Investigate the relationship between Lean and Industry 4.0 Technologies

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Purpose: Lean manufacturing is a comprehensive worldwide best practice methodology for continuous improvement focused on minimizing all kinds of waste with the objective to maximize customer perceived value of the product and its connected services. Industry 4.0 (I4.0) technologies easily mesh into standardized lean manufacturing processes and have the potential to achieve quantum leaps in breakthrough improvement; drastically reducing the cost of poor quality and chronic waste inherent in processes. The objective of this investigative study is to establish the linkages amongst current Lean tools-techniques and I4.0 technologies.

Methodology: This work is centered on a critical review of the extant literature and a qualitative questionnaire-based survey of industry leaders, policy makers, trainers, consultants and academicians
Findings: This study provides a linkage amongst the lean tools and I4.0 technologies by a relation diagram based on feedback given by experts.

Research limitations/implications: Limited experience at present with the application of I4.0 know-hows in engineering comes in the way of doing meaningful quantitative research. Considering this, our present research is qualitative in nature. This work does lead to in-depth hypothesis building. Subsequent research will help test hypothesis and lead to theory building.

Practical implications: The relations between Industry 4.0 technologies and learn techniques identified in this paper will support policymakers, researchers, academicians, and practitioner's to design and develop Industry 4.0 enabled lean factories.

Originality/value: The work done in Lean 4.0 is still conceptual and till now very few studies have been done to investigate the relationship between lean and I4.0. This qualitative study is primarily an attempt to map experts' feedback to establish the relationship between these two domains.

Key Words*:* Industry 4.0, Lean

1. Introduction

Lean manufacturing methodology achieves operational excellence through waste reduction, standardization of processes, instilling the ethos of constant improvement (Powell et al., 2012). Nevertheless, with the ever-increasing complexity of the business environment, numerous corporations are finding that lean manufacturing tools by themselves are not sufficient to overcome many operational challenges (Simpson and Power, 2005; De Treville and Antonakis 2006)

Global manufacturing industries are experiencing the 4th Industrial revolution, regarded as Industry 4.0 (I4.0). This is giving birth to smart factories, many of which are already producing smart products (Kagermann, 2015; Liao et al., 2017; Almada, 2016). The future will be dominated by companies which quickly transform current businesses into I4.0 smart manufacturing which will supply smart products and services across the world markets. (Liao, et al., 2017; Li, 2018)

Lean Production techniques are retaining their importance since they enable adding value by continuously reducing all kinds of waste. On the other side, I4.0 technologies focus on creating low latency; digitized artificially intelligence enabled real-time processes. To enable this requires the use of flexible and adaptable autonomous machines and equipment plus collaborating shop floor workers and top floor managers; all working together to produce smart products for smart customers. Organizations are looking for optimization of their processes by the deployment of I4.0 technologies to improve productivity, quality and reduce risks across the system. This study endeavors to establish the relationship between lean tools and I4.0 technologies.

2 Literature Review

2.1 Overview of Industry 4.0

"Industry 4.0 is digitalization of manufacturing built around cyber-physical systems and has the potential of the radical transformation of the manufacturing sector"(Chief Operating Officer of an Indian Manufacturing organization)

“I4.0 is the fourth industrial revolution”, made possible by disruptive internet technologies that are dynamically redefining the way organizations create, shape, deliver and service products (Liao et al., 2017) These systems monitor and augment practically all existing processes across the complete life cycle of products, Processes and devices have become inseparable in I4.0. The citation table of I4.0 technologies is given in table 1

Table 1: Summary of I4.0 technologies

Industry 4.0 (I4.0) technology	Overview	Citation
Advanced Robotics	Advanced industrial robots are designed to collaborate with supplementary systems and humans in real time. They have embedded electronic software, integrated sensors, actuators and standardized interfaces that enable them to wirelessly connect with the internet and interact in real time with other equipment and establish human collaboration	Bahrin et al., 2016; Almada,2016; Bloss 2016; Oesterreich &Teuteberg, 2016; Liao et al., 201; Lu, 2017; Jones & Pimdee, 2017
Additive Manufacturing	3D Printing used for rapid prototyping and production components. The focus is on creating in situ 3D centers to produce components so as to minimize transportation, inventory and other lean manufacturing defined waste.	Bahrin et al., 2016; Almada,2016; Oesterreich &Teuteberg, 2016; Park, 2016; Hofmann &Rüsch, 2017; Jones&Pimdee, 2017; Li, 2018
Augmented Reality	Interactive representation of the real-world environment. This is enlarged and improved by computer-generated interpretation of required information. Augmented reality is now possible across sensory perceptions, including auditory, visual, touch, smell, heat/cold and pressure. Innumerable applications are possible, including customer co-creation, remote maintenance, predictive maintenance, virtually guided self-service, and remote monitoring and control.	Almada,2016; Bloss 2016; Oesterreich &Teuteberg, 2016 ; Liao et al., 2017; Lu, 2017;Jones & Pimdee, 2017;
Simulation	Rapid experimentation and simulation methodologies are modeling tools that are used to predict and evaluate the potential of complex systems and give unique empowerment and autonomy to operators, machines and processes.	Almada,2016; Bloss 2016; Bahrin et al., 2016; Jones & Pimdee, 2017; Li, 2018
Vertical and Horizontal Integration	Horizontal Integration is a modular system that connects the data, information across entire value chain. Vertical Integration pulls together information from across all verticals and levels of the organization and seamlessly exchanges this across all levels of the organization. It covers all activities of the Manufacturing Execution System (MES).It links through Wi-Fi, in real time, all steps in the firm's internal processes using sensor-generated data which has been converted into decision-focused information.	Almada,2016; Park, 2016; Oesterreich &Teuteberg, 2016; Jones & Pimdee, 2017;Liao et al., 2017
Internet of Things (IOT)	IoT establishes inter-connections across objects and humans using internet technologies. Industrial IoT enables networking of machines, manufacturing operations, managers, engineers, plant workers, suppliers, products and customers. Real-time communication between all networked entities is an essential requirement.	Kagermann, 2015; Bahrin et al., 2016; Almada,2016; Park, 2016; Hofmann & Rüsch, 2017; Jones & Pimdee, 2017; Lu, 2017

Cloud Computing	Industrial cloud computing involves real-time computing and management of a very large amount of data using an open network for instantaneous availability of data through value chain.	Bahrin et al., 2016; Almada,2016; Jiafu et al., 2016; Jones & Pimdee, 2017;Liao et al., 2017; Li, 2018
Cybersecurity	Ensuring secure operations within connected networks and open systems is a challenging requirement of digitized industries and their supply chain operations.	Adam et al., 2016; Bahrin et al., 2016; Hofmann & Rüsch, 2017; Jones & Pimdee, 2017; De Sousa et al., 2018
Big Data and Big Data Analytics	This involves storing and retrieving unstructured, raw data which is being continuously generated in diverse formats and in huge quantities Big data analytics uses qualitative and quantitative techniques to make sense of raw big data and convert it into information which is used for arriving at autonomous as well as guided business decisions across all product development and manufacturing processes and other decision points.	Almada,2016; Liao et al., 2017; Hofmann & Rüsch, 2017; Jones & Pimdee, 2017; Liao et al., 2017

2.2 Lean Manufacturing

"Lean manufacturing is all about optimization of the process by reducing the wastages by better management of workplaces, just in time production by value stream mapping and pull production" (Head Operational excellence of an Indian manufacturing organization)

Lean manufacturing technologies have an objective of relentlessly curtailing unwanted wastages in the entire value chain and maximizing flow (Seth and Gupta, 2005; Alves et al. 2012). This philosophy focuses on satisfying customer needs, leading to a competitive advantage for the manufacturer (Storch and Lim, 1999). The objective is real-time optimization of products, services, internal processes and all the process steps across the supply chain. This enables matching supply and demand across all sub-processes (Haque and Moore, 2004; Simpson and Power, 2005). Lean comprises use a set of tools, such as Hoshin Kanri, the two lean pillars Jidoka and Just in Time, 5S and Visual Factory, Line Balancing, Continuous flow, Gemba, Single Minute Exchange of Die (SMED), Kaizen, Kanban, 3M (Muda, Mura, Muri), Total Productive Maintenance (TPM), Poka-Yoke, PDCA, Work Standardization, Value Stream Mapping, and Continuous Flow. (Mohanty et al., 2007; Powell et al., 2012)

2.3 Integrating Lean tools with I4.0 technologies

"I4.0 is a subdivision of lean methods, the whole lot Industry 4.0 can be perceived as the slice of the lean approach" (Director of a German organization)

"The smart industrial technologies of I4.0 focus to archive the same effects like lean i.e. waste elimination, continual improvements, value for customers"
(Chief Operating Officer of a Taiwan company based in India)

"Lean tools and Industry 4.0 technologies work together to recognize the unexploited possibilities in manufacturing" (Director Minister of Industrial Promotion, Government of India)

"Industry 4.0 technologies are a stimulating concept for a new level of automation to improve efficiency in the lean plants" (V.P of an Indian manufacturing organization)

The authors have summarised the feedback received from 25 experts of Industry 4.0 and Lean to establish the relationship between these two concepts, given in figure 1

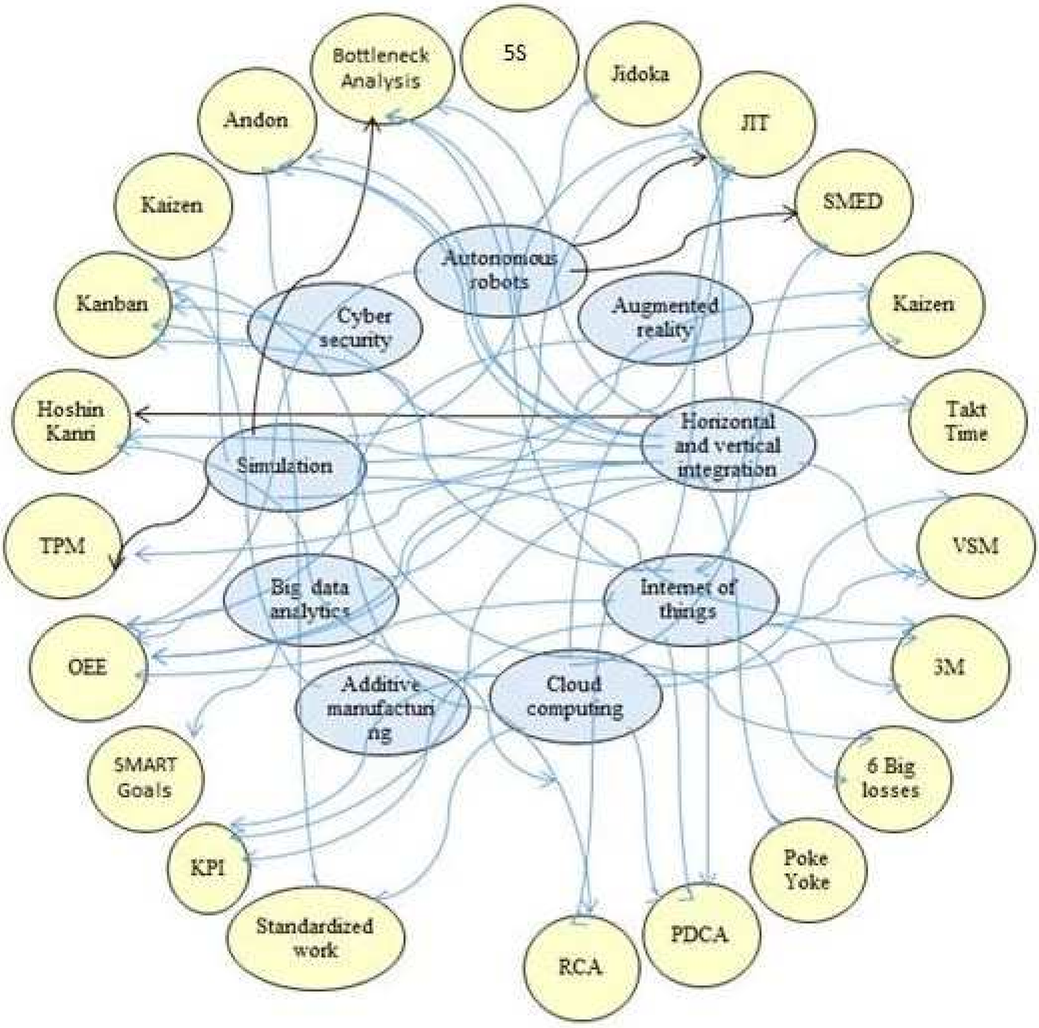

Figure 1: Relation between Industry 4.0 technologies and Lean tools

3 Conclusion

This study carried out a comprehensive literature review. This was followed by a qualitative survey of experts in the field of I4.0 and Lean. The objective of the survey was to establish a relationship between I4.0 technologies and lean tools. We found that both I4.0 and Lean in tandem to achieve common goals i.e. focus on process simplification, eliminating waste across the supply chain, optimizing customer value, quick product redesign and productionizing to meet emerging customer needs, and achieving mass customization at minimum cost.

Relationship diagram, as in Figure 1, is designed to serve as a ready reckoner for policymakers, industrialists and researchers in Asia to develop strategies for effective transformation of current lean plants into Industry 4.0 smart factories that will innovatively develop and supply smart products and services.

Going forward, validation of the relationship diagram by quantitative research is seen as a potential area for future research work.

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