



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

IJIRSET

International Journal of Innovative Research in
SCIENCE | ENGINEERING | TECHNOLOGY

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 10, Issue 8, August 2021

ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

Impact Factor: 7.569

9940 572 462

6381 907 438

ijirset@gmail.com

www.ijirset.com

An Overview of Lean Production and Industry 4.0

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ABSTRACT: Most of the company's goal is to increase productivity and minimizing the usage of resources. In this sense, Lean Production (LP) is one of the major concepts in the creation of highly efficient processes, reducing non-value-added activities, and delivering quality products focused on customers' satisfaction. The Fourth Industrial Revolution and their related Industry 4.0 technologies are driving the current manufacturing systems to a new level of organizational development. It is a strategic initiative introduced by the German government. The purpose of this initiative is the transformation of industrial manufacturing through digitalization and exploitation of new technologies introduced in industry 4.0. An Industry 4.0 production system is helped to get flexibility and enables the Individualization and customization of products. The purpose of this study consists of a systematic literature review to know how the emerging disruptive technologies can enhance lean practices and how the integration of both lean and industry 4.0 can exist so that a proper framework could achieve, with the help of which we can implement these both concepts together in the industry.

KEYWORDS: Framework, Industry 4.0, Lean Automation, New Technologies, Lean Production.

I. INTRODUCTION

In latest years, the markets expansion and the fast technological changes are driving very challenging competitiveness in business. In such an uncertain environment, the companies' ability to develop new knowledge and innovate – either at the organizational, managerial or operational level – flexibly integrating this knowledge, become fundamental to build up a sustainable competitive advantage. Therefore, several questions and challenges arise regarding which management approach should be used alongside or even which ones should be preferred over others. In the early 1990s, Lean Production (LP) has emerged as one of the key concepts in management and operation, to create highly efficient processes by reducing non-value-added activities, delivering quality products focused on customers' satisfaction [1]. But considering the market demand, we need some improvement in on-going methodology so that industry can achieve the quality of product and customer's satisfaction in a faster and efficient way so that industry could face challenges with lots of benefits to keep in view the customer's satisfaction.

Therefore, while LP is still considered a valuable optimizing manufacturing processing approach, LP requires the latest technologies and strategies to cope with the large variations related to the marketplace demand [1]. So, in the last few years, many new global concepts have emerged, due to disruptive advancements in manufacturing processes and technology. Industry 4.0 is one of these concepts, being a new industrial paradigm that embraces a set of new technologies and holds enormous potential for organizations. On the other hand, a Lean Production is an approach widely used in manufacturing for decades, whose main aim is reducing wastes and improving productivity, while meeting customer's requirements. So much research has been performed on the integration between Industry 4.0 and lean production in recent years by academics and companies, however, despite numerous studies approaching the integration between these two topics, the potential of each 4.0 technology in lean practices and tools is not clear [2]. The purpose of this study consists of a systematic literature review is to know how the emerging disruptive technologies can enhance lean practices and how the integration of both lean and industry 4.0 can exist so that a proper framework could achieve with the help of which we can implement these both concepts together in the industry.

II. LEAN PRODUCTION

Lean means, the use of less space, less human effort, less invention, less investment in tools, less processing time, less waste and producing high-quality reliable products [3].

In the field of lean's history involves luminaries such as Toyoda, Ford, Ohno, Taylor and many others. Let's read about their accomplishments and contributions stepwise coming into existence. Early in the 1890s, the father of scientific management, Frederick Taylor investigated closely the work methods and workers at the factory level. After his supervision, he propounded the concepts like standardization of work, time studies and motion studies, to achieve efficiency in the work methods, processes and operations. However, the behavioural aspect of the work was ignored by him, which invited many criticisms against him.

Further in Starting of 1910, Henry Ford pioneered the famous manufacturing strategy, in which all the resources used at the manufacturing site- people, machines, equipment, tools and products were arranged in such a manner that the continuous flow of production is facilitated. However, as the world began to change, Ford could not change the work methods and failed when the market demanded to add new models, colours and varieties to the products.

After that Sakichi Toyoda established the Toyoda spinning and weaving company in the year 1918. Sakichi Toyoda was one among the initial contributors of success towards the famous Toyota Production system that aim was eliminating all the wastes, by propounding the Jidoka concept. Jidoka- 'automation with a person's touch' means to facilitate quality at source. He invented the automatic loom in 1896 that not only substituted the manual work but also installed the potential to form judgments into the machine itself. The system enhanced the work effectiveness and efficiency by mitigating the product's defects and associated wasteful work practices. Kiichiro Toyoda was the second president and founder of Toyota Motor Corporation. He was the son of Sakichi Toyoda and later in 1937, The Toyota Motor Corporation was founded by him. He took forward Jidoka's concept of his father and developed his philosophy about the just-in-time concept in manufacturing. He paid for visiting Ford's plant in Michigan to understand the flow of assembly line concept and then proposed the Toyota Production System. The new system aimed toward right-sizing the machines concerning the particular volume needed and introduced mistake-proofing in order that quality is ensured and proper sequencing of work processes are done [4]. Further, some enhanced thoughts on the subject at Toyota in the 1930s were applied by Shigeo Shingo and Taiichi Ohno. Then finally resulting methods were researched in the mid of 20th century and dubbed "Lean" by John Krafcik in 1988 and further detailed by James Womack and Daniel Jones in Lean Thinking (1996) [5]. In which the authors put forward five principles: Value, Value Stream, Flow, Pull and Perfection. [6] Like this, there are many engineers and industrialists come in front and gave a various tool to implement lean production.

Some important Lean Production Tools is discussed below: -

A) 5s

Organize the Work Area:

- Sort (eliminate that which is not required in the work area)
- Set in Order (organize remaining items)
- Shine (clean and inspect work area)
- Standardize (write standards for above)
- Sustain (regularly apply the standards)

B) ANDON: The visual feedback system empowers operators to stop the production process and for the shop floor indicates production status alerts when assistance is needed. It brings immediate attention to problems as they occur so they can be instantly addressed by acting as a real-time communication tool for the plant floor.

C) BOTTLENECK ANALYSIS: Identify by which part of the manufacturing process limits the overall amount of work and enhance the performance of that part of the process. Improves the overall amount of work by strengthening the weakest link in the manufacturing process.

D) CONTINUOUS FLOW: Manufacturing where work-in-process smoothly flows throughout production with no buffers between steps of the manufacturing process. Eliminates many forms of waste for example waiting time, inventory, and transport.

E) GEMBA (THE REAL PLACE): A philosophy that tells us to get out of our offices and give time on the plant floor the place where real action take place to know real-world problems. Understanding the real-world manufacturing problems improve the deep and complete of a plant by first-hand observation and by talking with plant floor employees.

F) HEIJUNKA (LEVEL SCHEDULING): A sort of production scheduling that aim is to manufacture in much smaller batches by sequencing (or mixing) product variants within the same process. Reduces inventory (since batches are smaller) and lead times (since each product or variant is manufactured more frequently).

G) JIDOKA (AUTOMATION): Design equipment to automate the manufacturing process partially because partial automation is usually less expensive than full automation and automatically stop when defects are detected. After Jidoka, multiple stations can be frequently monitored by workers (reducing labour costs) and many quality issues can be detected immediately (improving quality).

I) KAIZEN (CONTINUOUS IMPROVEMENT):A strategy where employees work together in an active manner to achieve regular, incremental improvements in the manufacturing process. Combines the collective talents of a corporation to make an engine for continually eliminating waste from manufacturing processes so that continuous improvement takes place.

J) KANBAN (PULL SYSTEM):A way of regulating the good’s flow within the factory and with outside suppliers and customers. When more goods are needed is showed by signal cards Based on automatic replenishment. Eliminates waste from overproduction and inventory Can remove the need for physical inventories (rather than relying on signal cards to indicate when more goods need to be ordered) [7].

III. INDUSTRY 4.0

An Industry 4.0 revolution was first introduced by a team of scientists developing a high-tech strategy for the German government to ensure technology leadership, and the development of smarter strategies to upgrade the national industry as a whole. As also called the fourth industrial revolution, Industry 4.0 concepts aim to create smart factories combining physical operations and several advanced technologies, such as big data analytics, the internet-of-things, additive manufacturing, virtual reality, cloud computing, robotic systems, and cyber-physical systems (CPS) [1]. Industry 4.0 was introduced publicly at the Hannover Fair in the same year, symbolizing the advent of a new era of the industrial revolution. When the idea was first raised for discussion, extensive efforts were undertaken by European manufacturing researchers and companies to embrace it. Their interest in this project is due to the fact that under the concept of Industry 4.0, production will become more efficient and less costly. This is achieved by simply the exchange of information and the integrated control of manufacturing goods and machines acting simultaneously and smartly in interoperability [8]. The term Industry 4.0 or the Industrial Internet is characterized in the industrial revolution as the fourth stage (Fig.1).

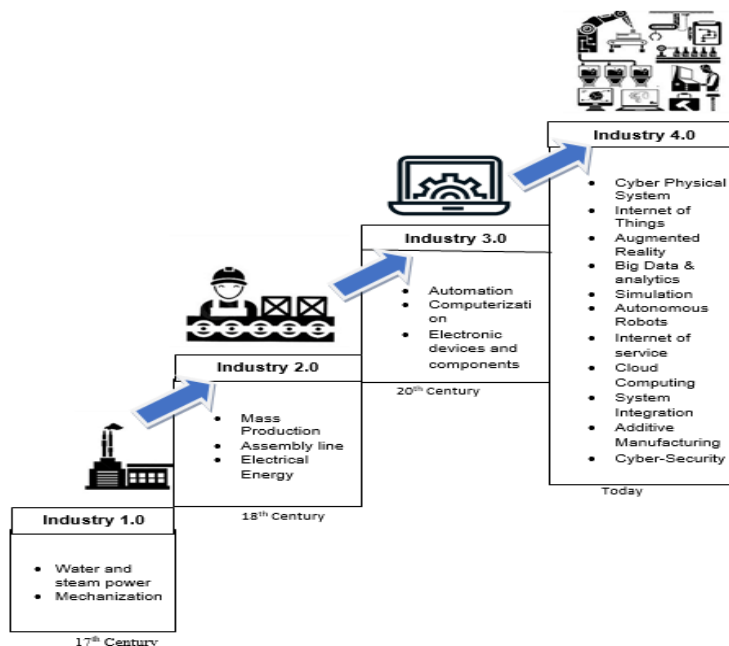


Fig1: - Stages of Industrial Revolution [8]

And consists of an increasing interconnectedness of products and systems. Focusing on the enhancement of the automation, flexibility, and individualization of products, production, and connected business processes, Industry 4.0 aims at connecting the physical and virtual worlds. From a production perspective, the movement of intelligent workpieces is understood as Industry 4.0 that independently coordinate their paths through the factory. Machines can “realize” these tracks and communicate in real-time with the corresponding warehouse. If necessary, orders are automatically triggered with the help of targeted calculations, errors can be computed before reaching the stage of production, and the right interpretation enables a machine to change its production order. To assess and control current processes Information is primarily used. Thus, an essential feature of Industry 4.0 can be seen in information aggregation in engineering and operations across different projects, plants, and plant operators [9]. For the term Industry 4.0, a universal definition does not exist. However, many researchers have different perceptions of the true meaning of Industry 4.0. Therefore, we concluded a working definition to serve as the foundation; Industry 4.0 encourages manufacturing efficiency by making correct decisions, collecting data smartly and executing decisions without any doubts. By utilizing the most advanced technologies, the procedures of collecting and interpreting data will be simple. To provide a reliable manufacturing environment in Industry 4.0 the interoperability operating ability acts as a ‘connecting bridge’. This overall consciousness gives Industry 4.0 the most important aspect of artificial intelligent functions [8].

There are nine tools that driving Industry 4.0.

A) INTERNET OF THINGS (IOT): Embedded networking and computing connect devices and sensors. The Internet of Things connects more and more systems, devices, sensors, assets, and other people through networks ranging from wireless, low-power wide-area networks to wired high-capacity networks.

B) CLOUD COMPUTING: Many small enterprises cannot afford to have the storage for an increasing amount of knowledge. Some of them lack the analytical and computational capabilities of processing a huge amount of data. However, the info and therefore the capabilities of analytics and computation are even more important to them. Cloud service providers are offering a growing opportunity to small enterprises through data storage and data processing at affordable costs.

C) CYBER-SECURITY: Industrial systems are becoming increasingly vulnerable to threats as there are various devices and a large number of data sets. Cyber-security has to be put in place, which can recognize new challenges and vulnerabilities, and ensure businesses and industrial systems free of attacks.

D) AUTONOMOUS ROBOTS: The robots that are used in manufacturing is no longer new. In Industry 4.0, robots are autonomous, interactive and self-sufficient, which are not any longer simply tools employed by humans but are integral work units.

E) ADDITIVE MANUFACTURING: Additive manufacturing, especially, 3D printing enables manufacturers to dramatically reduce the design time and cost and increase the variety and customization of products. Additive manufacturing brought benefits and values that are even more evident in the high mix low volume (HMLV) manufacturing.

F) AUGMENTED REALITY: Customers are now more and more demanding. All-round service has to provide by Businesses to the customer, from personalized product design, dedicated manufacturing process to individualized after-sales services. Augmented reality-based systems can assist enterprises to gain their competitive edges and win more business opportunities in such a competitive marketplace [10].

G) BIG DATA: Besides connectedness through the internet, big data and information processing are other core elements in this new industry 4.0 concept of a connected environment. The basis of Big Data is information. Due to the ability to collect lots of data by smart machines and smart products, e.g. from the environment or manufacturing processes, the number of available information increases. Moreover, information systems and machines can also exchange more data. New in Industry 4.0 is that data are available in real-time. This means that information is available everywhere at any time. This states a new situation for information processing as the incoming data always reflect the present situation [11].

H) CYBER-PHYSICAL SYSTEMS: Cyber-Physical Systems (CPS) are systems of collaborating computational entities which are connected intensively with the surrounding physical world and its on-going processes, providing and using, at the same time, data-accessing and data-processing services available on the internet [12].

I) SIMULATION: When it comes to the design of production processes or parts, there is always room for improvement. The challenge for manufacturers is to figure out what to change to get the best results. Simulation software can assist with this process. Manufacturers can create virtual representations of a part or process on a computer using simulations.



This allows businesses to validate a product, process or improvement idea without needing to incur the full expense upfront [13].

IV. INDUSTRY 4.0 & LEAN PRODUCTION INTEGRATION

Two of the most popular manufacturing paradigms between academics and companies are Lean Production and the newest Industry 4.0. As LP has been widely adopted in a wide range of companies in the last decades, it would not be appropriate to consider the implementation of related Industry 4.0 technologies without considering the initial companies’ statesuch features increased the research interest to integrate these two paradigms (LP and Industry 4.0) [1]. A lean Production is a value-based approach where employees are constantly improving processes by systematically solving problems and eliminating waste, and in doing these things they become better problem solvers. In the centre of lean production stands the concept of a continuously operating plan, do, check and act process (PDCA). Also, the digitalization of industrial production gives companies the ability to improve their products and processes. Even though a great number of companies made statements about implementing new IT systems to connect machinery, workers and products, the question has been raised what the future position of the production workforce may be. For sure their daily targets and necessary competencies may change but they still will be essential to solve problems in a future connected production environment or maintain machinery. The German coined term Industry 4.0 holds the connected factory as a core value every product connects itself with its counterparts as well as with machinery. The concept bears great potential to relieve workers from monotonous tasks and enhance the quality of decisions on the plant floor both approaches, Lean Production, and Industry 4.0, in terms of their goals are similar [14].

TABLE 1. Different approaches for similar targets [14].

S.No.	Goals	Lean production	Industry 4.0
1.	Approach	Holistic (human + technology + organisation)	Technology-driven
2.	Philosophy	People development + problem solving	Feasibility, (self) optimisation
3.	Foundation	Stability and standardisation	Interconnectivity, adaptivity
4.	Control principle	Flow, pull, FiFo	Dynamic, depending on the current situation
5.	Improvement + problem solving	Proactive → standard, abnormality → reactive	Data-based learning → predictive
6.	Information acquisition	A real place, real material (Go and See)	Problem-specific data provision, real time

Furthermore, this integration is called the name of Lean Automation (LA), which aims to have shorter information flows to meet future market demands and greater variability [15].

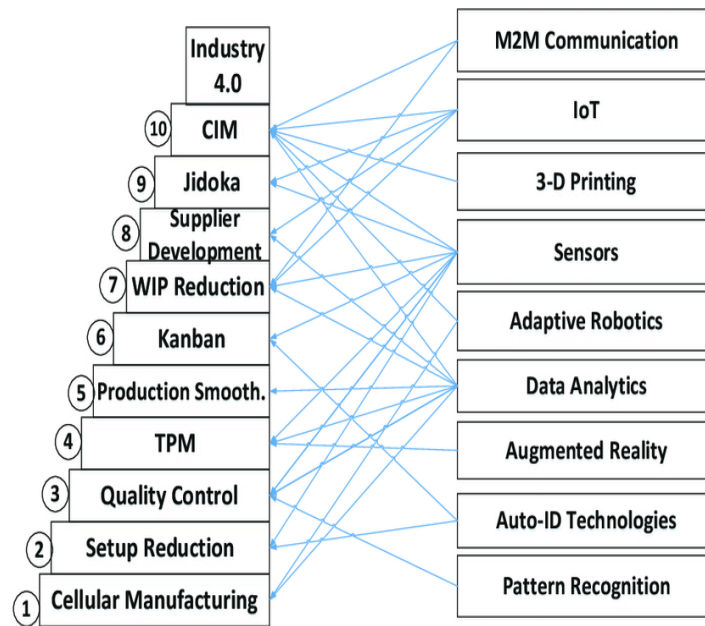


Fig 2:- Lean tools and Industry 4.0 technologies ladder [16].

Figure 2 shows the relationship between the Lean tools/techniques and the advanced technologies. The figure is implying that the lean techniques or tools should be implemented in a sequential manner [16].

Some examples of how industry 4.0 technologies and lean principles meet or are integrated.

A. CUSTOMER CENTRICITY: Lean has always emphasized a customer-centric production approach first and now digital technologies are enabling manufacturers to gain a clearer picture of their customers’ needs.

For example, artificial intelligence and advanced data analysis can be applied to customer data for determining customer needs. The simplest example is in analyzing app user behaviour or in understanding when, where and how many people access a product’s origin information via the label. Mass customization is also enabled through integrating automated and semi-automated robots into production lines as they can cope with higher degrees of variety so customers can heavily customize their orders.

This is how the industry 4.0 technology-enhanced customer-centric ‘just-in-time’ philosophies of lean.

B. CONTINUOUS IMPROVEMENT: On the production line a continuous improvement program might selectively alter a variable, to do tests in real-time, and accordingly review the results. New technologies like powerful simulation tools and the digital twin allow manufacturers to test their assumptions in the virtual world first, before implementing them or testing them in the physical world. In this way, new industry 4.0 technologies continuously improving lean.

C. INTEGRATED VALUE CHAIN: To eliminate waste of all types from the supply chain is lean aims from customer order through to delivery – and industry 4.0 enablers like vertical and horizontal system integration and data analysis are invaluable to this pursuit. Integration and connection of your enterprise, operational systems, machines and devices create a holistic view of the entire value chain. It enables managers the identification of weak spots in the process or patterns and prioritizes them for improvement opportunities [17].

V. INDUSTRY 4.0 ENHANCE LEAN PRODUCTION

Both Industry 4.0 and Lean are industrial paradigms in which philosophy provides (or gives) a central base to design manufacturing operations. However, unlike Industry 4.0, which is based on modern technology for directing the contemporary problems that companies face, Lean is a technology that is easy to implement and its philosophy centred on persons, processes and a culture of continuous improvement. Thus, initially glance, it’s

going to seem that the Lean principles of people-orientation and ease are antagonistic to the state-of-the-art digital and automatic technologies of Industry 4.0.

It is necessary to keep in mind that people and process aspects which are central or related to Lean will still play a critical role in modern digital production systems and supply chains despite the technology-driven approach followed by Industry 4.0, people and process aspects which are central to Lean will still play a critical role in modern digital production systems and supply chains. At the top of the day, and despite the high and widespread computerization, digitalization and automation of production and supply chain operations, companies still believe in people to design, programme, operate, maintain and improve the machines and robots that enable digitalization and automation. Even the most automatic and digital production systems and supply chains will need some sort of people input and interaction for them to be able to function. Industry 4.0 technologies won't replace Lean but quite the opposite, they're going to co-exist since the implementation of Industry 4.0 technologies require effective and efficient processes as a precondition to operate successfully, and like this, it enhances lean production[18].

VI. FROM LEAN PRODUCTION TO LEAN AUTOMATION BY INDUSTRY 4.0

Notwithstanding that the tools of Industry 4.0 are very useful for the industry; they need to integrate the industry 4.0 tools with Lean Production. This will be useful to allow companies to improve SOP, the acronym of Standard Operating Procedures. Thus, integration between Industry 4.0 tools and Lean Production offers a lot of advantages for the companies with a reduction of cost in areas where it could be difficult to put on this integration. Furthermore, this integration is called Lean Automation (LA) [15].

The equipment becomes a cyber-physical system since it has a certain level of self-control. Jidoka was conceived as Toyota understood that generally, automation did not perform any quality checking in industry, resulting in its lead defective parts without human supervision. In other words, Jidoka is an important part of the management system since it allows the visualization of production's current state and identification of problems whenever they occur. However, adopting more high-technology solutions as introduced in industry 4.0 can enhance existing solutions and provide new ones. Such benefits became more latent after the formal acknowledgement of Industry 4.0 in 2011 and its novel technologies. In practical terms, companies generally improve their processes, products and services through the adoption of a small set of practices or technologies, so that they can properly manage the required efforts and verify the actual outcomes. Such a conventional approach establishes the need to understand better specific pairwise relationships between Lean Production practice and Industry 4.0 technologies, since these are more likely to occur and whose implications may slightly be different from the association at a bundle or construct level. Studies from Kolberg et al. (2017) and Ma et al. (2017) indeed focused on the benefits and challenges related to the concurrent implementation of certain practices and technologies [19].

With these systems, lean automation can be implemented to support and expand the approaches and concepts of lean production (LP). Lean automation automates a process with as little waste takes place as possible. The objectives of short lead times with minimum costs and the highest quality remain unaffected. Consequently, it is possible to provide an industry-wide representation of the actual situation in real-time and to enable simulation-based optimization measures based on decentralized control systems. Each workpiece is thus clearly identifiable, and the enterprise systems have complete information of the customer-specific mass product. Optimization measures and new services can be created from the collection of resulting data. The smart operator is, for e.g., notified by means of e-mail or SMS in the event of a fault reported by sensors during the process. Thereby, the time from the occurrence of the error to the noticing of the error will reduce. At the same time, the system makes suggestions for troubleshooting for the process. In addition, modern technology like Augmented Reality can provide a far better representation of the process flows. The employee has access to previously available data such as cycle times in his immediate field of view [9].

VII. A FRAMEWORK FOR INDUSTRY 4.0 & LEAN PRODUCTION

The framework should define interfaces how these solutions can complement each other and how to embed them into an existing environment [20]. With regards to the development of a Lean Automation framework that successfully integrates Industry 4.0 into Lean Production; a few studies have provided initial evidence. Malik and Bilberg (2017), for instance, have specifically proposed a framework for implementing collaborative robots into manual assembly cells and verified the results through virtual simulation. Wagner et al. (2017) presented a conceptual matrix that establishes a relationship between 11 LP practices with 8 Industry 4.0 technologies. The relationship intensities were assigned based on the opinion of 24 experts in I4.0, from which only eight were also experienced in LP. Finally, Dombrowski et al.



(2017), based on 260 cases in the German industry, examined the interdependencies between several I4.0 elements and eight LP principles, suggesting the most synergistic pairwise relationships. In general, we argue that our study expands on Dombrowski et al.'s (2017) and Wagner et al.'s (2017) by empirically identifying these pairwise relationships and proposing a LA framework at a practice-technology level based on the intensity of such relations. Both studies acknowledged the need to extend their analyses and verify how I4.0 could be synergistically integrated into LP, allowing the design of an implementation framework. Hence, the necessity of such empirical analysis to support the proposition of a LA framework is the motivation of this work [19].

VIII. CONCLUSIONS

This review paper aims to find out how Industry 4.0 emerging disruptive technologies can enhance lean practices and how the integration of both Lean and Industry 4.0 can exist so that a proper framework could achieve, with the help of which we can implement these both concepts together in the industry from different papers, article, books and website we try to find out the integration between these both approaches.

The concept is very comprehensive and complex; although three main points can be identified for Industry 4.0:

- The Industry 4.0 concept isn't limited just to the direct manufacturing in the industry but it includes also an entire supply chain from providers to customers and every one enterprise's business functions and services.
- Industry 4.0 is considered as broad support of a whole life cycle of a product in systems, products and series, distributed both spatially and organizationally. The smart products aren't smart only during the manufacturing process of the product but they continuous provide the data about their state also during their lifetime. These data can be used for preventive maintenance in the process flow; it can provide the manufacturer with useful information about the lifetime and reliability of their products.

Industry 4.0 may be a specialization of the Internet of Things applied to the manufacturing/industrial environment. It assumes real-time data collection leading to the issue of handling and analysing huge data and cybersecurity in a company. Industry 4.0 is the new industrial revolution, which enables companies to create "smarter" products and services by reducing costs and increasing efficiency, where the human factor is very important for the application and the work is based on existing literature in the area [21].

This review paper concluded that technologies from Industry 4.0 do not seem to cover the integrated news of Lean principles, but can reinforce the efficiency of these principles. Although, specific Lean principles and methods, such as levelled production and standardised and stable processes, could be questioned. However, Industry 4.0 does not replace Lean management principles, which is being pursued in companies for many years. Therefore, a clear need to pursue the deployment of Lean management while improving some of the Lean principles by using technologies of Industry 4.0, according to the capability level targeted. This paper provides a better understanding of the link between Industry 4.0 and Lean [6].

Further research should be undertaken to suggest new applications for Industry 4.0 technologies to further support Lean principles at the control, optimisation and autonomy levels and to integrate this concept so that a proper framework could achieve so that the industry could implement these together and achieve their target.

ACKNOWLEDGEMENT

We express a deep sense of gratitude to project guide Assistant Professor MohitGarg, whose overall direction and guidance have successfully helped us complete this project. We want to thank all the Mechanical and Automation Engineering Department faculty who motivated throughout despite their schedules and commitments. We are grateful to the almighty for bestowing upon us all his blessings to compile this project. We want to express our depth of gratitude to our parents for supporting us and motivating us toward our studies.

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