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The automation of lean practices: digitalized or digitally wasted?

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Abstract. Lean manufacturing has experienced massive changes under the influence of Industry 4.0, with the automation of lean practices becoming common among manufacturing companies in many countries and different industries. Automating lean practices promises a number of opportunities for growth and competitiveness. One of the key advantages of lean automation has been acknowledged to be the significant reduction of waste. Meanwhile, there is also discussion of a new form of waste: *digital waste*. However, do companies consider digital waste a part of production waste? It is also unclear if automation of lean practices is a trigger for digital waste with a negative impact on value creation. This paper aims to investigate companies with automated lean practices and the particular case of digital waste in automated processes. The research is based on case studies of manufacturing based in Sweden.

Keywords: Lean, digitalization, digital waste, automation, manufacturing, Sweden

1 Introduction

Industry 4.0 is pushing the automation of lean practices [1-5]. The study of manufacturing process automation has increased spectacularly within the last few years, corresponding to the expected improvements in production, quality, and safety [6-8]. Substantial reduction of waste under the control of technologies is one of the key benefits attracting manufacturing practitioners [3-4, 9-10]. Lean automation leads to manufacturing transformation, with cheaper, smarter, and more adaptable processes [11]. “Industrial IT and automation have annual sales of over SEK 70 billion in Sweden, of which the Stockholm region accounts for 70 percent” [12]. The Norwegian Research Council initiated the project to promote small and medium enterprise (SME) cooperation and flexibility by automating the manufacturing processes within the Norwegian SMEs to help them stay competitive in global competition [13]. Two definitions of lean automation are the networking of equipment and people for rapid communication with the aid of digitalization [14], or the establishment of the platform and connective mechanisms to utilize data analytics from the real world [15]. Lean automation is also associated with a disruptive digital technology from Industry 4.0. It emphasizes the importance of adoption levels of technologies based on the performance of the companies, as well as how advanced the adoption of their lean practices is [4]. Research findings also indicate the positive correlation between Industry 4.0 technologies and lean practices, with a high potential to overcome traditional barriers and challenges of the lean management approach [3, 16].

Indeed, while the potential benefits that adoption of lean automation can bring are discussed by researchers [2-5, 8-10], studies investigating potential risks associated with automating lean practices are lacking. The topic of digital waste is relatively new in the field of lean manufacturing [17-18]. We need a deeper discussion of digital waste in the context of lean automation.

2 Literature review

2.1 Lean, waste and Industry 4.0.

The elimination of waste (*muda*) was discussed in 1990 in *The Machine that Changed the World* [19] through a five-stage process: specification of value, identification of value stream, creation of flow, pulling the product as needed, and aiming for perfection. Often, lean

production was primarily associated with elimination of waste as excess inventory or excess capacity to impact the variability in supply, processing time, or demand [20].

In the digital era, a new way of lean thinking integrated with digital technologies—sensors, CPS, Internet of Things (IoT), and social networks—has arisen [21]. Industry 4.0 and lean methodology have a strong correlation while sharing similar priorities of waste reduction and efficiency gains [22]. The new concept of digital lean manufacturing involves human capabilities and strategic digital technologies, as well as quality planning, control, and improvement [23]. Industry 4.0 should not be treated as a single technology. Instead, it integrates product, process, and system levels to reveal its potential for advance manufacturing competitiveness [24].

Manufacturers need to systematically combine lean thinking and practices with advanced industry 4.0 technologies to build competitive advantage in the digital era and implement successful lean transformation through improved performance and capability. By applying “lean and learn” as a lens for strategic lean practice automation, learning can play a vital role in the continuous improvement process [25]. Learning in combination with an automation approach would improve the efficiency of manufacturing processes and develop the workforce skills to adopt advanced automation solutions [25-27].

The topic of digital waste is sensitive in the context of growing volumes of data in close to real time. A “lean data approach” was developed for information aggregation to derive machine-based knowledge [28]. Digital waste has been discussed as buffer waste in the context of the cyber-physical production system from four interdependent perspectives: physical to physical, physical to digital, digital to physical, and digital to digital [18]. It has also been defined as any non-value-adding digital activity to women/men, materials, machines, methods, measurements and it can appear due to lost digital opportunities and/or overuse of the digital capabilities of new digital manufacturing technologies [29]. In this paper, we follow the definition of digital waste as uncollected, unprocessed, or misinterpreted data in the production process [17].

2.2 Industry 4.0 and technology.

Among a number of resources tested as essential for Industry 4.0 adoption, production systems (product and process traceability), and big data analytics (big data processing capability) were recognized as key [30]. Production data employing servers, sensors, and cloud computing have impacted data exchange procedures that became more complex. Lean manufacturing and the decision-making process are likely to be improved on the process level with the integration of data analytics and IoT [31]. The increased amount of production data requires autonomous monitoring, control, and optimization of value creation processes through the lean-data approach. There is a need for new, process-based technological solutions, such as decentralized sensor systems dealing with growing volumes of data at close to real time with an accuracy of more than 95% [32-33].

Industry 4.0 offers technologies for product improvement and innovation of manufacturing operations. It is important not to dismiss the focus on smart products through simulation, additive manufacturing, and augmented reality [34]. 3D printing is one of the examples of smart product concept early in the product life cycle, as the foundation for building multifunctional structures as smart products with integrated sensors in the manufacturing process chain [35]. Big data analytics, additive manufacturing, and sustainable smart manufacturing technologies are beneficial to manufacturing enterprises to make better decisions for the beginning-of-life stage of the product life cycle [36-37].

The lean method can integrate new technologies and allow better support of continuous improvement in the world of increasing product complexity. Smart products are connected to sensors and able to store a large amount of data, self-process, and communicate with industrial systems throughout their in-service life [38]. Data prediction has increased popularity in the manufacturing sector for the planning and control forecasting and covering the entire life cycle of a product. Service-oriented and cloud-based technologies are implemented throughout the supply chain to ensure secure data access for testing, prototyping, and factory optimization [39]. Additive manufacturing, augmented reality, and 3D simulation of product/service development and production processes are promising technologies in the Industry 4.0 environment. They disruptively change supply chains, business models, and business processes through interoperability, virtualization, decentralization, real-time capability, service orientation, and modularity [40]. A study at an auto-parts manufacturing firm [2] discovered the combination of lean manufacturing and

Industry 4.0, where the positive influence of smart production control and cyber-physical systems optimized lead times, non-value-added time, and value-added time by 25.60%, 56.20% and 24.68%, respectively.

2.3 Internally related lean practice.

Production scheduling involves continuous flow processes that provide support for achieving production of standardized products, and control of product flow forecasting approaches and monitoring take time [41]. The synergy between quality and lean practices leads to an improved flow process [42]. For increased productivity and a better working environment for the operator, a one-piece flow technique is used to manufacture product components. The flow describes the sequence of transient activities in a process within a single stage of production within a certain time frame. It increases the number of products through the process steps simultaneously [43].

Identification of techniques for setup time reduction is listed as one of the biggest challenges faced by automobile component manufacturing firms while implementing lean [44]. Some of the reasons for increased setup time are underutilization of creel, lack of tools, improper scheduling [45]. The single-minute exchange of dies is a lean technique that involves separation and conversion of internal setup operations into external operations. The goal of the technique is to achieve a setup time of less than ten minutes [46]. Advanced manufacturing is moving towards mass customization, where long setup times between variants are unacceptable for the competitive priority through process technology [47].

2.4 Supplier and customer related lean practices.

Supplier management was highlighted as one of the most important social factors for successful lean implementations along with employee involvement, internal technical practices, and customer management. It requires long-term relations with suppliers; feedback on quality and delivery performance; close contact with suppliers, especially senior management on the most important issues related to suppliers' involvement [48]. The just-in-time (JIT) lean purchasing approach is very convenient for long-term relations with suppliers. It can be optimized in three dimensions: management, financial, and technological. Technological dimension improvement expects partners to be more willing to share/give access to technology. It can also motivate partners to participate in product design based on knowledge and commitment to the other partner. Supplier involvement in design could lead to improved quality and reduced time to market [49]. Supplier integration is positively associated with the speed of new product introduction, but it does not support lean practices for operational performance indicators. Lean practices are positively associated with operational performance indicators, but not with delivery [50].

Companies widely consider customer involvement to help with issues such as quality standards, facilitating customer participation in product development processes, and technical assistance [51]. Customer focus was recognized as one of the key success (external) factors for lean manufacturing, along with government intervention [52]. Customer focus addresses emerging customer requirements and expectations, manages customer relationships, and defines customer satisfaction [53]. The relationship between lean and customer-focused performance is mediated by process improvement. Lean is positively related to customer-focused performance in an environment where customer effectiveness is considered important [54]. The level of lean maturity is related to customer focus, especially regarding external customer involvement in product development [51]. Attention to customer satisfaction, customer relationships, and customer involvement are discussed in the context of indicators of soft lean practices and have an impact on quality. Among the hard lean practices, total quality management is an indicator for the delivery to customers [55].

2.5 Theoretical Framework

A summary of our theory can be seen in Figure 1.:

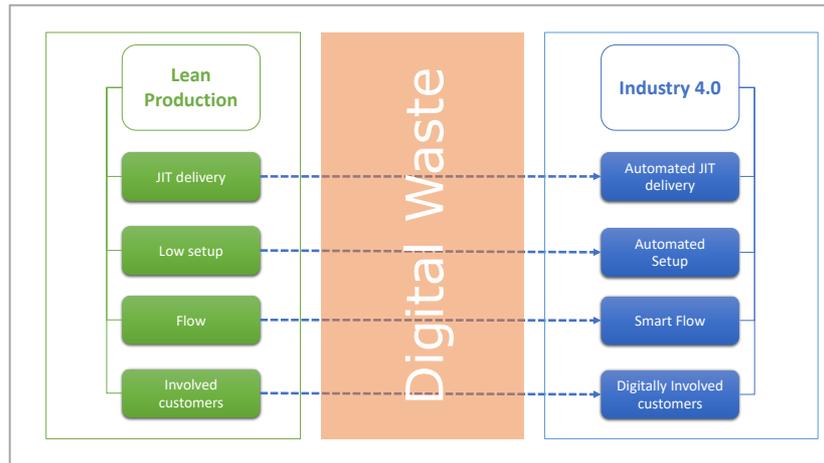


Figure 1. Theoretical framework of this study.

3 Method

Qualitative study was conducted through two case studies. The data was collected through the semi-structured interviews with plant managers [56]. There were several criteria in selection of cases [57]. The first, both companies are following lean principles. The second, both companies are the same size – SME. The third, both companies engaged with technologies in their production.

4 Results

Company A, based in Gävle, Sweden, has 20 years of experience in customized switchboard production for private companies. There are 22 people employed by the company, with an average age of 40 years and approximately 95% of employees are males. Each switchboard is assembled by one employee within approximately 24 hours at one working desk. Consequently, there is no need for automated setup or smart flow, due to the nature and simplicity of the tasks. Daily interactions with customers are time-consuming and often require middle management involvement to negotiate delivery, price discounts, or order specifications. All the information is saved on the company's drive and is not sorted or processed systematically for continuous improvements. However, Company A has very automated relations with their suppliers. About 60% of orders are packed by robots, with zero human interaction. In cases when the order formulation is done by robot, it is possible to receive wrong items inside the box. The items are accompanied by packing slips. In the case of a robot mistake, the description on paper is correct (matching the order), but the items inside the box are wrong.

Company B, established in Sweden in 2013, works closely with three sister companies. There are 16 male employees with an average age of 35 years working one shift at the plant, which is based in Gävle. The company produces stairs and railings made from steel, with a focus on firefighting stairs. Their standard portfolio of stairs allows assembly of one order within 20 hours from the half-finished items supplied by their partners. Communication with suppliers is dominantly digital, via ERP systems and emails. About 30% of orders are packed by robots, leading to a problem like that faced by Company A. The supplier might also delay the delivery due to poor digital order management and uncollected orders attached to emails from Company B. As a result, delivery to customers of company B can be delayed. It is outsourced to a post company and all the communication is fully digital. Often, delays can't be fixed without personal interaction between management and the outsource company.

5 Discussion

We suggest that the automation of supplier-related lean practices can lead to digital waste in product- and service-oriented technologies. The case company managers reflected that the number of mistakes caused by robots during automated JIT delivery is very small (1% of orders). Yet it is important to recognize the mistakes done by robots and associate this with digital waste, specifically misinterpreted data. There is evidence of digital waste in supplier-

related lean practices with service-oriented technologies. Suppliers might miss or ignore emails with attached orders unless they receive a phone call or personal confirmation. There is no evidence of digital waste in internal lean practices, due to the absence of automation processes, which can be associated with the small size of the enterprise and the lack of need to automate setup time or the flow of manufacturing processes. In customer-related lean practices on service-oriented technologies, the delivery service that outsources to a third party and misleading information of delivery address can cause delay and digital waste. A summary of our results can be seen in Table 1. The digital waste is ‘not available’ when the lean practice is not automated, consequently it cannot generate the digital waste at any product, process or service levels. The digital waste is ‘not detected’ when lean practice it is automated, but it is not causing any obvious digital waste.

Underlying Construct	Lean Practice	Product oriented technology	Service oriented technology	Process oriented technology
Supplier related	Automated JIT delivery	DIGITAL WASTE	DIGITAL WASTE	Not detected
Internally related	Automated setup	Not available	Not available	Not available
	Smart flow	Not available	Not available	Not available
Customer related	Digitally involved customers	Not available	DIGITAL WASTE	Not available

Table 1. Digital waste detection.

6 Conclusion and Further Work

Digital waste was detected in product- and service-oriented technologies through automation of supplier- and customer-related lean practices. There was no digital waste detected in the process-oriented technologies. Internal lean practices were not automated in the cases investigated in this paper, so no digital waste potentially could be investigated in those technologies. The study contributes to the discussion of both production waste [19-20] and digital waste [17-18, 29] under the influence of Industry 4.0. It also contributes to the discussion of automating lean practices [3-4] at the product, process, and system levels [24]. This study aims to encourage practitioners to detect digital waste and work on reducing it. Practitioners might also be motivated to consider digital waste as part of production waste and include it in value stream mapping. This study discussing the digital waste only in the context of lean manufacturing. The study is also limited to SME companies, where internally related lean practices are not automated. This study is limited to Swedish manufacturing plants located in the Gävle region. The study is also limited to only four lean practices. The technologies discussed in the study are limited by robots. Further research could investigate digital waste in automated lean practices such as: smart suppliers’ development, automated pull, digitally controlled processes, employee involvement in digital technologies, and smart productive maintenance outside of Sweden.

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