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Lean and digitalization status in manufacturing companies located in Norway

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Abstract. Manufacturing companies are always on the lookout for methods to boost productivity, improve quality, and enhance their service offerings to remain competitive. Two methods that are extensively debated in both industry and academia are digitalization and lean. The main objective of this study discussed is to identify the current status of lean and digitalization use in manufacturing companies located in Norway and to uncover their synergies and potential influence on each other. Specifically, the study aims to explore the history of lean and digitalization implementation in these companies, the lean practices and digital solutions currently in use, the influence of lean on strategic and operational results and people, the difficulties faced in lean implementation, and the potential synergies between lean and digitalization in improving operational excellence in manufacturing companies.

Keywords: Lean, digitalization, manufacturing.

1 Introduction

In order to be competitive manufacturing companies are constantly looking for ways to increase productivity, quality, and the level of services. Digitalization and lean are among the ways discussed widely in industry and academia. The lean concept has been verified empirically and there is available extensive literature on empirical studies proving a positive impact on operational excellence in manufacturing companies [1, 2, 3]. In recent years, the concept of digitalization has gained significant attention in the manufacturing industry, and it has become increasingly clear that it has the potential to revolutionize the way manufacturers operate [4, 5]. Digitalization refers to the use of digital technologies and systems to improve operational efficiency, quality, and overall performance. However, despite the potential benefits of digitalization, it is still a relatively new concept with limited industrial applications and measurable positive results.

Combining Lean and digital solutions seems to be a necessary evolutionary step to further raise levels of operational excellence. Lean management remains the

fundamental approach to operational excellence within Norwegian industry. Digitalization should not replace lean management. Rather industrial companies are seeking to understand how the two approaches can be utilized synergistically.

This study attempted to identify the current status of lean and digitalization use in manufacturing companies located in Norway, as well as to uncover their synergies and potential influence the two have on each other.

2 Theoretical background

2.1 Lean

Up until recently lean were seen as mechanistic identification and elimination of waste in production processes by replicating lean tools and practices such as value stream mapping, 5S, kanban, poka-yoke, A3, etc. [1]. However, now researchers see that this approach is faulty. They argue that the scope of lean goes much further. According to Powell (from [1]), lean is a meta-theory – a system to develop better products, time after time. The core of Lean thinking is continuous improvement through shared understanding of problems, cross-functional communication, and employee participation. Lean is an education system that emphasizes deliberate learning through the scientific method of Plan-Do-Study-Act and structured experiments.

When viewed as a learning paradigm, Lean tools and techniques can be regarded as enhancers of learning, instead of just a means of achieving operational excellence. They help identify areas for improvement and the actual improvement is carried out by the people involved in the system, rather than solely by the tools. However, adopting Lean best practices for static optimization without understanding its theoretical and enterprise-wide underpinnings may hinder extraordinary business results [1, 2, 3].

2.2 Digitalization

For this study we employ description of digitalization in manufacturing as provided by [6]. They break it down into shop floor digitalization, technologies for vertical and horizontal integration and organizational IT competence. Shop floor digitalization has cyber-physical production in the center to collect and control real-time production data. Vertical integration involves integrating IT systems at different hierarchical levels within a factory, such as production sensors, enterprise systems, and product development, and is a key aspect of Industry 4.0. Horizontal integration, on the other hand, refers to integrating IT systems across different stages of manufacturing and business planning processes. Organizational IT competence is an organization's understanding and effective utilization of IT.

According to the literature review by [7], production scheduling and control is the process that is most investigated when it comes to Industry 4.0 implementation. They found that not all technologies are equally discussed in the literature with IoT, Big Data Analytics and Cloud at the forefront of the research. Furthermore, even though the topic of Industry 4.0 and digitalization is much debated in the literature, it remains at a conceptual level, without examples of real-life applications. The issue of digitalization and

Industry 4.0 often remains at an abstract level, making it challenging for practitioners to understand where and how to effectively utilize the new technologies, and what are the benefits of technology implementation [6 ,7].

2.3 Interplay between lean and digitalization

The emergence of digitalization and Industry 4.0 technologies has sparked a renewed discussion on the introduction of new technologies into established managerial systems that are centered around human-focused philosophies like lean management [9].

As pointed out by [10] in their recent systematic literature review, the papers on lean and digitalization interplay can be divided into three main categories: lean supporting/influencing digitalization, mutual support of lean and digitalization, and digitalization supporting/influencing lean. In their paper they have also found that lean paves the way for the adoption of digitalization at a strategic level, while digitalization technologies enhance lean practices at the operational level (the authors are talking about lean supply chain management in this paper). Research on the strategic level examines the interplay between lean management and digitalization from a system perspective, focusing on long-term implementation paths. In contrast, research on the operative level analyzes the interplay between the two paradigms from a single implementation point of view, with a short-term perspective linked to specific practices or technology implementation (such as big data, augmented reality, blockchain, etc.) in a particular context.

[10] take a perspective of using lean for solving digitalization problems. They identified and listed possible types of waste from the digital industry and argue that lean can helps in identifying and eliminating wastes. In their paper authors take an "old school" perspective of lean being a set of waste reduction tools. [11] studied impacts of lean on Industry 4.0. Their conclusion is that lean thinking facilitates the implementation of Industry 4.0 by simplifying processes and eliminating waste in a way that prevent waste from reoccurring, reduce the risk of depleting scarce resources, and enhance transparency in work processes and organizational practices. Their argument is in line with statement "lean first, then digitalize".

Study conducted by [12] studies impact of digitalization on lean. Through the survey of academic community, they found that digitalization impacts lean operations practices. Specifically, just-in-time, visual management, total production maintenance, continuous improvement, and poka-yoke. These authors take perspective of lean being a set of practices as opposed to the view suggested in the recent research of Lean being an educational system to develop better products.

Similar to [12, 13] concluded that digitalization and Industry 4.0 technologies impact lean by giving lean tools a more dynamic way of working, accelerating information sharing processes and improving production manager's and operator's decision making. They argue that there is little practical and theoretical contribution of lean to Industry 4.0 and thus the actual contribution is still blurred.

3 Method

Qualitative research method was chosen to study the current status of lean and digitalization in Norway. Qualitative research methods are valuable in providing rich descriptions of complex phenomena. It can be used to gather in-depth insights into a problem. Semi-structured interviews were chosen for data collection. Semi-structured interviews are open-ended, allowing for flexibility, but follow a predetermined thematic framework, giving a sense of order. Semi-structured interview guide was created to cover four main topics:

- Background information about the company/interview participant (background information was collected to group and analyze companies, understand the context information and control variables)
- Lean management in the company (why, when and how did the lean implementation started; implementation process; outcomes at strategic and operational levels)
- Digital manufacturing technologies in the company (why, when and how did the work with digitalization started; implementation process; outcomes at strategic and operational levels)
- Interplay between Lean management and Digital manufacturing technologies (how specifically are the two used together; influence on each other – advantages and disadvantages; synergetic influence at strategic and operational levels)

3.1 Data collection

The interview guide was designed to help in conducting interviews. In order to find interview participants, researchers and research assistants involved in this study created an invitation that was sent to manufacturing companies located in Norway. In total, 19 interviews were conducted. In some of the interviews, more than one participant were involved (see Table 1). The participants received interview guides in advance to be able to prepare for the interview. Each interview lasted for 1-2 hours. The participants were interviewed by the research assistants. 1-3 research assistants were present during each interview. Interviews are usually conducted by a single investigator, but as [14] points out, the use of multiple investigators can have advantages. They can enhance the creative potential of the teams and convergence of observations increases confidence in the findings. The participants were asked, to the extent possible, the same questions to increase the reliability of the collected interview data. The interviews were audio-recorded with the permission of the participants. Interview transcripts were written and sent to the participants for verification.

3.2 Data analysis

Recommendations of [14] were followed for data analysis. The interview transcripts were coded – descriptive codes were assigned both deductively and inductively to data chunks. Several categories of codes were assigned:

1. Codes describing company's characteristics: size, products, degree of customization, degree of repetitiveness of production processes,
2. Codes describing interview participant's experience and competences: position in the company, experience working with lean and/or digitalization, years of experience,
3. Codes describing company's lean practices: the history of lean implementation in the company, lean practices used now, influence of lean on strategic and operational results, lean implementation difficulties,
4. Codes describing company's digitalization practices: the history of digital solutions implementation in the company, digital solutions used now, influence of digitalization on strategic and operational results, digitalization implementation difficulties.

Based on the coding, a cross-case analysis was performed. Using the methods suggested by [14], the authors looked for the presence of same factors across multiple cases and examined whether familiar themes emerged in multiple settings. To aid the analysis at this stage, all cases were combined in a meta-matrix created by assembling each case in a common format and displaying them together in one large table. Reformatting and resorting the cells and rows in the table helped the authors to identify patterns in the cases and determine whether new observations can be constructed.

4 Results

This chapter presents the results of the study without interpreting them.

4.1 Background information about the company and interview participants.

In total, representatives from 19 companies were interviewed. In some instances, several participants from one company were interviewed (see information about interview participants in Table 1). In the event where several representatives were present, interviews were carried out simultaneously. Interview participants had different degrees of experience working with lean and digitalization – from several month to more than 20 years.

The participating companies vary depending on their size, the type of produced products and types of production processes. Companies' size varies from small to large: between 50 and 3500 employees and turnover from 40 mill. NOK to 4.5 mrd. NOK. Both Norwegian companies and companies located in Norway, but belonging to international conglomerates participated in the study. Table 1 shows products and production processes of the studied companies

Table 1. Information about interview participants and manufacturing companies

Comp.	Interview participants	Product or service	Product's degree of customization	Degree of repetitiveness in production processes
1	Lean coordinator	Electronics	Products are customized based on	Mix of mass- and project-based production

			customers' specification	
2	Production mgr.	Roofs	Products are customized based on customers' specification	Processes are similar, but vary depending on the product
3	Operations developer	Milk and milk products	Products are standard	Mass production, repetitive
4	Lean department mgr.	Services within insulation, scaffolding and surface treatment	Products are customized	Processes are similar, but vary depending on the product
5	Chairman of the board	Doors	Make-to-order, high customization degree	Processes are repetitive, but not mass production. Customization starts at surface treatment
6	Staff and support mgr.	Construction	Products are customized	Project-based production
7	Operations developer	Cheese and yoghurt	Products are standard	Mass production, repetitive
8	IT/digitalization department leader	Industrial lighting	Products are customized	Project-based production
9	Coordinator for cont. improvement and business devt., Chief information officer	Service of procurement, management and disposal of material for the military	-	Project-based procurement
10	Quality and HMS leader	Steel component and structures	Products are customized	Project-based production
11	Lean coordinator	Windows and doors	Products are customized	N/A
12	Corporate mgmt., responsible for digitization and operational mgmt..	Furniture	Make-to-order (millions of combinations of furniture)	Processes are repetitive, variation in the end of production
13	Production coordinator Organizational developer and improvement leader	Fastening materials and bolts	Products are customized depending on dimensions and materials	Processes are repetitive
14	Technology mgr. Research and sustainability mgr.	Composite gas containers, propane-butane mix	Products are standard, the only customization	Processes are repetitive

			possible is product appearance	
15	General mgr., technical mgr., IT mgr., Lean mgr.	Doors and windows	Products are customized	N/A
16	Head of commercial production	Radioactive drugs	Products are standard	Processes are repetitive
17	Lean and quality mgr.	Construction	Products are customized	Processes are non-repetitive
18	Production responsible	Ammunition products and rocket engines	Many product variants	Processes are non-repetitive
19	Business systems developer	Thruster, dynamic positioning equipment	Products are customized	Processes are similar, vary depending on the product size

4.2 Lean status

The history of lean implementation in the companies and lean practices used now. The studied companies all have been working with lean management during the last 2-19 years. One of the companies stated that they have been working with lean since 1972. Only one company explicitly emphasized that they see lean as a philosophy rather than a set of tools. The rest of the companies listed tools they are working with as a part of lean management. The most mentioned tools are: 5S, work with whiteboards, improvement work meetings and work on improving the flow. Other tools mentioned include teamwork, reading circles, takt, poka-yoke, standardisation, waste reduction, Hoshin Kanri, problem solving, zero defect, VSM, PDCA, Lean Six Sigma (please note that we report the tools the way they were named by the participants, without interpreting whether it can be interpreted as a lean tool or not). 4 companies mentioned that either lean course or lean programme was purchased from external consultants, 2 companies used lean programmes developed in the company's headquarters abroad. The rest of the companies attempted lean implementation on their own or it was not clear (or not known to participants) how the lean implementation started in the company.

Influence of lean on strategic and operational results and people. 9 companies answered that it was difficult to assess lean influence on operational results, 10 companies were able to give examples of the lean influence on operational results, and 4 companies were able to give quantified assessment of operational results.

Following impacts on operations were mentioned:

- less material waste (6 companies),
- cleaner workstations (6 companies).
- reduced production time (4 companies),
- increased uptime (4 companies),
- better quality (4 companies),
- increased profit (2 companies),
- increased lead time (2 companies),

- increased level of service (2 companies),
- reduced inventories (1 company),
- increased production volume (1 company),

Quantified improvements mentioned by the companies are:

- Time used for one of the production operations went down from 4 days to 4 hours,
- 57 million NOK more profit from lean implementation (across the conglomerate),
- Reduced throughput time from several days to several hours,
- 80% reduction in internal fails,
- Increased production volume from 55 to 130 items.

Only one company stated that lean had a clear ***influence on company's strategy*** and that projects' effectivization was included in their strategy.

13 companies stated that lean had positive effect on employees. Following positive effects were mentioned:

- Calmer, more predictable work (7 companies),
- Better work culture (7 companies),
- Increased interest and pride in work, better ownership of own work (6 companies),
- Increase engagement in work (6 companies),
- Generation of new ideas and improvement suggestions (6 companies),
- Tidy workplace (4 companies),
- Better collaboration between the teams (4 companies),
- Better HSE (2 companies),
- Better understanding of business tasks and processes (2 companies),
- Reduced manual work (2 companies).

Lean implementation difficulties. 16 companies mentioned different lean implementation difficulties:

- Lack of time (8 companies),
- Disruption in lean implementation due to COVID pandemic (8 companies),
- Lack of commitment (8 companies),
- Inability to ensure continuous focus and commitment (8 companies),
- Lean work is dependent on individual managers (6 companies),
- Lack of managerial support (5 companies),
- Resistance from employees (4 companies),
- Little competence and understanding of lean (3 companies),
- Difficult to get out of comfort zones and habitual patterns (3 companies).
- Difficult to practice lean in external projects (geographically distant projects) (1 company),
- Some resources are difficult to measure (in case of Lean Six Sigma) (1 company).

4.3 Digitalization status

The history of digitalization implementation in the companies and digitalization now. The studied companies have been working with digitalization during the last 2-30 years. The companies mentioned both hardware and software as part of their digitalization practices. The most mentioned ones were:

- Sensors to measure machine performance (5 companies),
- Screens/boards with visualization of the status of workstations/production/the entire company (5 companies),
- Power BI (6 companies),
- ERP systems (12 companies),
- Robots (2 companies).

Other digital solutions mentioned: SharePoint, Office Dynamics, automated registration of deviations, automatic reporting system, digital training system, digital HR system, digital checklists, Salesforce, Optimizely, product development software, production planning systems, FO365, CNC machines, KPI-dashboards, Hololens, etc.

Influence of digitalization on strategic and operational results and people. Eleven companies stated that it is difficult to answer whether digitalization influence operational results. None of the companies were able to quantify the operational results. 8 companies provided following examples of positive influence of digitalization on operational results:

- Improved machine uptime (4 companies),
- Reduced waste (4 companies),
- Reduced production deviations (3 companies),
- Resource savings (2 companies),
- Better quality (2 companies),
- Improved in the database (1 company),
- Better information flow (1 company),
- Better process control (1 company),
- Better service (1 company).

All of the participants found it difficult to answer whether digitalization influence company's strategy.

Digitalization implementation difficulties. 15 companies gave following examples of digitalization implementation difficulties:

- There are no ready-to-use digital tools, everything must be adapted and customized to fit the company's needs (8 companies),
- Resistance from employees (fear of changes or fear that digital tools are there to evaluate employees' work) (7 companies),
- Economy (7 companies),
- People may see digitization as unnecessary work (e.g., data must be recorded, which requires additional effort) (6 companies),
- Lack of competence (5 companies),

- Lack of time (5 companies),
- Lack of structure in the development and implementation of digital solutions (4 companies),
- Lack of support from management (4 companies),
- Difficult to get different IT systems to "talk to each other" (4 companies),
- Low level of competence in the company (2 companies),
- Reluctance to change or lack of capacity to absorb changes (2 companies),
- Cyber-security (1 company).

4.4 Lean and digitalization synergies

The last part of the interview was dedicated to studying how lean influenced digitalization (and vice versa). This part of the interview had the least answers. When asked if Lean influenced digitalization, most of the interview participants answered "yes", but struggled to give a clear answer how. 5 companies, however, explained that lean helps to find out which data is required to work further with lean, based on that, the companies can decide which technologies are needed to collect and process the needed data. 3 companies explained that problems identified through lean work are sometimes solved with the help of digital solutions. When asked if and how digitalization influences lean, thirteen companies explained that digitalization (specifically, data collection and analysis) helps to find problems and bottlenecks for further lean work.

When it comes to negative influences, some companies mentioned that digitalization influences lean somewhat negatively by:

- Digitization can cause some lean principles to not fit in with the new tools -> digitization makes simple tasks that everyone can do into something difficult. Here, no specific example was given by the interview participants, except maybe an example given in the next bullet point below.
- Easier to use whiteboards than digital boards. The interview participants think that digitalization of work with boards creates unnecessary barrier for lean work,
- Digitalization can be a distraction from improvement work,
- Difficult to choose digital platforms that support lean work,
- Digitalization efforts take away time and resources from lean implementation work.

5 Discussion and conclusions

There are several important observations that can be made based on the available results:

1. It is clear that manufacturing companies are lagging behind in current understanding of lean. Most of the companies participating in our study see lean as a set of predefined tools. It is understandable since even now many researchers see lean merely as a set of tools that should be replicated by companies to improve their performance. It is important to spread new knowledge, educate and update companies on new research. It should be stated that the new research does not cancel the usefulness of

existing lean tools, but rather encourages people across the organization to develop solutions suitable for specific problems, rather than impose existing solutions.
The interview scope is quite limited, and it was not possible to see specifics of lean implementation. The idea for further research can be in-depth case studies with 5-10 companies that have been working with lean.

2. Very few companies are able to see and measure the real influence of lean and digitization on operational performance, corporate strategy, and people. The results of digitization are especially difficult to see. This can be explained by the fact that digitalization is a relatively new initiative in manufacturing companies (except from old technologies, such as CNC-machines) and it needs to mature to see real results. The impacts of lean are somewhat clearer, but still quantitatively limited, even though lean initiatives started quite a long time ago in most companies. This can be explained by the fact that it is difficult to isolate the impact of lean if several initiatives are being implemented in the company. However, the companies should try to estimate real impacts of both lean and digitalization for assessment and learning. This is also a task for future research.
3. It is not clear how manufacturing companies define digitalization. This can be a limitation of the interview guide since we did not give a definition of what we mean under digitalization, but it was done intentionally to see how the companies would answer. Most of the digitalization examples were given are related to information flow digitalization, much less is about digitalization of material flows. This can be because of how companies define digitalization or because information flow digitalization is more advanced. This too requires further research.
4. No clear answers on how lean influences digitalization were given, even though people intuitively say that the influence is positive. Most of the participants were able to clearly say that digitalization supports lean work by helping to find problems and bottlenecks for further lean work. This is clearly a research and practice area that should be worked on.
5. The quality and depth of answers depend on who was interviewed. Many interview participants were working with lean, not digitalization. Hence, their knowledge on digitalization can be somewhat limited. This is a limitation of our research and should be addressed in further studies. Additionally, it is difficult to find experts that apply both lean and digitalization in their firms because of the novelty of the paradigm combination.

Study limitations

This study is subjected to limitations. First, it does not constitute either survey or in-depth case study. Since only interviews were conducted with company representatives, it does not allow for data triangulation and results depend on who was interviewed as we stated above. This considerably weakens the reliability of the research and the results should be treated with care. It is important to note that this are preliminary explorative results and case studies with several of the companies were conducted after these interviews and will be published later.

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