hit Micro, Small, and Medium-Enterprises (MSMEs). The concepts of lean 4.0 were tested in selected Micro, Small, and Medium-Sized Enterprises at the NCR region in India. Different parameters of productivity and customer satisfaction index has been compared after traditional lean and lean 4.0 implementation, there is a significant improvement has been observed as a result, another aim of this study is to put effort to persuade MSMEs to accept this fusion in order to boost productivity, quality and customer satisfaction.

Keywords: - Lean production (LP); Industry 4.0; Smart Factory; Lean 4.0

1. Introduction

In 1950 the term lean production has been coined under the Toyota production system, in Japan [1]. It has some set of principles that enhance the productivity of the industry along with customer satisfaction while eliminating waste [2]. Industry 4.0 is the amalgamation of different advance technologies or it can be the blend of information technologies, cyber technologies, automation and physical industrial systems [3]. In this fast-moving industrial world, every customer needs a specific high-quality product in low cost and to fulfil their immediate requirements. Cut-throat competition, market instability & complexity, customization of product, shorter product life cycle etc. are the bigger challenges for the enterprises and during in such period to meet the customer demand, industries are bound to upgrade their traditional manufacturing approach with digital technologies [4]. Industry 4.0 will have full supervision and impact over the complete manufacturing process from the beginning of processes like the design phase to the delivery of the finished product and related services. Slow responsiveness of traditional lean can be overcome by integration of industry 4.0 technologies to meet the higher and faster expectations of the [5]. Lean integration with industry 4.0 technology may bring some drastic shift to the production system and enterprises.

In Indian MSMEs, Lean Manufacturing has proven itself as and when required. Thus, a new principle- a cross of Lean Manufacturing and Industry 4.0 or the Lean 4.0 can prove to be a solution for the Indian MSME sector to boost their performance with long term cost effectiveness. Lean Industry 4.0 is a fusion of the cost effective and timeless lean principles with the constantly developing digital technologies that aims at reducing the wastes in the processes.

Lean 4.0 enhances the effectiveness of Lean Manufacturing by bridging the gaps in the production process and making its application more impactful. Say for an example, the system of records Enterprise Resource Planning (ERP) reports on the various business aspects of the users in traditional way, a Lean 4.0 can help in providing detailed cloud based information on all the aspects of the company. Lean 4.0 uses the industry 4.0 tools that can provide precise, timely and accurate reports about the processes. Thus, Lean Industry 4.0 consists of the cost effectiveness and benefits of Lean Manufacturing principles and the advantages of Industry 4.0 which shadows the shortcomings of both. Lean 4.0 can identify and mitigate the wastes faster in comparison to the traditional lean manufacturing methods by giving detailed and targeted information to the human factors [6].

2. LITERATURE REVIEW

The existing literature summarized the detailed information about lean production system and industry 4.0 technologies.

2.1. Lean production

After World War 2 in the phase of rebuilding the industry JIT was deployed in Japan [6], for the rest of the world the JIT/ TPS was introduced in Australia that later shifted to Toyota [7]. Lean production is eliminating waste from the value stream and improving the productivity of the production system or organizations [8]. The five principles of lean production that enhance the production efficiency are "Value", "Value stream mapping", "Flow", "Pull", "perfection" [9] shown in the figure 1. There is more than 60% avoidable waste present in the value stream in an organization at operational level, lean production is helping the organization to eliminate eight kinds of waste form the value stream, among these eight wastes 7 were identified by Toyota production system and are belong to production process [10] and the eighth waste directly related to personals ability and management, that was later considered by the western world, [11]. Figure 2 is representing all eight lean production wastes.

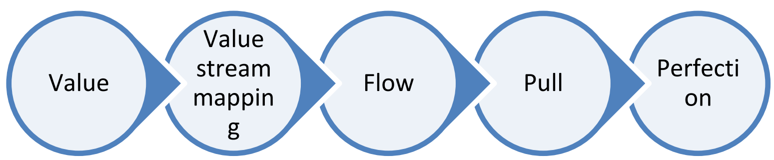


Figure1. Principles of lean production.

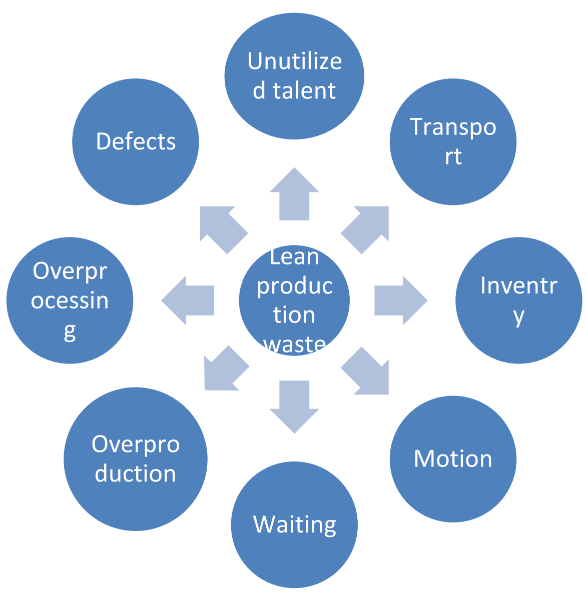


Figure 2. Eight lean production waste.

Lean production is a method that have attentions on reducing effective cost and increasing the productivity while eliminating waste. Rachna et. al claim that [12], any movement that makes use of assets however presents no value for customers is estimated fruitless and must be obsolete. The objective of Lean manufacturing is to streamline the production processes, procedures for creating items based on client needs [12]. With the help of value stream mapping inventory level, lead time is reducing [13], Dhruv and Pritesh [14] also contributed a variety of Lean manufacturing tools that can aid in the reduction of waste, such tools are (JIT), Production smoothing, and Total predictive maintenance (TPM). Naveen & Kaliyan [15] claimed that despite the fact that Lean is a speedy and convincing tool, companies can also additionally find it hard to keep long-time period performance the use of this to decrease waste. Lean production could be very stressful and calls for constant efforts and economic support to overcome numerous difficulties. Jadhav et. al [16] has showed this by declaring that despite the fact that Lean production has helped organizations to reduce waste, organizations have wriggled to enforce the Lean thinking. Member of staff crew improvement and Lean subculture discussions are examples of the way an enterprise can reap Lean sustainability [15]. Nevertheless, of all of the blessings and makes use of Lean, several researchers have faith in Lean, it is old and could fail to hold tempo with customer's needs and developments of the present-day world. The utilization of Lean production tools, as well as the collective activity and motivation of all corporate personnel are required for Lean production adoption in the organizational environment. In this article, the lean tools JIT, predictive maintenance, Poka-Yoke, VSM, etc. are described in table 1.

Table 1. Lean production tools

S. No.	Lean tool	Description
1	5S & 6S	Removes waste that occurs from a disorganized work environment, 5S represent for "Sort", "Set in Order", "Shine" "Standardize" "Sustain" and the 6S just upgradation of 5S lean with the Safety awareness [17].
2	Andon	visual response and alert system for the operators on the shop floor that indicate the real time problem and accordingly a corrective measure can be possible, A real time monitoring and control system [18].
3	Bottleneck Analysis	Determine which portion of the production process is limiting overall throughput and increase that part's performance [19].
4	Continuous Flow	A manufacturing process where work-in-progress moves seamlessly from one step to the next with shorter time between them [20].
5	Heijunka	A method of production planning that arranges product variations inside the same procedure to produce goods in comparatively smaller batches [21].
6	Hoshin Kanri	Certifies that growth toward strategic goals is constant and thorough, reducing waste caused by poor communication and ambiguous direction [22].
7	Jidoka	Design machinery to moderately automate the production process and to stop automatically when errors are discovered [23].
8	JIT	JIT emphasises a pull-based approach where materials and components are brought to the manufacturing line or assembly point precisely when they are needed, as opposed to holding vast stocks. This strategy lowers inventory expenses, gets rid of surplus inventory, and lessens the possibility of having products that are out-of-date or damaged. [21].
9	Kaizen	Kaizen frequently related continuous improvement with waste identification and elimination strategies while considering lead time, work/load balancing. [24].
10	Kanban	Exchange/control the merchandises both within the manufacturing and market or outside the plant. Automatic renewal is based on signal cards that indicate when additional products are required [25].
11	PDCA	Plan for the expected result, execute the plan, check feasibility from evaluated result, review result and refine process that try another way [26].
12	Poka-Yoke	Error detecting and prevention from the manufacturing process while keeping zero defect strategy in mind [27].
13	Root Cause Analysis	A problem-solving method known as root cause analysis (RCA) is used to determine the underlying reasons or elements that lead to a particular issue, occurrence, or problem [28].
14	Standardized Work	Eliminates waste by following best practices on a regular basis, establishes a benchmark for future improvement efforts [29].
15	Takt Time	The rate at which production is aligned with customer demand, calculated by multiplying the planned production time by the customer demand. Provides a way of pacing production that is easy, consistent, and straightforward. Is simply expanded to give a plant-floor efficiency objective [30].
16	TPM	TPM's major goal is to achieve zero breakdowns, zero defects, and zero accidents. It makes all employees in an organisation responsible for equipment upkeep rather to just the maintenance department. [31].
17	VSM	VSM is a tool for visualising, analysing, and improving the flow of resources, knowledge, and tasks involved in providing goods or services to customers. [32].

2.2. Industry 4.0

To minimize manual and human intervention in industries the fourth industrial revolution was introduced in Germany in 2011, It is the future of Industry in which complete digitization of the manufacturing process will take place and the industry will become the smart industry [3]. It can be possible by integrating the information & communication systems with the physical Industrial world [33]. Industry 4.0 combines the customers, suppliers, and manufacturing processes with consideration of economic and environmental impact [34]. The cyber-physical system (CPS) will increase the decision-making ability of the industry up to an optimum level, where IoT works as communicator and smoothly exchange data for improved decision making. Technical assistance will help the organization to visualize the processes and collect the information for assisting the systems, which helps operator for decision making. Sensors are the first layer of the smart industry; they work on the ground level and collect data from the environment and perform various functions to support the technology [37]. The control system monitors different events in the manufacturing process and all the subsystems in the industry [11]. Industry 4.0 technologies are shown in figure 3. Table 2 has a bibliographic description of industry 4.0 technologies.

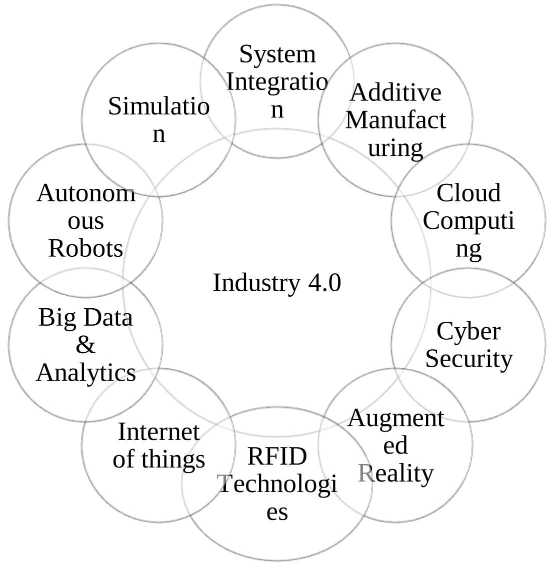


Figure 3. Technologies of industry 4.0.

3. CONJUNCTION OF LEAN PRODUCTION SYSTEM AND INDUSTRY 4.0

The essential query that all businesses want to be addressed is whether the Lean production system and Industry 4.0 are interconnected and can collaborate & support. Some firms are also concerned that Industry 4.0 may overtake Lean ideals. Lean and Industry 4.0 are philosophies that are not so unlike one another but rather complement and aid one another when applied in tandem [38]. Autonomy is another essential element of Lean production that can have a big influence on Industry 4.0 technologies. Autonomy, as defined by Adam et al [39], is a phenomenon in which an automated approach comes to a complete halt when a fault is found, preventing the problem from progressing further down the assembly line. As a result, even if a mistake is detected, only an individual's intervention will be regulated; the remainder of the procedure will be totally done by machines. B. Ding at al [40], have many common objectives since they strive to encourage simple and centralized organizations rather than massive and complicated structures. Because personalization and customization have become key trends, Industry 4.0 can assist lean manufacturing in keeping up with client needs, [41] the Andon approach is a lean principle that is used in conjunction with Industry 4.0 technologies, such as the usage of a robot. [39], current technology can assist industrial businesses in overcoming the barriers to using lean methods. The impact of lean production and intelligent technologies together has the ability to increase production & reduce waste. Industry 4.0 technologies, as per Nai et al [42], can help decrease excess production and lessen the waiting period. Lean practices and digital technologies [43] utilized the Google trends tool to examine public attention in Industry 4.0. They discovered that public interest in digitalization has never been higher in the recent several years. Industry 4.0 technologies do not cover the integration of lean concepts, but they can help to improve their efficiency, by adopting industry 4.0 technologies to deliver embattled and precise information to workers to assist them to recognize and eliminate waste, [43] claims that digital Lean increases waste detection better than traditional lean approaches. Furthermore, according to Sule et al [44], Industry 4.0 will not fix the issues of poorly accomplished and structured industrial organizations. Table 3 shows the contribution for different authors in the field of digitalization of lean tools.

Table 2. Industry 4.0 technologies.

S. No.	Lean tool	Description
1	System Integration	A method of integrating various subsystems or components into a bigger system that works as a single, cohesive unit. It involves connecting and coordinating various software, hardware, and network components to ensure they work together seamlessly and effectively [3].
2	Additive Manufacturing	A cutting-edge manufacturing technique known as additive manufacturing involves building three-dimensional items out of material layer by layer. Contrary to conventional subtractive manufacturing techniques, which entail cutting or sculpting materials, additive manufacturing constructs objects by carefully depositing or solidifying material based on a computer design. [45].
3	Cloud Computing	The supply of computing resources, such as servers, storage, databases, software, and networking, through the internet is known as the "cloud computing".[46].
4	Cyber Security	Cyber security is a protocol that must be considered for the safety of important information, data, software, and hardware of the organization or individual from the theft and damage; it protects your system during the human-machine interface and also improves the efficiency of the system [47].
5	Augmented Reality	Augmented reality (AR) blends computer-generated virtual elements with the physical world to improve how well users can perceive and interact with their surroundings [48].
6	RFID Technologies	RFID system uses antenna, transceiver and a transponder to establish a wireless communication through electromagnetic spectrum for uniquely identify objects [49].
7	Industrial Internet of things	It entails fusing together physical devices, systems, and digital technologies to build a networked ecosystem that allows for the collection, analysis, and control of data in real time [50].
8	Big Data & Analytics	The terms "big data" and "analytics" relate to the gathering, storing, processing, and analysis of enormous and complicated data sets in order to identify significant trends, patterns, and insights [51].
9	Autonomous Robots	An autonomous robot performs the work efficiently and precisely and also utilized at places that are hazardous or impossible to work by the humans, they also provide flexibility, safety, collaboration and versatility to the production systems [52]
10	Artificial intelligence (AI)/ Machine learning	Artificial intelligence (AI) is the emulation of human intelligence in computer-controlled devices that are configured to carry out activities that ordinarily call for human intelligence. It includes a wide range of methods and tools that provide robots the ability to see, think critically, pick up new information, and make judgements. A branch of artificial intelligence called machine learning (ML) concentrates on creating models and algorithms that let computers learn from data and make predictions or judgements based on it. Algorithms for machine learning (ML) are created to automatically enhance and modify their performance without explicit programming. [53]

Table 3 contribution of different authors in digitalization of lean production system

Author	Country	Year	Contribution
Stephen Laaper and Brian Kiefer [6]	USA	2020	Created a guideline for implementing of Digital Lean through incorporating the digital frameworks into lean manufacturing system.
Gallo et al. [54]	Italy	2021	Studies Industry 4.0 tools and their use in increasing the productivity and the factor of efficiency.
Bevilacqua et al. [55]	Italy	2019	Gives an idea to manage warehouse and lessen the time of finding an item through the use of Automated Storage and Retrieval System (ASRS).
Buer et al. [56]	Norway	2018	Defines digitization and illustrates how it can be used to improve the organization by focusing on new possibilities of data already available.
Haartman et al. [57]	Sweden	2021	• Surveyed manufacturing units in Europe • Explored relation between lean and digital technologies in the manufacturing firms.
Hoellthaler et al. [58]	Germany	2019	• Demonstrated the lean and Industry 4.0 tools together. • Measures the profitability in application of Digital Lean in manufacturing units.
Schumacher et al. [59]	Germany	2021	• Examines contribution of Digitization on lean in present scenario. • Studies Lean Production 4.0 in industries.
Powell et al. [60]	Norway	2021	Reviews Digital Lean Manufacturing and brings insights into the intensifying and emergent research field.
Buer et al. [61]	Norway	2020	Presents schematic research on the Digital Lean Manufacturing.
Sony al. [62]	South Africa	2018	Proposes an integrated model of Lean Manufacturing and Industry 4.0

4. METHODOLOGY

This case study that has been carried out in the National capital region (NCR) India, to evaluate the effect of lean 4.0 implementation over MSMEs. There are several studies has been spotted in the literature who has already talked about integration of lean tools and industry 4.0 technologies, and among them there are several success stories of this joint venture in the industry. Still MSME sector is afraid of adopting digital technologies, due to high initial investment and majorly due to the uncertainty of growth as the infrastructure and the architecture of industry 4.0 technologies is not adequately standardized. Indian MSME sector always has a fear of collapsibility due to hesitation to adopt new technologies, lack of skills, higher capital investment which may create MSME sector vulnerable. This study spread awareness and influence the MSME sector to adopt this new technological amalgamation to enhance the performance and productivity with high quality and profitability of the organization. In light of the topic's novelty, this research aims to advance the ideas using all accessible information. The methodology has been illustrated in figure 3.

This data has been collected from various companies at NCR. Companies registered themselves for the lean manufacturing scheme started by the Government of India in association with the National Productivity Council and Quality Council of India. Questionnaires were used to collect the data. 10 companies were selected on the basis of lean audit report, as they have successfully implemented lean tools. Later all 10 companies implemented industry 4.0 technologies. The data was recorded and analysed using the statistical tools and excel, and the different parameters of industrial performance was evaluated and compared.

Before implementing lean, these industries had no signs of organizational setup and the work was very unorganized. Their owners complained about the rising manufacturing and quality costs which in turn was taking on the profits from the organization. Moreover, an extended range of quality issues also raised the customer complaints and decreased their confidence on these companies. Primary data has also provided by the firms is used in evaluating the results. Industry performance variables like productivity, quality, machine availability, Overall Equipment Efficiency (OEE) and Customer Satisfaction Index (CSI) in the context of Indian MSME were calculated, statistical approach is used to analyse the data. Figure 4 has illustrated the methodology for the study.

The objective of the study is to integrate various tools of lean production system with industry 4.0 technologies and analyse the performance of MSME's in NCR, India, with joint venture of lean industry 4.0 (lean 4.0).

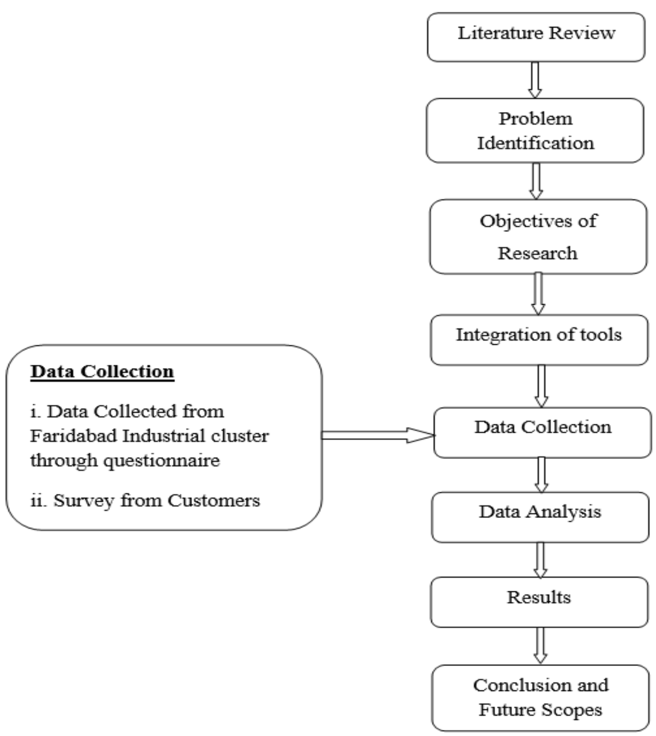


Figure 4. Methodology for this study

Average Productivity, Average Quality and Average machine Availability are calculated by taking all the recorded lean implemantation and later after implimanting industry 4.0 technologies. The Overall Equipment Efficiency (OEE) is calculated by the equations (i, ii,……..v). All the obeservations were recorded on monthly basis for 12 months.

$$\text{Average Productivity} = \frac{\Sigma\text{Productivity recorded in an year}}{12} \quad \text{…(i)}$$

$$\text{Average Quality} = \frac{\Sigma(\text{Quality recorded in an year})}{12} \quad \text{…(ii)}$$

$$\text{Average Availability} = \frac{\Sigma\text{ Machine Availability recorded in an year}}{12} \quad \text{…(iii)}$$

$$\text{OEE} = \frac{\text{Availability} \times \text{Productivity} \times \text{Quality}}{12} \quad \text{…(iv)}$$

$$\text{Average OEE} = \frac{\Sigma\text{ OEE recorded in the year}}{12} \quad \text{…(v)}$$

After these companies joined in the lean manufacturing sheme, the customers were asked to rate the companies based on the questionnaire prepared.
As per the questionnares, an average Customer Satisfaction Index (CSI) was calculated as under:

$$\text{Average C. S. I.} = \frac{(\text{Scores obtained from customer})}{25} \quad \text{…(vi)}$$

5. POSSIBLE FUSION OF LEAN INDUSTRY 4.0 (LEAN 4.0)

Industry 4.0 technologies can help lean tools by installing diverse abilities based on the requirements of the manufacturing operation. Four different factors Visualization, control, administrative, and optimization, come together that create the system truly independent, which equivalent to the Autonomy standard. Systems may then make real-time judgments while keeping in mind their surroundings. The system may also 'learn' from the outcomes of previous decisions or respond effectively to a change in demand. To boost performance, this may also include cooperation and communication with other products and systems.

5.1Just In Time (JIT) 4.0

JIT focuses on reduction of the overall production cost by making available the resources as and when required. It is a tool that very much depends on the information of inventory on time and accuracy for reducing the large buffers and the safety stocks. As per Thoben et al. [63], with the digitization in the Supply Chain, a better transparency can be attained through accuracy in data and better tracking of the level of inventories. Moreover, it will also help in locating the places of the inventories. This digitization can be achieved with the help of tracking sensors, storage of data on the cloud and Artificial Intelligence (AI).

5.2Heijunka 4.0

Heijunka support the pull system focuses on the production at a constant rate so that all the other production processes are maintained at a predicted and constant rate. Heijunka is determined by the bulk of order that a customer places with the manufacturer. Thus, it can also be utilized for the prediction of the customer’s demand. Further the integration of production levelling with information and technology system along with internet of things (IoT) and big data analytics will increase reliability for materials, processes, equipment in the industry [64].

5.3Kanban 4.0

One piece flow and Kanban can be complemented with Industry 4.0 tools and technologies. RFID as well as sensor-based Kanban racks ("E-Racks") and "smart Kanban-Sensors," which provide automatic Kanban signals by gauging material weights or distances. The Integrated Kanban System analyses and displays these signals. customers may streamline their business operations and increase the effectiveness of their material supply chains by using new Kanban [65].

5.4Value Stream Mapping (VSM) 4.0

Value Stream Mapping is a Lean tool that is utilized to eliminate the wastes in a system. But there is a shortcoming that it provides us with an understanding and snapshot of the process at a specific time. If we club it with the IoT and the RFID, and big data it can overcome its shortcoming. The RFID will identify the location and the stages and IoT will help in autonomous decision making thus making the waste elimination method dynamic [66].

5.5Total Productive Maintenance (TPM) 4.0

Manual preventive maintenance is tough in a factory where thousands of tools working for resolving such issues industry 4.0 technologies play an important role, advanced manufacturing cloud of things and cyber-physical agent used for construction on intelligent preventive maintenance system, this system has the supervision on the condition of all the machine tools and equipment in the entire industry, implementation of such system will cure the industry from sudden breakdown of machine or tools and increase the profitability productivity and efficiency of tools equipment and the company[67]. Total Productive Maintenance is a philosophy that focuses on the autonomous maintenance i.e., planned maintenance without waiting for the equipment to actually fail. VR/ AR can be used by the companies to train the maintenance personnel about the possible breakdowns or critical parts. Big Data and Machine Learning technologies of Industry 4.0 can help in monitoring of the wear, defects and loads to put a check on the possible future faults. They can also contribute to building a strong production and supply chain [68].

5.6Automation 4.0

The capability of machines to identify or detect the abnormal situation is termed as the automation. This lean tool can be integrated with the Cyber-Physical System (CPS), Industrial Internet of Things (IIoT), sensors which can connect, control and monitor machines and operations through clouds in real time. This will help in automatic corrective actions, root cause analysis and a better tracking system thereby, enhancing the automation.

6. RESULT ANALYSIS

After one year of implementation of Lean Principles in selected industries, the data was analysed which showed an appreciable improvement in the machine availability, productivity and quality thereby increasing the Overall Equipment Efficiency (OEE). Such improvement was also reflected in the Customer Satisfaction Index (CSI). Table 5 represent the availability of different lean tools in selected organizations after one year of lean audit.

Table 5 Availability of lean principles a year after lean audit in selected industries

Companies/Lean Tools	5S	Scheduling	Kaizen	JIT	Poka-Yoke	RCA	SMED	TPM	Visual Factory	Takt Time
A	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
B	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
C	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
D	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
E	☑	☑	X☑	☑	☑	☑	X☑	☑	☑	X☑
F	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
G	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
H	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
I	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
J	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑

X: Completely Absent X☑: Incompletely Present ☑: Present

The average productivity, quality, availability and overall equipment efficiency are calculated and tabulated in Table 6 for each unit of selected organizations.

Table 6 Performance on Parameters after an year of lean implementation

Companies	Average Productivity	Average Quality	Average Machine Availability	Average OEE
A	0.8847	0.9248	0.7512	0.64829
B	0.8945	0.9055	0.8954	0.748
C	0.856	0.984	0.8545	7197
D	0.8951	0.9	0.8456	0.7183
E	0.8456	0.9854	0.925	0.7708
F	0.8611	0.958	0.8546	73148
G	0.745	0.7202	0.7401	0.3971
H	0.8435	0.9875	0.94556	0.79728
I	0.8615	0.9565	0.84565	0.69684
J	0.8024	0.9559	0.88946	0.68223

After the maturity of lean principles in the organizations further they have proceeds for adopting the digital technologies or technologies belongs to the industry 4.0 Table 7 represent the availability of lean 4.0 implementation in different companies. After one year of implementing industry 4.0 technologies the performance of the companies was evaluated and found a positive response. Table 8 present the result of performance parameters in different organizations in NCR, India.

Table 7 Availability of Lean 4.0 tools in Indian MSME

Companies/Lean 4.0 tools	VSM 4.0	TPM 4.0	KANBAN 4.0	Heijunka 4.0	JIT 4.0
A	X☑	X	X☑	X☑	X
B	X☑	X	X☑	X☑	X☑
C	X☑	X	X☑	X☑	X
D	X☑	X	X☑	X☑	X
E	X☑	X☑	X☑	X☑	☑
F	X☑	X	X☑	X☑	☑
G	X☑	X	X☑	X☑	X☑
H	X☑	X	X☑	X☑	X
I	X☑	X	X☑	X☑	X
J	X☑	X	X☑	X☑	X

X: Completely Absent X☑: Incompletely Present ☑: Present

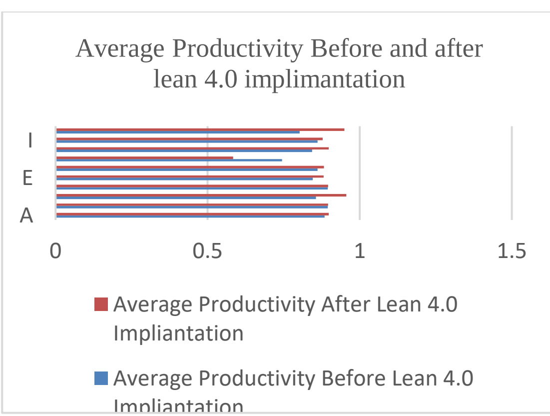
Table 8 Performance of MSME companies after Lean 4.0 implimantation

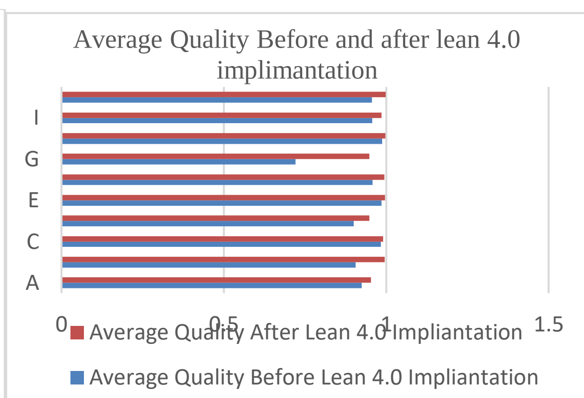
Companies	Average Productivity	Average Quality	Average Machine Availability	Average OEE
A	0.8985	0.9525	0.9815	0.803
B	0.8956	0.9956	0.9235	0.79839
C	0.9555	0.9902	0.9252	8754
D	0.8958	0.9485	0.9892	0.7969
E	0.8815	0.9959	0.94557	0.8301
F	0.8825	0.994	0.9562	0.9
G	0.5841	0.9485	0.9565	0.77487
H	0.8984	0.9975	0.9568	0.8488
I	0.8784	0.9855	0.9855	0.8531
J	0.95	0.9985	0.9822	0.9317

Moreover, the Customer Satisfaction Index (CSI), calculated shows through the Table 9, increased with the implementation of lean principles.

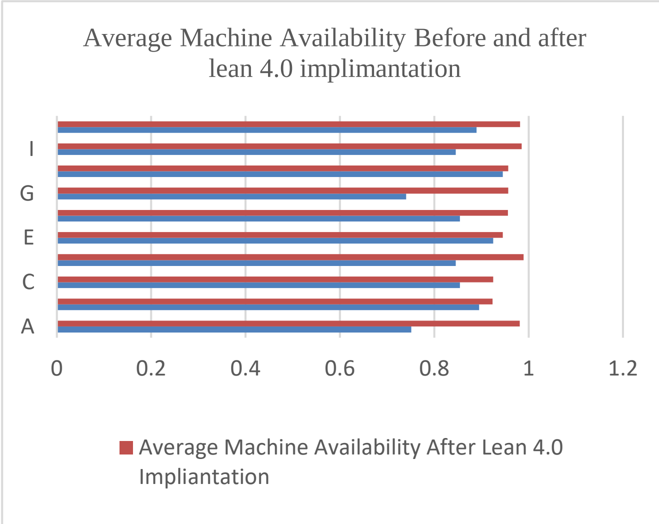
Table 9 Customer Satisfaction Index before and after Lean 4.0 Implementation

Companies	Lean	Lean 4.0
A	0.6	0.8
B	0.56	0.76
C	0.62	0.72
D	0.58	0.74
E	0.64	0.8
F	0.6	0.7
G	0.6	0.8
H	0.54	0.72
I	0.5	0.8
J	0.56	0.84

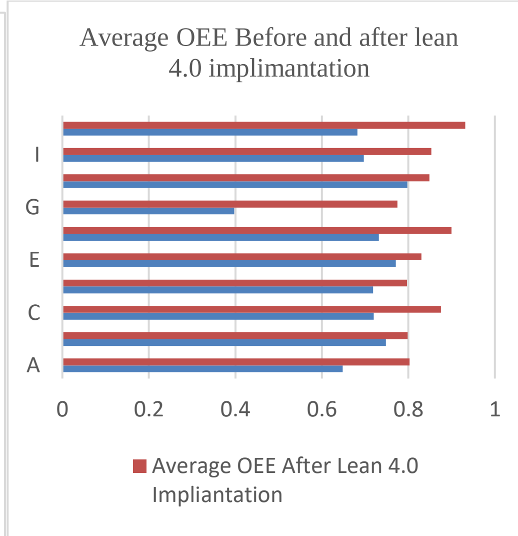




(a) (b)



(c)



(d)

Figure 5. Comparison between different variables of performance before and after Industry 4.0 implementation
(a) Average Productivity, (b) Average Quality (c)Average Machine Availability (d) Overall Equipment Efficiency (OEE)

Figure 5 represent the calculated results in the form of graphs, different parameters of performance evaluation of industries, 10 MSMEs of Faridabad engineering cluster India, was compared and find positive response regarding performance enhancement with the digital merger of different industry 4.0 technologies with lean tools. Figure 6 indicate the customer satisfaction index comparison after implementation of industry 4.0 technologies over lean tools.

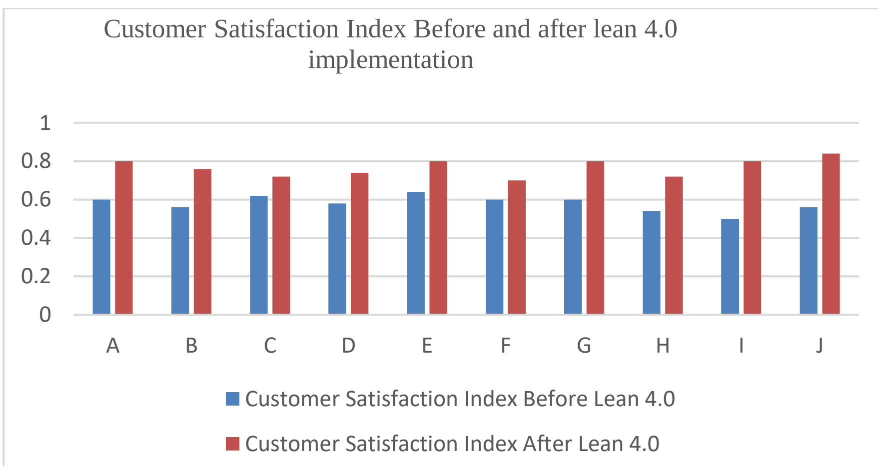


Figure 6. Customer Satisfaction Index Before and after lean 4.0 implementation

CONCLUSION

In collaboration with the National Productivity Council and the Quality Council of India, the Indian government launched a programme to introduce lean principle in Indian industries, the participation is voluntary. Many Indian MSMEs in the NCR, India have achieved certification as Lean Adopters after excelling in the Lean audits, few of them have also begun the process of implementing Industry 4.0 in their respective industries. The results are very lucrative as the parameters of performance has boosted up. Average quality, productivity, machine availability, overall equipment effectiveness (OEE) was observed and showing a positive response for adoption digital technologies along with the lean principles. The customer satisfaction index (CSI) was increased up to 33% after implementing digital lean in Indian MSMEs. This study may bring the awareness in Indian manufacturing sector and other industries for adopting industry 4.0 technologies, the positive results may counter the adoption barriers or the fear of industrialists or owners of the firms to opt digital technologies with lean for the overall enhancement of the business. Lean Industry 4.0 or lean 4.0 has the potential to revolutionise Indian MSME industry, but both owners and employees' restricted mindsets and resistance to change need to shift. This study may provide a practical stand point to the hard hit Indian MSMEs, that seems to be on ventilators now a days. The positive result of this paper may generate a hope among the businessmen and industrialists.

Limitations

The study is restricted to the type of industry and the number of responses observed, the results may differ with more number of respondents, also the study is conducted during or post COVID-19 phase that also have a huge impact over industries specially MSMEs in India, the results may change. The amalgamation of lean principles with industry 4.0 technologies may highly impactful and boon for the Indian MSMEs in future.

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