Integrating Lean manufacturing and Industry 4.0 – A Systematic Review

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Abstract

Lean Manufacturing is being used by the industries since years to improve the operational performances of the company. Anything that doesn't add a monetary value to the product is a waste in Lean. The tools of Lean help in minimizing the wastes and thereby, increasing the profit in an industry. It proved to be a boon for the industries and it is adopted by almost all the industries. The industries are reaping the benefits in the form of higher productivity, quality and customer satisfaction. But with the changing times, Lean Manufacturing needs to be evolved too. Industry 4.0 supports mass production and a high range of customization Although, Industry 4.0 can meet the ever increasing digital era demands, yet they are more of a solution provider with a little scope of improving the organizational processes. Hence, an integration of Lean Manufacturing techniques with Industry 4.0 can lead to an overall improvement in manufacturing processes and can lead towards a better future of Indian MSMEs. The newly integrated system can be termed as Lean 4.0 or Lean Industry 4.0.

***Keywords*: Lean Manufacturing, Industry 4.0, Systematic Review**

Introduction

Presently, Indian Micro, Small and Medium Scale Enterprises (MSMEs) are facing many challenges like the changing trends of customer demands, competition, globalization, economic turbulence and financial crisis [1]. Moreover, the Corona Virus pandemic proved to be a huge setback for the world. It engulfed a large number of lives as well as businesses. Indian MSMEs were the hardest hit. The lockdown imposed took a huge toll on their businesses. Although, the Indian Government introduced many measures to bring MSMEs on their feet again but as per a study by the Reserve Bank of India, "If India continues to grow at the same rate; it is expected to overcome the losses by 2034-35." Under these challenging environments, companies need to adopt the most effective methodologies and techniques. Lean Manufacturing, Six Sigma, Lean Six Sigma etc. are some such methodologies. Lean Manufacturing uses tools such as 5S, JIT, Jidoka, Kanban, Gemba, TPM, VSM etc. to eliminate the 8 wastes identified by it. The eight wastes are- defects, overproduction, waiting, transportation, inventory, motion, over processing and un-utilized talents. Although, Lean aims at increasing the Overall Equipment Efficiency of a company by increasing the machine availability, productivity and quality yet, for staying in the race the industries need to equip themselves with the latest technologies [2]. Industry 4.0, or the 4th Industrial revolution is the latest advancement in industrial process. It involves use of automation and data exchanges in a manufacturing process [3]. The third Industrial revolution gave birth to Lean Manufacturing and it focuses on overall improvement of an organization's efficiency [4]. It is a methodology that helps in improving the quality, reducing the lead times, reducing cost and improving the productivity of the company [5]. Lean Manufacturing is easy to implement and provides an effective result. This is the reason for its widespread adaptability [6]. Lean Manufacturing is related with fixed production sequence and a relatively slow responsiveness and with ever changing consumer demands; it may not be able to meet the demands of the changing world [7]. Integrating Lean Manufacturing with Industry 4.0 can be a solution [8]. Lean Manufacturing and Industry 4.0 have similar goals, i.e. improved quality, productivity, elimination of wastes and customer satisfaction [9]. Lean Manufacturing is considered to be a employee- focused and low technology approach while, Industry 4.0 leads to reduction in manpower [10].

Research Methodology

This research work contributes to the Systematic Literature Review on the integration of Industry 4.0 with Lean Manufacturing Techniques. According to [11], SLR is a methodology that identifies the works of researchers in the field, selection and assessment of contribution from various researchers, analysis and synthesizing data, and producing the result such that there is a clear summary of what is already known and what is not. As shown in the figure 1, this study follows

Key words: Lean, JIT, Industry 4.0, Smart Factory, Smart Manufacturing

Database: Web of Science: 230 Papers, Pro Quest: 187 Papers, Scopus: 353 papers

The analysis involves the breakdown of the studies into constituent parts and describes their relations with each other.

The synthesis part associates constituent parts from individual studies.

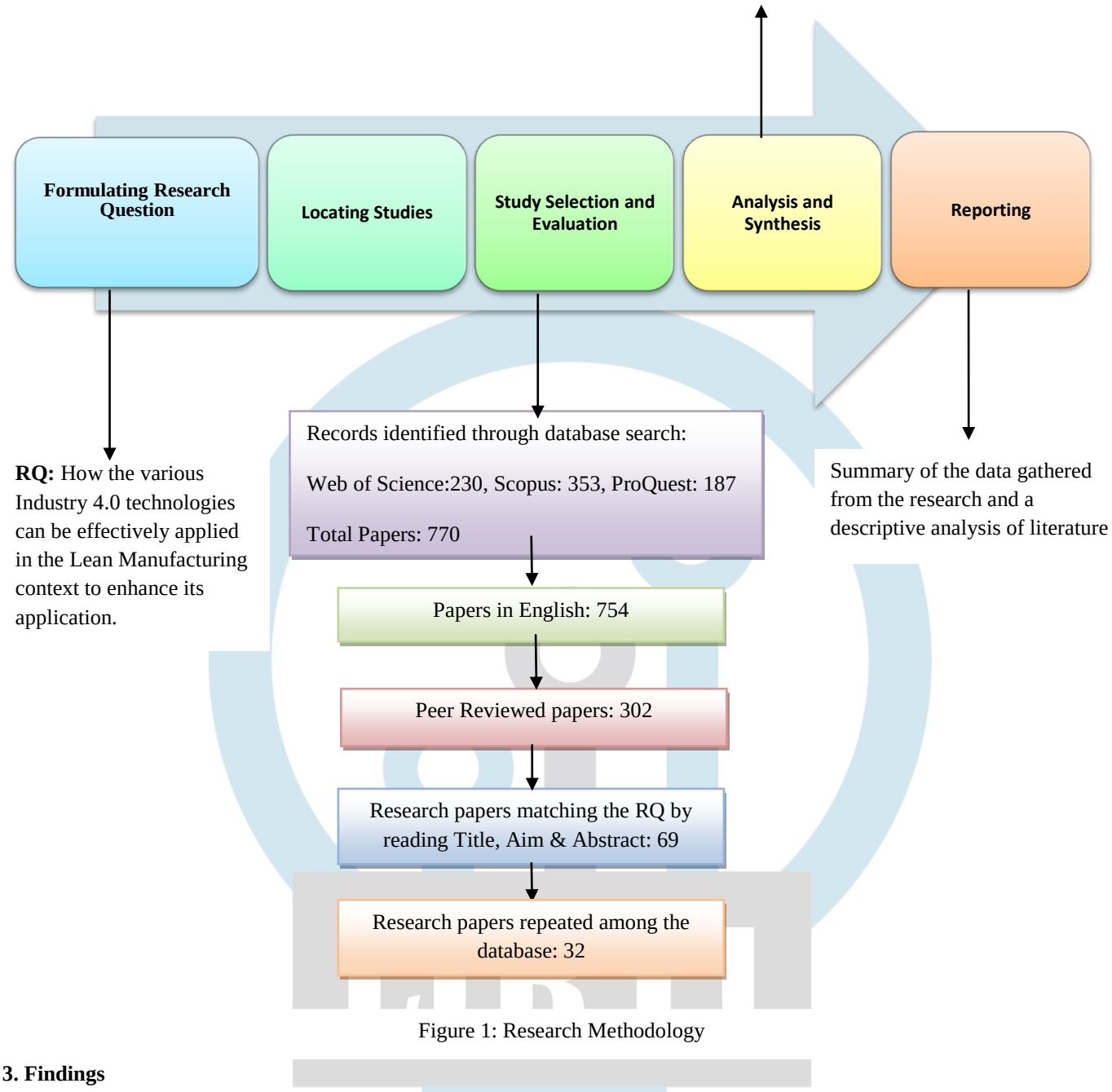

Figure 1: Research Methodology

3. Findings

3.1. Industry 4.0 tools that supports Lean Manufacturing

Internet of Things (IoT) technologies like the Radio Frequency Identification (RFID) and Low Power Wide Area Network (LPWAN) are used to enhance traceability and provide real time information. This can be implied in Lean Manufacturing to eliminate the wastes [12-13]. Internet of Things is also used to integrate machines in the shop floor and also in connecting them with Andon systems to improve the decision support system for process improvement [14-15]. IoT has also been applied to transform the traditional Just In Time approach to dynamic Just In Time by integrating modules integrated with Internet of Things into Manufacturing Execution System (MES) [16]. IoT has also benefitted Single Minute Exchange of Die concept (SMED). It ensures lesser changeover time by providing embedded information to the product which can be communicated to the machine directly which needs a changeover [17]. IoT provides real time requirements and proposes optimum travel routes to the logistics operator thereby, bridging the gaps between production and logistics and improving efficiency [18].

The decision support system in JIT can be enhanced through Machine Learning by providing flexibility to operator with re-scheduling options [19]. Machine Learning aims to contribute to continuous improvement by selecting the best improvising pathways under dynamic change of production. This can be a tough task, if done manually [20]. It also reduces the process lead times and is successfully implemented in an additive manufacturing by predicting the exact cooling times [21]. Integration of operator and robot is termed as Cobot. These are also effective in lean manufacturing [22]. These cobots can be used to perform tedious jobs or can be used at a place which involves hazards to human life.

Augmented Reality (AR) is effectively used in Poka-Yoke/ Jidoka systems. A. Chiarini and M. Kumar [23] quote examples from a survey where AR is used for Jidoka and ensures that the operator follows the SOP (standard operating procedure). There

are system where the operator can do things in the corrected manner like in tightening a bolt, the operator sees a green line when he is at the right spot in tightening and see the required torque etc. This shows that an effective amalgamation of Lean with Industry 4.0 can give desired results. Virtual Reality (VR) is used to create a prototype of the manufacturing process before it is actually implemented. This allows the planners and implementers that everything is in its place before the actual installation [24]. This implementation of Virtual Reality in the conformance process helps in reducing waste, rework and lead time thereby cutting the chances of extra cost that would have been incurred if the process didn't work well.

To characterize and discerning between the behavior, electro-encephalographical sensors are used along with Artificial Intelligence. This is carried on a hoshin kanri tree and it conveys the characteristics observed by the operator and the leader [25]. These can be used to give training of Lean Manufacturing on the shop floor and a better thinking can be inculcated. To create a real-time scheduling and dispatching, Cyber Physical Systems (CPS) is used. It runs on a dynamic VSM (Value Stream Mapping). It can analyze the times between various processes and can help in eliminating the wastes identified through the Lean Manufacturing [26]. The pull production strategy of lean manufacturing can be integrated with cyber physical system to reduce the cost of production [27]. It is also used in to determine the optimum tool wear time through integration with Jidoka system. It will change the tool automatically when it wears out thus, reducing the tool changeover time and need for operator to do this repetitive task [28]. Cloud Computing can be used for making an effective and fast decision [29]. The data collected from various points can be uploaded directly to the cloud which can be accessed by managers or the management. This will reduce the time for permissions and implementations. The real time production reports of the operators can be grasped by a mechanism created by integration of Cloud Computing and RFID [30]. Cloud computing when integrated with Enterprise Resource Planning (ERP) will create a cloud ERP that support Kanban, Just in Time, Failure Mode and Effect Analysis (FMEA), real time monitoring of production, Preventive Maintenance (PM), machine break down history and spare parts [31].

Values Stream Mapping (VSM) can be integrated with the Big Data Analytics t enhance the VSM design. It enables effective decision making, real time takt definition, selecting finished goods strategy. It can successfully permit the re-dimensioning of supermarket policies. It can also update instant updates regarding variations and fluctuations [32].

4. Conclusion

This research paper contributes to the SLR on Lean Manufacturing and Industry 4.0 in the manufacturing context. Nine technologies out of the list of Industry 4.0 concepts were identified which were prominent in research fields. These technologies were then integrated with the Lean Manufacturing tools and principles. It is clear that an integration of Lean Manufacturing with Industry 4.0 has led to advancement in the production process through technological advancements, use of internet and digitalization. The bibliometric analysis of literature review shows that this area is young with an increasing trend of interest from academicians and researchers in the field. This research of integrating Lean Manufacturing concepts with those of Industry 4.0 provides a foundation that may inspire the future research efforts.

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