Industry 4.0 technologies as drivers for eliminating waste in Lean Production: A French-Norwegian study

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Abstract. The aim of this paper is to provide insights about the operational performance improvements that may arise from the combination of Industry 4.0 technologies with the tools of Lean Production. Indeed, companies and their decision makers are looking for actionable knowledge around the usefulness of Industry 4.0 technologies and their inclusion in existing operational excellence programs. Lean is a tried and tested means of promoting better thinking in organizations, contributing to an increase in customer satisfaction and business performance. The emergent technologies of industry 4.0 are also influencing performance improvement in both the development and delivery of products and services. Yet actionable knowledge of the combination of Lean Production and Industry 4.0 is relatively immature and requires deeper analysis. This paper presents insights into the possible integration of Lean Production and Industry 4.0 technologies by analyzing multiple case studies in France and Norway. We suggest an approach that depicts the way in which such integration can reduce and ultimately eliminate waste.

Keywords: Lean Production, Industry 4.0, new technologies, operational performance.

1 Introduction

For many decades, Lean Production (LP) has proven itself to be a powerful way of thinking, an adapted managerial approach and set of tools to reduce inefficiency and improve the operational performance. However, lean thinking spans beyond the simple tools of operational and productivity improvement. It is a global learning approach that empowers teams and individuals, enabling them to solve problems by engaging in their own learning process – discovering and exploring problems and discussing interesting, novel solutions. Many companies around the world have experimented with LP and have been satisfied by the positive results.

The emerging technologies of Industry 4.0 (I4.0) are nowadays grasping the interest of many decision makers in various companies of different sizes, in different sectors, and on different hierarchical levels in the company. Indeed, the new technologies may be useful for large companies and SMEs alike, from automotive industry to food and

pharmaceutical, from engineer-to-order (ETO) [1] context to make-to-stock (MTS), and from research and development services to production and maintenance departments. However as stated in [2] the competencies and the know-how about the use, choice, and deployment of these new technologies is still problematic. The decision makers are often tackling the problem of the relevancy of the tools to their contexts [3], the contribution of their choice to ecological standards [4], and the difficulty to match the technologies contribution with LP initiatives. Grasping the relevancy of using both LP and I4.0 is therefore an interesting step which leads to greater combined optimization potential, accelerated operational improvement, and increased learning within and across teams [5].

In the following section, we present a literature review to position our contribution in the research community. The problem statement is provided in section 3 summarizes the current challenges for decision makers and outlines the remaining gap. Thus consolidating the research topic and offering insights may increase our understanding of the association of both LP and I4.0 technologies.

2 Literature review

Many research publications mention the benefits of combining LP and I4.0 [6-14]. For example, Perreira *et al.* [6] analyzes over 54 articles and finds that 55% present I4.0 as enhancing LP efficiency. Among the technologies presented are cyber-physical systems (CPS), additive manufacturing (3D printing), and cloud computing. Bittencourt [7] highlights the essential fact that the enhanced process capability of LP is further improved through the integration of I4.0.

Only 45% of the documents reviewed highlighted the support of LP for I4.0. Buer *et al.* [8] points out that a high Lean implementation level enables successful digitalization. As such, the literature often reveals a lean first, then digitalize approach (e.g., Powell *et al.* [9]). However, it is also interesting to analyze situations when I4.0 is adopted and perceive how LP can also be considered thereafter. Ciano *et al.* [10] remind that when I4.0 is implemented first, managers can take benefit of value stream mapping (VSM) to reinforce vertical integration and succeed in technology deployment. Rosin [11] establishes a wide analysis to find the linkage between LP and I4.0 without an in-depth analysis into how they influence performance improvement.

Regarding the useful combination of both paradigms stated in the literature, we would like to go deeper in this analysis to understand not only if one is influencing the other and in which chronology but also to perceive in which ways both paradigms can be linked to influence operational performance.

3 Problem statement

As authors resident to France and Norway, we notice that companies in these countries have demonstrated an increase in performance and productivity when using LP and I4.0 in isolation and indeed in association. The combination of the two approaches obviously exists, and the intention of using both paradigms for operational

improvement is obviously perceived, however the way this combination has been done remains unclear. Is it just managerial choice? Is it a coincidental feeling of experience? Is it a benchmark done with competitors? Is it a technological opportunity? For the moment there is no clear model or roadmap helping managers to perceive similarities and common points of LP and I4.0 integration to allow a replicable deployment and help as a decision-support tool towards a common deployment.

In the following figure (Fig. 1) we have chosen to analyze the situation regarding the common deployment of LP and I4.0 in France and Norway. Four case studies will be described (two from each country, from aerospace and automotive sectors) to perceive the strengths and / or weaknesses during the deployment of both paradigms. Indeed, an analysis of real situations reveals actionable knowledge as to how a successful combination of LP and I4.0 is possible. We also identify gaps to pursue with further research. This combined study is useful for understanding how to propose a better parallel transformation using LP and I4.0 in different companies.

Fig. 1: Positioning of the paper – Problem statement

3.1 Lean & Industry 4.0 – French cases

Dassault Aviation in France (Mérignac – Bordeaux) is a French producer of the Falcon business jet. It has based its lean approach upon its *Amelioration de la réactivité en Production* (ARP) program, which means "Improvement of the reactivity in Production". In parallel the company is leading technological transformation through adoption of Digital twin, the use of Fabrication laboratories (fablabs) for production, and 3D printed components for spare parts, reducing the waiting times in production lines and speeding up the maintenance repair times. Sensors and internet of things (IOT) have also proved useful, deployed to pursue and monitor the state of the machines (Temperature, vibration, etc.), with many parameters monitored in real time remotely to enable the predictive maintenance program. Evidence of both LP and I4.0 are prominent in this large Aeronautic Group [15] and the relevance of LP tools adoption in aerospace has already been demonstrated in [16].

In the automotive industry, we chose the example of Faurecia (Caligny), a French producer of several automotive systems. They have been labelled in France, in 2017, by AIF Alliance Francaise de l'industrie, as being an example of the factory of the Future. Indeed, this company, beside the typical tools-oriented LP approach (e.g., Just-in-Time, which is well implemented), has built up a strategic approach to LP called Faurecia Excellence System (FES). Faurecia has undertaken a big plan of new

technologies integration in association with LP. The evidence coming from their development is well represented by the “digital Kanban”. Kanban is an essential Lean tool [17]. A recent transformation project at Faurecia (in 2018) has been led to associate the principle of Just-in-Time in Logistics with new technologies. Near Field Communication (NFC) has been chosen as a solution to pick up the Kanban cards in production shop floors. When previously production points in different workshops were waiting the arrival of physical Kanban cards (with a risk of lost cards). Now the sourcing of the different components from the different shops is ensured by NFC terminals positioned in specific places to get by digital information (tags) the required quantities to trigger the delivery of the different points in the production shop.

3.2 Lean & Industry 4.0 – Norway cases

GKN Aerospace Norway (GAN) is a Norwegian producer of complex jet engine components for military and civilian aero-engine programs. With the goal of reducing activities that add cost without adding any value (often referred to as waste in the lean terminology) and to improve operational efficiency, GAN introduced LP in its shopfloor operations in 2012. In 2018, GAN extended the focus of LP to other business areas, under the umbrella of business process improvement (BPI). This is because much of the waste and inefficiencies in the company were found outside of the manufacturing shopfloor. In these back office areas, the digitalization of otherwise manual / analogue business processes has contributed significantly to increased effectiveness. GAN was in fact awarded the prestigious title of Norway's smartest company in 2016 – having reduced its quality costs by 70% using digitalization and automation to provide real-time surveillance and self-optimizing, adaptive control of processes to drive systematic operational improvement.

In the automotive sector, we describe the case of Benteler Aluminum Systems Norway (BASN), a Norwegian producer of aluminum bumper beams and crash protection systems. The company has its own operational excellence program, Benteler Operating System – Lean Enterprise (BOSLE), and has more recently adopted several I4.0 technologies including IOT and big data applications to promote reliability and efficiency and to enhance the quality and sustainability of its products and processes. For example, Benteler's Production and Process Database (PPDB) and Smart Production Data Platform (SPDP) allows the company to continuously evaluate its wide range of process and product data easily and quickly. As a result, the company can understand technical issues in real time and recognize otherwise unknown correlations – supporting the BOSLE culture of continuous improvement and learning. This means better maintenance, higher output, and even greater quality.

Regarding the insights from these four cases, we can suggest for both practitioners and the research community a global framework which will help to perceive the common points between the improvement approaches presented through integrating LP and I4.0 technologies.

4 How to combine Lean and Industry 4.0: The elimination of wastes as a common ridge

Using one of both paradigms (LP or I4.0) in industry is sufficient for improving operational performance. However, combining the two appears to hold greater promise, as the two paradigms positively influence the global performance of companies and increase the possibilities for the teams to continuously learn and improve their products and processes. Enabling managers to lead both with increased visibility, understanding how to transform the company and knowing the steps to establish coherent deployment would be highly appreciated in practice. Indeed, often the companies reveal to be "lost" when exposed to such mammoth transformations. We suggest in this section a combined approach.

As shown in the Fig. 2, even LP and I4.0 technologies are commonly targeting increase operational performance (costs, lead-times, quality, conformity, flexibility, robustness, service increase, energy consumption) and also increase the teams involvement and the skills development by building supporting learning systems [18]. Lean helps to develop managerial skills through key visual management techniques, helping individuals and teams to learn how to solve problems.

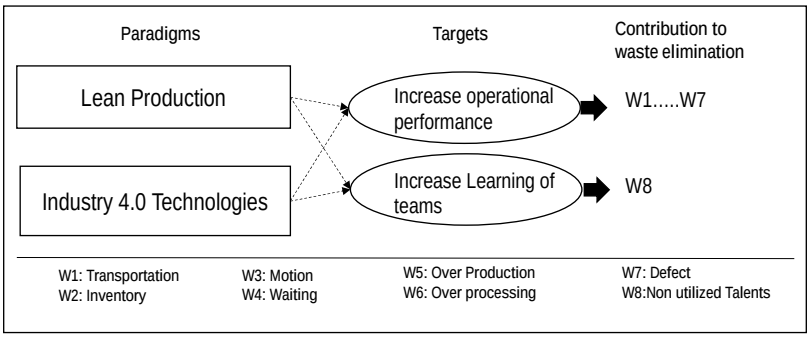

Fig. 2 Combined analysis: Waste as a common ridge between LP and I4.0

Emerging I4.0 technologies also help to empower the operator – contributing to the development of skills through real-time connectivity and monitoring, which also increases the learning abilities and enhances the company capabilities [19]. If a company is wondering whether to use LP or I4.0, we suggest that the common contribution is that towards the elimination of waste.

The 8 wastes are used as a discovery mechanism to find problems, through recognizing symptoms and exploring their underlying syndromes when doing Gemba walks [20]. If such problems and wastes go unaddressed, company's turnover may drop and the demotivation of the teams may rise. Active employee participation in the identification and reduction of such waste promises to improve the global process and helps to increase the outputs and the performance of the production system. The elimination of the 7 wastes in LP can be perceived as contributing to operational performance. The addition of the 8th waste (unutilized talent), as identified by Jeffrey

Liker [21] is interesting to consider in LP and I4.0 integration, as it promotes a human-centric approach to its achievement. Indeed, many interesting technical and managerial skills are already existing in the company. As such, integration of LP and I4.0 may contribute to enhancing the learning system that empowers teams and helps to maintain high level of capability.

When highlighting that the elimination of waste is enhanced by combining LP and I4.0 technologies, we can proceed with the next analysis, showing paradigm by paradigm, tool by tool, the contribution to the elimination of the 8 wastes. For example, Table 1 presents how LP tools and I4.0 technologies are more likely to contribute to waste elimination. The assignment of the wastes was derived according to practical insights from the industrial cases described in the previous section. The choice of the relevant LP tool or I4.0 technology would become possible regarding this common ridge analysis.
Regarding the used operational performance (Service rate, conformity level, reliability rate, on-time-delivery, time-to-market, etc.) the manager can jointly follow up the impact of technologies of industry 4.0 used and the impact of lean practices implemented. The learning of teams can be measured by another set of managerial indicators (number of improvements / lean projects implemented, absence rate, level of involvement of the teams, etc.). The more the teams are consulted and included in the implementation, the more the team becomes autonomous and able to enlarge lean deployment.

Table 1. Lean and Industry 4.0 contributions to waste elimination

Paradigm	Analysed LP tools / I4.0 tech.	Contribution to waste elimination
Lean Production	Kanban	W2, W3, W4, W5, W8
	Poka Yoke	W1,W4, W5, W7
	Andon	W2, W7
	Visual Management	W2, W3,W4, W5, W7
	SMED	W2, W3,W4, W5, W6
	5S	W3,W4, W5, W6, W7
	Plant Layout	W1,W4, W5, W6
	Value Stream Mapping	W1-8
	Heijunka	W2,W4, W5, W6
Industry 4.0	Internet of things (IOT)	W2, W3,W4, W5, W6, W7
	RFID	W1, W2, W3,W4,W7
	Digital Twin	W1, W3,W4, W6, W7
	Augmented Reality/Virtual Reality	W1,W2, W3,W4, W7
	Articial Intelligence/Machine Learning	W3,W4, W7
	Cloud Computing/Edge Computing	W3, W4, W6
	Robotics/Cobots	W1, W2, W3,W4, W7, W8

5 Conclusion and perspectives

LP and I4.0 are two paradigms of upmost importance in the current economic context, where resource consumption must be reduced, ecological considerations are high, and customer requirements are extremely diversified. This preliminary analysis of LP and I4.0 integration for waste elimination is an initial attempt to figure out the linkages existing between the two paradigms for leading common transformations. From a technical point of view: waste such as over processing, waiting times, inventory, transportation, motion, overproduction, defects and non-utilized talents are the main elements to be aware of. From a managerial perspective, leading in tandem lean and I4.0 transformation requires careful consideration of pain-points (problems) to allow people to agree on the underlying problems, followed by convincing the team to lead transformation showing respect to them in order to get them on board. Initial "quick wins" demonstrating the effect of Lean and I4.0 implementation makes it easier to extend the approach to remaining departments. The next step would be to develop a global framework to provide a roadmap for companies and get feedback regarding the adoption of a structured approach – compared to the otherwise common, traditional approach to transformation (which is likely full of intuition, experience, and some benchmarking, but certainly not structured, modular, designed and detailed). At the moment we conclude that there is no "cookie-cutter" approach to standard sequencing a lean and I4.0 implementation. However, this will be investigated in a further study. Yet we strongly support the view presented in [9], which adopts a lean first … the digitalize approach. Further findings will be revealed in future work from the collaboration between France and Norway.

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