Implementation of Lean Manufacturing through Industry 4.0

Sanjib Kumar Dey Sarker Chayan

Abstract— Lean Production is well known and accepted within the industrial setting. It considerations the strict integration of humans within the manufacturing method, endless improvement and target value-adding activities by avoiding waste. However, a new paradigm referred to as business 4.0 or the fourth historic period has recently emerged within the producing sector. It permits making a smart network of machines, products, components, properties, people and ICT systems within the entire worth chain to possess an intelligent manufactory. So, currently an issue arises if, and the way these 2 approaches will exist and support one another.

Index Terms— industry 4.0, lean automation, lean production, production management, lean manufacturing, lean, supply chain

1 Introduction

Lean considerations a production system that's minded on learning of organization through continuous enhancements. It has its origins within the Toyota Production System and has been recognized as doing additional with less. Therefore, it aims at reducing inessential variations and steps within the work method by the elimination of waste that is perceived as any action that doesn't add price to the merchandise or services. Originally, it had been targeted on the elimination of such wastes as defects of requiring work, inessential process steps, movement of materials or individuals, waiting time, excess inventory, and production. Nowadays, it covers numerous aspects of the producing ranging from the initial stage of product life cycle like development, procurement manufacturing and producing over to distribution [1]. It is implemented as a philosophy and a set of tools and practices to achieve the highest quality, lowest cost, and shortest lead time. It is an effect of a complex, pro-quality management in all areas of enterprise activities [2]. It can be also considered as an extended just-in-time including all parties involved in supply chain, intra and inter organization [3, 4]. Thus, it is a multidimensional approach that can work synergistically to create an efficient, high quality system to deliver products in accordance with the pace of customer demand with minimum waste [5, 6].

The implementation of automation equipment raises product quality, while making manufacturing processes more efficient (Landscheidt and Kans, 2016). Such trend is especially true when taking into account the transformation that many industries are undergoing as a result of Industry 4.0 (Lasi et al. 2014). The further development and integration of digital automation of production by means of electronics, information technology (IT) and industrial robots, led to computer-integrated manufacturing (CIM) systems, currently denoted as Cyber-Physical Systems (CPS). These CPS enable the production systems to be modular and changeable, which is required to produce highly customised products in mass production (Kagermann et al. 2013). However, the way that Industry 4.0 technologies are integrated into existing production systems and which processes they can support is still under investigation (Kolberg, Knobloch, and Züehlke 2016). Contrary to conventional belief, researchers claim that automation will not lead to less human interaction or workerless production facilities; but the competence requirements may change (Dworschak and Zaiser 2014; Weyer et al. 2015). In fact, the individuals' skills requirements are more likely to increase and become even more specialised. Further, the level of capital expenditure that underlies Industry 4.0 technologies is quite intensive, reducing its implementation attractiveness (Sanders, Elangeswaran, and Wulfsberg 2016), especially for manufacturing companies located in developing economies' context (Anderl 2014). In this scenario, additional aspects must be taken into account for implementing Industry 4.0, such as the existing low-cost labour force and predominance of high production volumes' manufacturers (Mexican Ministry of Economy 2016). On the other hand, lean production (LP) is an approach widely deemed and spread among several industries that aims at reducing waste and improving productivity and quality according to customers' requirements (Womack, Jones, and Roos 2007; Lage Junior and Godinho Filho 2010; Jasti and Kodali 2015). The implementation of LP means a systematic human-centred approach of various management principles and practices (Seppälä and Klemola 2004). The principles are the elements of the strategic level and they represent the ideals of the system, such as identifying value from the customer's perspective, eliminating all kinds of waste, producing according to the pull of the customer, and continuous flow production (Liker 2004; Papadopoulou and Özbayrak 2005). The practices are the elements that operationalize the principles (Tortorella, Vergara, and Ferreira 2016). In essence, the implementation of LP comprises a low-tech approach that excels for simplicity and effectiveness usually aligned with a shared business vision.

2 Lean Implimentation

Generally, the thriving implementation of any management observe typically depends on structure characteristics. However, it ought to be emphasizes that not all organizations will or perhaps ought to implement identical set of practices. The most typically discovered practices ordinarily related to lean production are: bottleneck removal (production smoothing), cellular producing, competitive benchmarking, continuous improvement programs, cross-functional work force, cycle time reductions, centered manufacturing plant production, just-in-time/continuous flow production, lot size reductions, maintenance improvement, new method equipment/technologies, coming up with and programing methods, preventive maintenance, method capability measurements, pull system/Kanban, quality management programs, quick change over techniques, reengineered production method, safety improvement programs, independent work groups, total quality management [5]. However, it should be emphasized that these tools create a system so they contribute to the elimination of a particular type of waste and they should be applied together. The following approaches are often treated as "lean toolbox" [2].

As far as the implementation process of lean production is concerned there are discussed diverse frameworks. According to Ålström [7] it is evident that improvement activities appear in the sequence in manufacturing, however, continuous improvement should be introduced late during the process to allow it to benefit from the earlier established other principles. Storhagen [8] suggests that continuous improvement and change can be supported by job rotation and teamwork which only in the beginning of lean implementation allow taking the advantage. Moreover, it is suggested that employees' attitudes to quality should be changed to get material flow which contains only value adding operations [9]. Following Womack and Jones's "lean leap process" [1] there is a need to identify a change agent to create a new lean organization. Such person should be the first one who acquires lean knowledge to be able to shareit with the rest of organization before mapping value streams. After creating a lean function and strategy, business systems should be fixed. Lean thinking can be recognized as completed when it is applied to suppliers and customers, a global strategy is developed, and continuous improvement program is transitioned from a top-down to a bottom up. Furthermore, in this sense, companies generally start their LP implementation using one or two practices, and implement them throughout the company, realising later that such practices do not lead to systemic improvements in the value stream (Bhasin and Burcher 2006). Further, the selection of appropriate LP practices and identification of their applicability in an operational environment feature an additional challenge for management (Herron and Braiden 2006). This problem can be potentially enhanced by the large number of LP practices cited in the literature (Pavnaskar, Gershenson, and Jambekar 2003). Despite that, the approach of measuring the maturity of LP implementation based on the assessment of the adoption level of pre-defined practices has been extensively used in previous studies (Netland and Ferdows 2014; Marodin et al. 2015). In fact, Shah and Ward (2007) proposed ten LP bundles composed by 41 practices (see Table 2), empirically validating such framework. Hobbs [10] proposed a step-by-step implementation of lean which hypothetically can reflect the five lean principles (Table 1).

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TABLE 1
LEAN STEPS AND PRINCIPLES

Step	Lean principle
Establish strategic vision	-
Identify and establish teams	-
Identify products	Value
Identify processes	Value Stream
Review factory layout	Flow
Select appropriate pull strategy	Pull
Continuously improve	Perfection

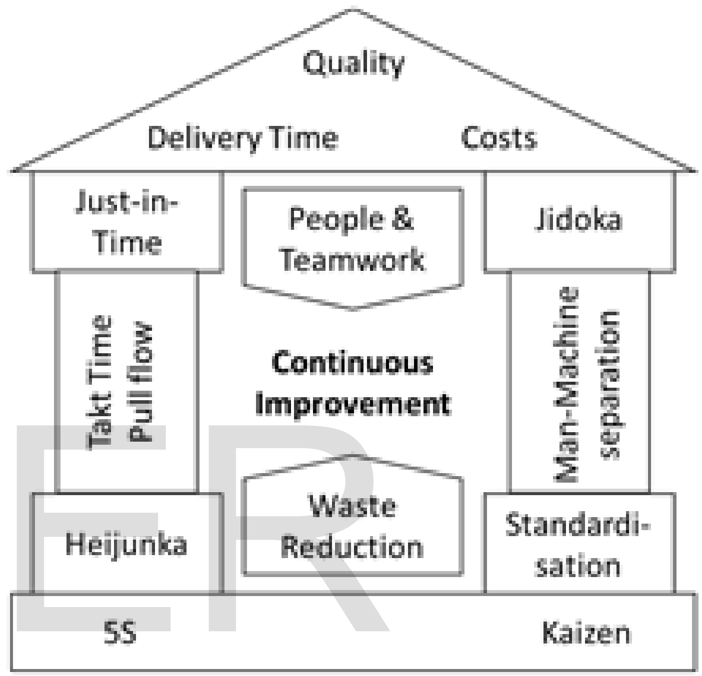

Fig. 1. Lean Production System

It can be noticed that steps three to seven are linked to the five lean principles, whereas it is difficult to assign the original lean principles to steps one and two. Therefore, Hines [11] proposes to extend the classical principles to "people" and if it is added the second step can reflect it. Finally, the first step can be suggested to be a starting point for any strategic implementation project, and thus it can be considered as "a pre-step". An alternative approach was proposed by Bicheno and Holweg [12]

- Understand the Lean Principles
- Understand your customers
- Understand the systems
- Strategy, Planning and Communication
- Product rationalization and lean
- Implement foundation stones
- Value stream implementation cycle
- Build a lean culture
- Implement lean supply
- Implement lean distribution
- Performance measure and costing
- Improve and sustain
- Design the lean scheduling design
- Cell and line design

This approach is established for a longer-term implementation, where the previous steps should be finalized before initiating the next ones. Moreover, in the case of lean production the research studies carried out in manufacturing industries revealed that any organization is likely to adopt lean practices regardless its scale [13, 14].

2.1 Small Business

- Ease ans speed of changing organizational culture
- Fast decision making
- Less layers of management
- High level of innovativeness
- Simple, Clear, Direct communication
- Close to customers, faster feedback and understanding
- Flexibility
- Easier implementation of multifunctional team, quality circles, total productive maintenance
- Strong staff loyalty

2.2 Large Business

- Access to resources
- Experiences and/or expert staff
- Experience in house lean or continuous improvement, understanding their potential benefits, processes, requirement and challenges
- Ease of making the commitment of Human Resources
- More likely to have metrics and data available
- Acceptibility of tools
- Opportunity for efficiency for not standardized processes
- Negotiating power over suppliers to develop a lean supply chain easier.

Generally, the characteristics of the organization, where lean production has been implemented, can be as follows
[14]:

- Team-work organization performed by operators who are flexible, multi-skilled and their responsibility for work within their areas is high
- Active shopfloor problem-solving structures, central to kaizen or continuous improvement activities
- Lean manufacturing operations, where problems are exposed and corrected by low inventories, quality management,
- Prevention rather than detection and correction, small number of direct workers and small-batch, just in time production
- High commitment of human resource policies emphasizing a shared destiny within the organization
- Closer relations with suppliers
- Cross-functional development teams
- Retailing and distribution channels liable for close links to customers.

3 Industry 4.0

The adoption of knowledge and engineering into producing business started within the Nineteen Seventies. However, the most concepts of business 4.0 were revealed for the primary time in 2011 [15]. within the same year it became a strategic initiative of the German government and was enclosed within the “High-Tech Strategy 2020 Action Plan” [16].Similar methods have conjointly been projected in different industrial countries, e.g., on a European level, the corresponding catch word is “Factories of the Future”,“ Industrial Internet” in USA and “Internet + ” in China. Despite of the nice interest within the idea of Industry 4.0 worldwide, there's nobody formally revered definition for it. it's outlined as “the integration of complicated physical machinery and devices with networked sensors and software, accustomed predict, management and arrange for higher business and social outcomes” [17], or “a new level important chain organization and management across the lifecycle of products” [18] or “a collective term for technologies and concepts important chain organization” [19]. Thus, the idea of business 4.0 are often perceived as a method for being competitive within the future. It’s targeted on the optimization important chains because of autonomously controlled and dynamic production [20]. It covers the look and implementation of competitive product and services, the administrative powerful and versatile supply and production systems” [21]. so as to attain the accrued automation the technological ideas of Cyber Physical Systems (CPS) are often accustomed work autonomously and interact with their production atmosphere via microcontroller, actuators, sensors and a communication interface [22].However, the introduction of each CSP and therefore the web of Things, wherever things are imagined to initiate each a method of preparation, design, planning, optimization, tasks for tools, and human if necessary, is leading in a very 4th Industrial Revolution relating future.

TABLE 2
PRODUCTION EVOLUTION

	Past	Present	Future
Communication system	analog	Internet and Intranet	Internet of Things Cyber Physics System
Concept	Neo-Taylorism	Lean Production	Smart Factory
Solution	Mechanization and automation	Automation and computerization	Virtualization and integration

CPS is similar to the Internet of Things as it shares the same basic architecture; however, it presents a higher combination and coordination between physical and computational elements [25].

The Industry 4.0 can be further described by three paradigms: the Smart Product, the Smart Machine and the Augmented Operator. The main idea of the Smart Product is to change the role of the work piece from a passive to an active part of the system. In such a system the products have a memory to store operational data and requirements individually, and are able to request for the required resources and coordinates the production processes for its completion [26]. In the paradigm of the Smart Machine a traditional production hierarchy is replaced by a decentralized self-organization which is realized by CPS [27]. In such a system open networks and semantic descriptions allow to communicate the autonomic components and local control intelligence communicates with other devices, production modules and products what makes the production line flexible and modular. It leads to the selforganization of machines within the production network, plug-and-play integration or even replacement of new manufacturing unities. Finally, the Augmented Operator addresses the automation of knowledge which makes it the most flexible and adaptive part in the production system [28]. Such a worker is supposed to be faced with a large variety of jobs such as specification, monitoring and verification of production strategies. In the same time he may manually interfere in the autonomously organized production system. He is provided the support by the mobile, context-sensitive user interfaces and user-focused assistance systems [29]. It allows him to fulfill the potential and be in the role of strategic decision-makers and flexible problem-solvers in the gradually growing technical complexity.

According to the results of a study "Industry 4.0" published by the Fraunhofer Institute, it is possible to indicate three future-relevant themes related to it such as: dealing with complexity, capacity for innovation and flexibility [30].

Moreover, it is possible to derive six design principles from its components: interoperability, virtualization, decentralization, real-time capability, service orientation and modularity. Interoperability ensures the connection and communication between physical components, humans and Smart Factories, whereas virtualization is realized as virtual copy of physical objects. Due to the decentralization and real-time capability the components are allowed to take decisions on their own on the basis of the collected and analyzed data in real time. The services of companies, CPS, and humans are provided by the Internet of Service and can be used by other contributors. The replacement or extension of particular modules assures a flexible adaptation of Smart Factories to the changing requirements [18, 31]. In order to realize these design principles, a dual strategy should be implied [31, 32]. The technologies, which have been already implemented, should be modified to fulfill the special requirements of manufacturing technology, research and development work in a new production location and market [33]. The attention should be paid to three types of integration: horizontal, vertical and end-to-end integration [33, 34]. Horizontal integration refers to a generation of value-creation networks involving integration of different agents such as business partners and clients, and business and cooperation models, whereas, vertical networking concerns smart production systems, e.g.: smart factories, smart products, the networking of smart logistics, production and marketing and services, with a strong needs-oriented [34]. End-to-end integration is targeted at gaining on product design, manufacturing and the customer [33]. However, according to Deloite [35] it is possible to differentiate four integrations, where the first two are the same, but they added two more such as through-engineering across the value chain and exponential technologies. Even though complexity of Industrie 4.0 system is growing it has a huge potential which is as follows [33, 35]:

- Specialized industry-specific solutions ("pull from the customer") and individualized understanding of customers needs even in a case of manufacturing one-off items, having very low production volumes (batch size of 1) and still gaining a profit
- Increase competitiveness and flexibility resulting from dynamic structure of business processes (i.e. quality, time, risk, robustness, price and eco-friendliness), adjustment to changes in demand or breakdowns in the value chain
- Optimized decision making due to end-to-end visibility in real time
- Increasing resource productivity (providing the highest output of products from a given volume of resources) and efficiency (using the lowest possible amount of resources to deliver a particular output)
- Value opportunities (innovative services, new forms of employment, opportunities for SMEs and startups to develop B2B services)
- Keeping productive workers for longer proving them diverse and flexible career paths
- Work-life-balance
- High-wage economy with tied-up capital cost, cut energy costs and reduced personal cost.

The recent integration between LP practices and Industry 4.0 technologies has been denoted as Lean Automation (LA), which aims for higher changeability and shorter information flows to meet future market demands (Kolberg and Zühlke 2015). The first initiatives for incorporating automation technology into LP date from the beginning of 1990s (e.g. Franke 1993; Groebel 1993; Schling 1994). Due to the potential benefits of implementation of Industry 4.0 technologies, a few authors (e.g. Takeda 2006; Gjeldum, Mladineo, and Veza 2016; Sanders, Elangeswaran, and Wulfsberg 2016) have been arguing the existence of new available fields of application for LA. However, current approaches are usually proprietary solutions which have to be tailored to individual needs. Overall, Kolberg, Knobloch, and Züehlke (2016) affirm that LP can be considered as a complement to the technological point of view emphasised in Industry 4.0. Both LP and Industry 4.0 favour decentralised and simple structures over large and complex systems; while aim for small and easily integrated modules with lower levels of complexity (Zuehlke 2010). However, contradictory evidences found in literature (e.g. Erol, Schumacher, and Sihn 2016; Sanders, Elangeswaran, and Wulfsberg 2016; Schumacher, Erol, and Sihn 2016) indicate that the comprehension of such association and its impact on operational performance still needs to be deepened and better explored. Hence, although research initiatives and practical experimentations already exist, they are mostly the application of a single or isolated aspect. In this study, we examine the relationship between the simultaneous implementation of LP and Industry 4.0 readiness, and their influence on the companies' operational performance.

4. Linking Lean Production and Industry 4.0 – Case Studies

4.1. Smart Product

In the reference to Kaizen, which helps to pave the way on lean journey, Smart Products can collect and use for analysis the information about repeating actions from their sensor and semantic technologies. They have unique properties such as: context-aware, adaptive, self-organized, and proactive and the ability to support the whole lifecycle which allows them for continuous improvement process. Moreover, their data allow for visualization of manufacturing process and flow of information for a chosen group of products. On this basis it is possible to create a Current State Map, which shows wastes in particular processes, and assign future strategic planning activities, what is the aim of Value Stream Mapping. Additionally, a Smart Product could contain Kanban information in order to control production processes what was already presented by SmartFactoryKL at Hannover Messe 2014 in Germany [36].

4.2. Smart Machine

A Smart Machine can contain a smart panel (e.g. Advan Panel [37]) which is based on RFID UHF. Such a solution enables to detect the tagged Kanban cards in real-time. It is assumed that a read-rate of cards placed on such a panel is typically 100%. Additionally, such panels can prevent detecting other tagged Kanban cards that are not placed on the panel, but which are at a close physical distance from the panel. Except RFID, the continuous improvement can be also assured due to production line data collected from machines with technologies such as actuators, sensors and wireless video. These data are analysed and proceeded in the cloud to give better operational intelligence but mainly to avoid mistakes what is the main idea of Poka Yoke. Furthermore, the application of Plug'n'Produce makes it also possible to introduce Single Minute Exchange of Die method into whole production lines.

4.3. Augmented Operator

The Augmented Operator should reduce the time between failure occurrence and failure notification. In order to achieve it the Andon method can be applied which is one of the principal elements of the Jidoka quality-control method recognized as a part of the Lean approach. It is realized by showing signal lights on an operator smart watch in close to real time. The information concerns both error messages and error locations. Such alerts may be recorded in a database and further studied as part of a continuous-improvement program. In addition, failures can be recognized with CPS equipped with proper sensors and automatically initiate fault-repair actions on other CPS.

	Data Acquisition and Data Processing				Machine to Machine Communication (M2M)		Human-Machine Interaction (HMI)	
	Sensors and Actuators	Cloud Computing	Big Data	Analytics	Vertical integration	Horizontal integration	Virtual Reality	Augmented Reality
5S	+	+	+	+	+	+	++	+++
Kaizen	+	++	+++	+++	+++	+++	+++	+++
Just-in-Time	++	++	+++	+++	+++	++	+	++
Jidoka	+	+++	+++	+++	++	++	+	+
Heijunka	++	++	+++	+++	+++	++	++	+
Standardisation	++	+++	+++	+++	++	++	+++	+++
Takt time	+	+	+++	+++	+++	+++	+	+
Pull flow	++	+	+	+	+++	+++	+	+
Man-machine separation	+	+	+	+	+	+	+++	+++
People and teamwork	+	+	+	+	+	+	+++	+++
Waste reduction	+	+	++	+++	+++	+++	+	+

Fig. 2. Data acquisition and data processing

5 Conclusion

Lean production with success challenged the production practices to the assembly systems centered on sensible quality product aimed toward customers' satisfaction, wherever everything that doesn't add price thinks about to be waste. It is the solution to a good flexibility of production systems and processes realizing advanced product and supply chains. In order to attain it, it's best to introduce IT integration of the assembly level with the design level, customers and suppliers by Hertz called "Industry 4.0". Within the given paper the review of literature concerning lean production and business 4.0 was given to indicate the likelihood of linking these 2 approaches. The examples were provided for good product, machine and increased operator in respect to lean production principles. It enabled to indicate that these 2 approaches will support one another.

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