Lean and Digitalization—Contradictions or Complements?

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Abstract. Lean has been the dominant production paradigm for the past few decades. With its focus on reducing complexity, lean suggests to limit the use of digital technologies on the shop floor. Recent advancements in digital technologies, however, promise significant improvements through its ability to manage complexity. This apparent conflict raises the question as to whether these two paradigms—lean and digitalization—contradict or complement each other. Furthermore, there is ambiguity about whether or not firms should excel in lean before investing in digitalization. This paper contributes to this discussion through an empirical investigation of this relationship. It draws on survey data from Swiss manufacturers as well as consecutive interviews with selected firms. The analyses indicate a positive correlation between the digital maturity and the lean maturity of firms. This relationship is discussed from two perspectives: first, how digitalization can support lean and, second, how lean can support digitalization. Furthermore, the different characteristics of companies of different maturities in lean and digitalization are examined. It is concluded that a favorable organizational culture and some specific continuous improvement practices help the mature implementers of lean and digitalization to achieve superior operational performance.

Keywords: Lean management · Digitalization · Smart manufacturing

1 Introduction

In manufacturing, state-of-the-art process innovation is built on many ideas from the rich literature on lean management—or its derivatives and relatives (e.g., agile, world-class manufacturing, six sigma, and total quality management) [1]. Historically, lean manufacturers have been intentionally slow to introduce new technology and IT systems [2, 3]. Instead, the lean philosophy focuses on human learning, with the purpose of "developing every employee into a scientist" who can continuously improve the work processes that have been tested and proven in the past [4].

Although digitalizing manufacturing processes allow for much better and accurate data collection—in near real time—it risks alienating the human being from the problem-solving process and, thereby, reduces the ability to innovate. Lean management emphasizes the reduction of complexity, leveled flow, visual control, and

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standardization as enablers for process innovation [5]. Digitalization, in contrast, enables the handling of high complexity in manufacturing processes [6].

Scholars and practitioners still struggle to understand how the two paradigms of lean and digitalization influence each other. It is still a question of how digitalization and lean will coexist in the future. Do they complement each other or will digitalization replace lean? To contribute to this discussion, this paper addresses the following two research questions with a focus on the Swiss manufacturing industry.

RQ 1: Is there a correlation between firms' lean maturity and digitalization maturity?
RQ 2: What characterizes companies with different lean- and digital maturities regarding performance and enabling structures?

2 Theoretical Background

This chapter briefly introduces the paradigms of lean and digitalization. Thereafter, it summarizes the current state of the discussion on the relationship between the two.

2.1 Lean

The term *lean* was introduced by Krafcik in 1988, following a study of the International Motor Vehicle Program [7]. Lean aims to align value creation with customer demand and to continuously eliminate waste in processes. Both these principles are necessary to be competitive and require continuous improvement within the existing processes [8]. The Japanese term *Kaizen,* which means change for the better, requires all employees to continuously challenge the status quo and to think about how they can improve the production system [4, 9]. To reduce wasteful activities and increase value for the customer, five lean principles have been defined by Womack and Jones: *specify customer value, identify the value stream, flow, pull,* and *strive for perfection* [10].

2.2 Digitalization in Manufacturing

The digitalization of manufacturing currently receives much attention from academia [11] and governmental agencies [12]. Although digitalization in manufacturing is discussed frequently in the literature, no universally accepted definition exists [13]. However, almost all definitions include the application of modern information and communication technologies (ICT), as well as data analytics, as enablers for increased efficiency and flexibility of manufacturing operations [14].

Even though scholars associate potential benefits with the digitalization of manufacturing [15], the actual implementation rate is slow [16]. Given the lack of personnel with the needed skills, as well as restrained financial resources, especially small and medium enterprises (SME) face the following question: does investment in digital technologies pay off? Digitalization needs to prove its contribution to operational and financial performance in order to convince managers to support its further implementation.

2.3 The Relationship Between Lean and Digitalization

The literature reveals a discourse about the relationship between lean and digitalization. The superior competitiveness of lean production systems does not originate from the extensive use of cutting edge technology [9]. Traditionally, the lean literature sees a conflict between lean and modern technology, such as IT systems. Whereas lean advocates simplicity, IT systems usually introduce high complexity [6]. For instance, Toyota is usually not among the first companies that introduce new technology. Instead, Toyota spends much time to test new equipment extensively and only introduces it if it does not interfere with the lean principles of the Toyota Production System. New technology needs to either reduce existing waste or contribute to higher customer value before it is introduced in lean production systems [9].

However, the literature also indicates that lean is the foundation for digitalization. Lean processes are transparent, robust, and standardized, and this foundation is, according to some research, crucial for the successful introduction of digital technologies [17]. The argument is that lean thinking, which reduces process and product complexity, facilitates the efficiency of digitalization. Companies with a high level of lean implementation are more likely to also implement "Industry 4.0" digital technologies [18]. Kolberg and Zühlke have identified use cases of the combined application of lean and "Industry 4.0" and conclude that "the integration of innovative automation technology in lean production is an up-to-date and promising topic [19]."

Furthermore, scholars argue that digital technologies likely to benefit from a high lean maturity that they also have the potential to raise lean maturity to an even higher level. Lean is not particularly good at handling increasing flexibility requirements (e.g., manufacturing highly customized products). Digitalization, in the context of "Industry 4.0" has the potential to enhance the flexibility of lean in order to successfully address the challenge of increasing product customization [20]. Moreover, digital technologies can contribute to further increasing the stability of lean processes [21]. Digital technologies can support lean in addressing some of its inherent limitations, such as increasing product customization [17].

The parallel implementation of lean and digitalization is estimated to yield a 40% improvement potential, compared to a 15% saving potential for the standalone implementation of lean or digitalization [22]. Scientific literature on the interplay of the two, however, is rare. Although the research suggests a positive link between both paradigms, it currently lacks rigorous empirical studies to test the relationship [18]. To contribute to the ongoing discussion, this paper empirically analyzes the interrelation of lean and digitalization with a focus on the Swiss manufacturing industry.

3 Method

To study the relationship between the paradigms, we used a mixed-method approach as described by Creswell [23]. First, a questionnaire was developed and tested together with academic and industrial experts in the field of operations management. The authors then conducted the survey throughout 2017 and distributed it to 500 manufacturing companies. When the survey closed, 74 usable responses had been returned.

Digital maturity is set as the dependent variable. In line with previous work (cf. [18]), digital maturity is defined by the implementation level of related digital technologies. Each technology is measured on a scale from (1) "no utilization" to (4) "company-wide roll-out." The mean from the maturities of the different technologies forms the overall digital maturity (Cronbach's alpha = 0.78).

Lean maturity is set as the independent variable. It is defined similarly by measuring the maturity of the company in lean within different areas of the firm. The investigated areas are production, quality, R&D, administration, procurement, logistics, marketing, sales, and services. Each area is measured on a scale from (1) "no application of lean" to (4) "history of lean success." The simple mean of the different areas represents the overall lean maturity (Cronbach's alpha = 0.85).

Multiple regression analysis is used to analyze the correlation between lean maturity and digital maturity. The companies are then clustered into four segments. We investigate the clusters regarding four different areas—namely, operational performance, financial performance, organizational culture, and continuous improvement (CI). *Operational performance* is measured by the relative performance in the areas of cost, quality, and delivery compared to the industry. *Financial performance* is measured by the change of revenue, EBIT, and market share within the last three years. The *organizational culture* is measured by questions about open communication, alignment to overall goals, understanding of value stream, and access to business intelligence. The measure CI is built from four questions about the continuous improvement process—namely, striving towards waste reduction, feedback evaluation, joint improvement program, and market screening for new technologies.

Two controls are included: *lean experience* and *size of the company*. The lean experience is divided into five levels: "no experience," "more than 3 years," "3–5 years," "5–10 years," and "more than 10 years." Finally, we control for the size of the investigated company; the binary measure SME gets one for companies smaller than 250 employees. Following the quantitative analysis, qualitative interviews were conducted with companies of the clusters. Six companies were interviewed and analyzed.

4 Results

Figure 1 illustrates the companies based on their lean and digital maturity. The resulting clusters are colored, and the size of the bubble indicates the size of the company. Most of the companies are in the first cluster with a lean maturity below 2.16 and a digital maturity below 2.17. Few companies fall in the high-lean and low-digital cluster (Cluster 2) and in the low-lean and high-digital cluster (Cluster 3). The impression of a correlation between the two maturities is supported by the regression results shown in Table 1. Thereby, a one-unit increase in the lean maturity is related with an increase of the digital maturity of 0.33 in the second model. The first model includes only the independent variable digital maturity as predictor, whereas the second model also includes the lean experience and the size as predictors for the digital maturity. The impact of the control variable SME is also significant, reducing the digital maturity by 0.29. The control variable lean experience returns insignificant effects.

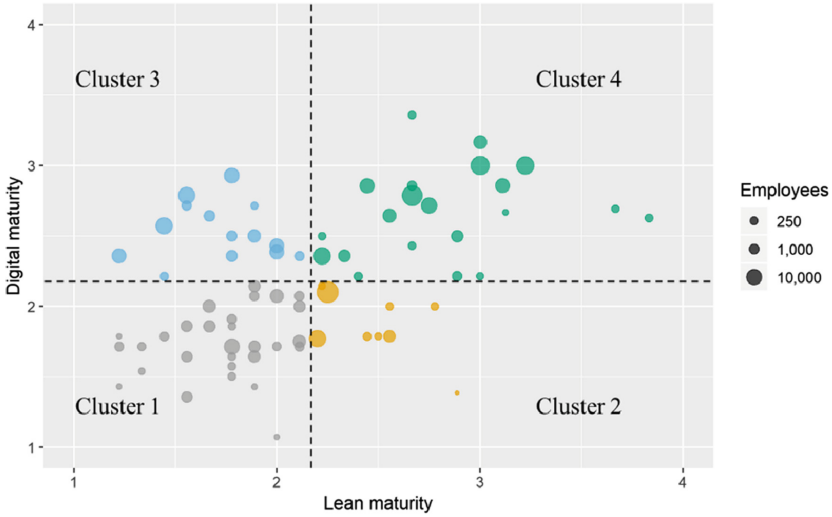

Fig. 1. Matching firm's digital and lean maturity (bubble sizes indicate company size) (Color figure online)

The analysis of the characteristics of the different clusters reveals significant differences within the clusters (Table 2). Companies with higher lean and digital maturity (Cluster 4) tend to perform better, have a better organizational culture, and have a better CI process in place. There was insignificant evidence that Cluster 4 companies have a better financial performance than the other clusters.

Table 1. Regression results on digital maturity

	Digital maturity	
	(1)	(2)
Constant	1.384***	1.241***
Lean maturity	0.364**	0.333**
Lean experience		0.084
SME		−0.289*
R-squared/Adjusted R-squared	0.197/0.186	0.319/0.289

Note: $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$

Table 2. Mean value of characteristics of the different clusters

Characteristic		Cluster 1		Cluster 2		Cluster 3		Cluster 4	
		Avg	SD	Avg	SD	Avg	SD	Avg	SD
Performance	Operational*	3.59	0.68	3.72	0.65	3.14	1.06	3.89	0.61
	Financial	2.24	1.67	3.13	1.57	2.81	1.47	2.68	1.63
Enablers	Culture**	3.31	0.91	3.95	0.77	3.14	0.85	4.13	0.77
	CI**	3.33	0.62	3.75	0.68	2.95	1.17	3.98	0.83

Note: $^{*}p < 0.05$; $^{**}p < 0.01$

5 Discussion

The results add insights to the discourse about the relationship between lean and digital by suggesting they do not contradict each other. In contrast, the results support a positive correlation between the two paradigms. This relationship thereby shows that firms implement lean and digital at the same time: Fig. 1 shows that most companies are situated along a diagonal of lean and digitalization and thereby supports the previous research [18]. The following paragraphs discuss the findings of the quantitative research in light of the insights from the qualitative interviews.

Digitalization can support the implementation of lean. Digitalization offers opportunities to manage and mitigate complexity for the operator on the shop floor. An example is digital shop floor management; complex processes are reduced to a few important influencing factors, which are discussed in a morning meeting. Digitization can further help in achieving lean principles [10]. For instance, flow and lot-size-one can be enhanced by improved production planning techniques through the manufacturing execution system or digital work instructions via augmented reality. Transparency about the value stream can be increased by process mining [24, 25], and prescriptive analytics helps to strive for perfection (i.e., quality) in the processes. The interviews with company representatives supported the finding that digitalization can enhance lean principles for two main reasons. First, the availability of up-to-date, high-quality data increases transparency and facilitates the identification of waste. Second, digitalization allows a higher degree of flexibility regarding to customer requirement (e.g., by enabling product customization or last-minute order changes).

In reverse, lean can also support digitalization. Efforts can be guided to not push technology into the production plant but to satisfy the relevant requirements of the operators. Lean principles simplify the data collection required for digital projects by having streamlined processes, which can reduce the time to integrate digital solutions. The interviewed company representatives described the risk of implementing digital technologies for the sake of applying state-of-the-art technology while neglecting the core purpose of new technology—to support and improve existing value creation processes. Lean thinking ensures a permanent focus on customer value and waste elimination, which facilitates the identification of technologies that support these objectives. One company manager expressed it concisely: “if we do not apply lean principles, we digitalize waste.”

The different characteristics suggest differences in the level of operational performance between the clusters. A higher level of operational performance is related with a high level of lean maturity (e.g., Cluster 2 and Cluster 4). Companies following a digitalization strategy while neglecting lean are represented in Cluster 3. These companies reveal the lowest average performance in the sample, supporting the argument that lean is needed as a foundation for successful digitalization. The results suggest that although the lean principles of customer orientation and elimination of waste remain the basis of efficient production, the combination of lean thinking and digital technologies enables superior performance compared to a standalone implementation of lean or digital technologies. For the financial performance, however, the results are not significant, which is likely due to other factors outside of manufacturing.

There is also a difference within the enablers. Companies achieving high values for the enabler category "organizational culture" consistently report an open communication culture, which includes appreciating contributions of all employees regardless of their hierarchical position as well as encouraging an open feedback and failure culture. This allows solution-oriented instead of blaming-oriented discussions about failure. CI may be supported by a structured process to contribute to CI suggestions. However, such processes are also in place in companies with lower CI levels, thus suggesting that it is more the design than the bare existence of a proposition system. Companies with high CI levels stress the importance of user friendliness and timely as well as qualified feedback on suggestions, whereas no pattern was found regarding financial incentives. Companies should further focus on culture and the continuous improvement process. Both enablers have shown differences within the clusters, hence providing a best practice for companies. Having an effective CI process in place differentiates the best-performing companies from the lower-performing ones.

6 Conclusion

Lean and digitalization are complementary, not contradictory. This paper adds empirical findings to support a symbiotic relationship between the two paradigms. Digitalization can support lean, but lean can also support digitalization. The paper reveals differences in the characteristic of companies with different lean- and digital maturities. It suggests companies to focus on continuous improvement and open organizational culture to achieve highest operational performance. Further research can focus on the paths that lead companies to higher maturity in both lean and digitalization.

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