UiA University of Agder

Is communication evolving?

A study of how a digital approach of Lean can enhance the information flow in a high variety – low volume manufacturer.

A qualitative case study of a Norwegian manufacturing company.

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PREFACE

This master thesis was written in the spring of 2022. I completed my master's degree in Industrial Economics and Technology Management at the University of Agder.

The decision to work alone was due to my interest in lean and the development of digitalisation. In addition, an exchange period lasted until mid-February. Further, the preparations and contact were limited due to the exchange period, resulting in a slow progression. However, the decision to use a case study at the company OPS Solutions and look at the possible implementation of Lean and digital technologies was already determined. Therefore, the master thesis was decided to be about the opportunity to implement Lean and digital technologies in a high variety and low volume manufacturing environment. However, during the literature review and investigation, the interest in the information flow became a clear area theme. For that reason, the thesis was narrowed to a digital approach of Lean to improve the flow of information.

I want to thank the company OPS Solutions for their contribution and respect during the process. In addition, I would like to show my gratitude to the different companies that granted me an interview with the top management.

The master's programme has been an instructive knowledge which has contributed to an educational experience. Due to the Covid pandemic, the study programme has been more challenging because of digital teaching. Nevertheless, it has contributed to a more digital approach and reminded the importance of digitalisation in companies.

GRIMSTAD, 22/5 2022
Aleksander Fridén

ABSTRACT

Information flow has always been crucial to success because the information will occur whatever one is doing. How to process, interpret and act regarding the information that occurs is a vital element of the business process. When looking at the manufacturing industry, one sees an increasing demand for customised products. Hence, the importance of improving HVLV manufacturing has become prevalent. The growing demand brings a narrow and competitive mark, further emphasising improving the manufacturing process. Thus, how companies handle their information flow is vital in the business process and competitiveness.

Additionally, with today's technologies and the ever-increasing emerging technologies, every company will become a digital company. In addition, the Lean philosophy has been a pursuit in the last decades, especially in the HVLV-environment, where it has shown some challenges. Hence, achieving a Lean foundation and evolving into a digital world is a pivotal change to stay competitive in the future. With that, the concept of Lean provides five principles which explores the mindset behind the system. By examining the philosophy in a not traditional way, a potential application of Lean can be identified in the HVLV environment. In addition, exploring digital technologies to collaborate with the lean concept creates a foundation for further research if digital technologies and lean can enhance the information flow. The research takes a qualitative foundation in a single case study at OPS Solutions. With the help of the case study, the paper has used the theory and prepared a proposal for the digital approach of Lean tools to how the company can enhance the information flow between management and production. The research concludes that adapting the Lean principles with a digital approach can be applied to HVLV manufacturing and enhance the information flow. During this research, it became clear that Lean is a process of aligning the organisation with its values and philosophy to implement and sustain the implementation.

Additionally, some fundamental digital technologies need to be functional, such as Information System infrastructure. Further, it could be beneficial to emphasise flow efficiency to reduce lead time and visual management to create information transparency to increase the workflow. This thesis establishes a hypothesis for further action research. Implementing these solutions will give it contribute to science.

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Abbreviations

ATO	Assemble-to-order
BPMN	Business Process Modelling Notation
CODP	Customer order decoupling
ConWIP	Constant Work in Progress
ETO	Engineering-to-Order
HVLV	High-Variety-Low-Volume
IoT	Internet of Things
ICT	Information and communication technology
IS	Information System
LP	Last Planner
MTO	Make-to-Order
MTS	Make-to-Stock
M2M	Machine-to-Machine
OPP	Order Penetration Point
PDCA	Plan-Do-Check-Act
PPC	Percent Planned Complete
POLCA	Paired-cell Overlapping Loops of Cards with Authorisation
PRP	Project requirement planning
VSM	Value Stream Mapping
SMED	Single Minute of Exchange of Dies
WIP	Work in Progress

1. Introduction

1.1 Background

A large part of Agder's value creation comes from the process and supplier industry, a world leader in technology and the environment (NHO, 2020). The supplier industry is strong and consists of clusters to maintain its competitiveness (NHO, 2020). This happens, among other things, through fast delivery time, low production cost, flexibility in volume and variation in the products (Prajogo et al., 2016). In the cluster GCE NODE, we find the member company OPS Composite Solutions (OPS) (NODE, 2020). The design freedom makes them capable of producing tailor-made solutions, and the work is therefore variable (Solutions, 2020). The non-repetitive work and tailor-made solutions make OPS a High Variety / Low Volume (HVLV) and make-to-order (MTO) company (Portioli-Staudacher & Tantardini, 2012). MTO companies that offer good design, flexibility, and short delivery times are winners in the industry (Olhager, 2003). Forza and Salvador (2002) believe that companies that offer purposeful products stains upon many difficulties in ensuring effective operation.

One of these difficulties is the flow of information. Puvanasvaran et al. (2009) emphasised that communication is a vital aspect and inseparable from the business environment.
In the earlier years, Warren (1985) expressed that being able to communicate what one knows is necessary to achieve real success in the workplace. Further, Le Vassan (1994) emphasised that effective communication is an added asset for the business sector to function in the economic network. As a result, in a modern organisation, the information flow is a vital element of the company's processes and product development (Eppinger, 2001). The information flow can be seen as the connections in a company, where every process, personal and equipment, are a part of the flow (Kroll et al., 2018, p. 207). The information flow is vital to stay fully connected along the value chain to create value for the customer (Porter & Heppelmann, 2015; Zangiacomi et al., 2020). This makes organisations critical dependent on information, knowing that wrong or defective information can cause waste. Thus, improving the information flow can yield significant benefits to all areas of an organisation and, importantly, its overall efficiency, competitiveness and responsiveness (Dietel, 2000; Hicks, 2007). As a result, Tomanek et al. (2020) stated that production companies can profit from moving from paper information to digitalisation. The digitalisation of information sharing (information technology) has enhanced the management of the information flow of mass-production companies (Richter et al., 2017).

With the increasing demand for customised products, the need for flexibility creates a necessary transformation in production processes, enabling a high level of connectivity and integration between business processes and systems (Fatorachian & Kazemi, 2018) across the value chain (Zangiacomi et al., 2020). Therefore, the manufacturing industry is evolving towards digitalisation. Adopting digital technologies in the Lean philosophy represents a novel paradigm. It initiates an industrial transformation in the business process (Agrifoglio et al., 2017). Much has been written about lean principles from mass production (Samuel et al., 2015), and questions have been asked about whether the philosophy can be transferred to HVLV companies (Jina et al., 1997). Tomašević et al. (2021) added that there had been a lack of effort in revealing how lean manufacturing can be implemented in HVLV manufacturing. Similar conditions appear, with an increasing focus on digitalisation of the mass-production by introducing the concept of Industry 4.0. As a result, the HVLV has been relatively overlooked, even though the benefits have mainly been demonstrated (Costa & Portioli-Staudacher, 2021). Hence, Olhager and Prajogo (2012) stated that MTO companies do not focus on digital technologies and the implementation of Lean. Hence, it has become a challenge researchers desire to solve (Buetfering et al., 2016; Katic & Agarwal, 2018). For this reason, this thesis will explore "*How can Lean principles and emerging digital technologies affect the HVLV-manufacturing environment?".*

1.2 Purpose and problem statement

Before the work on the master thesis started, a project assignment was written that dealt with Lean implementation in a case study which operated in HVLV-environment. The paper concluded that HVLV-environment has difficulties in implementing Lean. Nevertheless, several good tools are needed to provide desired development to achieve and sustain competitiveness. Reducing the adverse effects on the HVLV industry is considered extremely important to maintain the demand for customised products. When the work on the master thesis was to be formulated, the author had interested in possible concepts, lean and digitalisation. Even though the area of activity of the concepts is broad, it was exciting to look at both initiatives. Especially digitalisation has gotten much attention the recent years. At the start-up of the master thesis, it became clear that the information flow is an ever-changing process that is not addressed and emphasised enough in the manufacturing environment. Therefore, with the help of a case study, it was examined that highlighting and enhancing the information flow in the HVLV-environment is essential. This thesis investigates whether a digital transformation of lean principles and tools can improve the flow of information between the management and production and turn HVLV production to a competitive level. As a result, the thesis problem is chosen as:

How can a digital transformation of Lean principles and tools enhance the information flow in an HVLV-manufacturing environment?

The problem statement involves a comprehensive study and is therefore appropriate to concretise it with the help of research questions. Accordingly, two research questions have been formulated to answer the problem statement.

1. "*Do companies in the HVLV-environment have similar challenges in the information flow between the production and management?"*
2. *"How can a digital transformation of the Lean tools enhance the information flow?*

1.3 Research scope

The master thesis has been written for the department of Engineering and Science under the Faculty of the University of Agder (UIA) in Grimstad. The thesis was completed in the spring of 2022 under the subject IND590.

This study focuses on a specific manufacturing context representing several modes and manufacturing strategies, such as engineering-to-order (ETO) and MTO. These fall under the term HVLV (Buetfering et al., 2016; Katic & Agarwal, 2018). Further, it has been chosen to shed light on two different initiatives. Both initiatives have been well developed in mass production but are sparse in the HVLV production, which has led to opportunities and limitations in work. Both initiatives have been well developed in mass production. Still, they are sparse in the HVLV production, which has led to opportunities and limitations in work. Both Lean and digital technologies are in constant development, which has made it necessary to be up to date. Many stakeholders have studied these concepts, which made the collection of relevant data extensive. The database has, in part, appeared fragmented because the surveys often only cover specific parts such as mass production. Nevertheless, interviews, observation and comparisons with other schemes have done it possible to conclude the potential of the HVLV-manufacturer.

It was discovered early that Lean tools were initially more pressing in the HVLV-environment due to the complexity and advanced technology considered in digital technologies. In addition, this is a vast framework, which requires a broad data collection in order to be able to conclude. Based on this, the findings of the thesis are directed at lean tools and digital transformation used in the HVLV-environment, such as Value Stream Mapping (VSM), POLCA-cards, Last Planner (LP) System, Single Minute Exchange of Dies (SMED), 5S and Business Process Modelling Notation (BPMN).

The master's thesis was completed in 20 weeks (+1-week Easter). Due to the time frame, it has been necessary to make delimitations. Three distinct boundaries are set for the task. The first limitation is to examine HVLV-environment in the production industry. This is done because the research done in the HVLV-environment is sparse. It was considered appropriate to delve into this environment as the demand for customised products is rising (Strandhagen et al., 2018). The second limitation is the information flow, particular between production and management, was considered more specific and an essential aspect in the industry when the work on the master's thesis began. The third limitation was the detailed description of specific digital technologies. This was considered due to the extensive and advanced approach when exploring digital technologies.

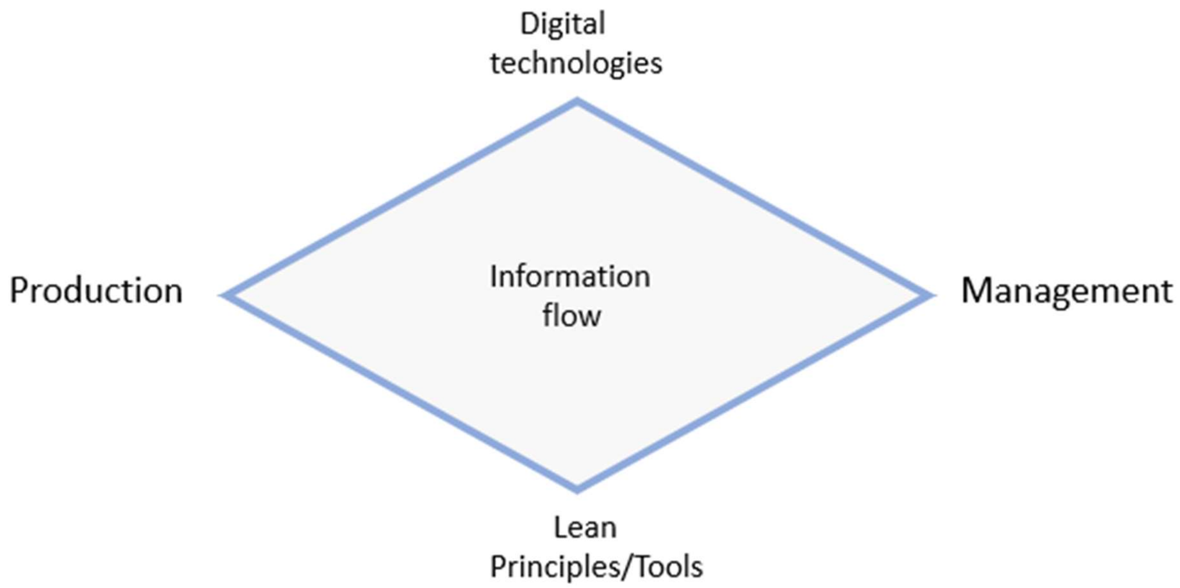

Figure 1. Focus areas of the study concerning covered research domains

1.4 Structural design

It is chosen to take the starting point in IMRaD-model for the thesis structure, presented in table 1 (NTNU, u.å.)

Table 1. Structural Structure

Introduction	Present background for and socially functional relevance for the chosen issue and research questions.
Theory	Explain concepts and theories that are relevant to the phenomena to be investigated.
Method and material	Describes the background for and the methods chosen to investigate the problem, including data collection, processing of data and strengths/weaknesses of the methods.
Result	Presentation of findings in information flow, lean and digitalisation.
Discussion	Discussion of the findings in connection with research questions and the overall problem.
Conclusion	Summarises the main findings of the thesis and answers questions and research questions.

2. Case description / Contextual framework

The research aims to identify opportunities for implementing a digital transformation of lean principles and tools to enhance the information flow. Hence, the case company will be described in this chapter. The case study is based on OPS Solution, a manufacturer of bespoke glass fibre products with a location in Kristiansand, Norway. The description is based on observations and information collected through interviews with informants. Further, the informants are referred to as interview objects 1-6 to provide anonymity. The knowledge about Lean in OPS is minimal.

2.1 The case

This thesis has been performed with the help of OPS. OPS is a manufacturer of composite solutions delivering products to land-based and offshore industries, such as aquaculture, oil and gas, and civil markets. Each product is unique and is either designed for the customer by the OPS engineering department or receives complete drawings. The volume of each product is low, usually ranging from one unique product to a group of a few products where the same mould is reused several times. An overview of their project progression is given in Figure 2.

Figure 2. Value chain at OPS Solution

Production is primarily based on project requirements planning (PRP) orders, i.e. specified orders from customers (Slomp et al., 2009). This leads to significant variation within the production line. Today they are behind the production schedule. This may be due to a weak control system, or the communication between the stations is not satisfactory. OPS wants to expand production, but first, control systems are required to ensure predictability in the completion of the projects and to ensure the divergent flow of information

OPS operates within several sectors. The oil and gas sector is well developed. The customers can often be large and rigid organisations with many requirements. On the contrary, they have the aquaculture industry, where many customers can be found in an entrepreneurial stage. It may be an entirely new product to the market, where the customer does not know what is required to bring the idea into reality. OPS delivers bespoke products customised for the customer's specific needs regardless of the sector. Nevertheless, they compete against manufacturers producing other materials, such as steel and concrete.

2.2 The production

The production is entirely according to customer requirements. Once the customer has accepted the production plan, production is initiated. The first step in all production is the design of the module. Then the module is winded. Once the module is winded, the product must be hardened and divided into two parts to remove the module. The product is then sent to the machining department for preparation of details. Finally, the product is glued together and made ready for shipping.

Figure 3. A simplified version of the production process at OPS

Employees in the production have different backgrounds and nationalities, causing cultural and linguistic barriers. In addition, a changing workforce and cultural differences cause additional challenges when implementing new changes in the manufacturing environment.

The manufacturing is based on stages where activities are performed in different sections in the facility. Depending on the production layout and size of the product, it moves from one section to another, where various activities are performed. It has been observed that people flow on the product and not the product on the people. The lead times are relatively long, with much non-value-added time. Several projects can run in parallel, and production may become chaotic during periods of high demand. It is expressed that the floor space is a bottleneck, which limits the work in progress.

3. Theoretical framework

3.1 Summary of the project-assignment

A literature study was conducted in the project assignment to explore the drivers and barriers to implementing lean in HVLV production. This was done by taking as a starting point in uncovering (1) drivers and barriers to carrying out the implementation of lean, (2) perspectives in the case study, (3) which lean tools can be adjusted to the HVLV environment and (4) the effect of this implementation. A wide range of factors was identified that affect lean implementation in the HVLV environment. Essential drivers are equal thinking, involvement of the entire organisation, adaptability and continuous improvement. Significant barriers are lack of financial resources, high investment costs, adaptability, and lack of knowledge and experience. Several instruments have been outlined to increase competitiveness, and these must be carefully prepared to give the desired effect. It is recommended to use a combination of instruments to minimise different barriers simultaneously (Buetfering et al., 2016; Womack & Jones, 2003).

3.2 High Variety and Low Volume (HVLV)

The manufacturing strategy representing the HVLV term is where product development, process development and production are natural and interconnected parts (Tomašević et al., 2021). In addition, project-based order-to-deliveries (Katic & Agarwal, 2018). According to Buetfering et al. (2016), it is related to a one-of-a-kind production with a low production environment. Often one-of-a-kind production brings high complexity, low volume and, in general, low demand (Strandhagen et al., 2018). In this segment, the customer seeks a high degree of customised product, which involves the customer in the earlier phase and is continuous (Birkie & Trucco, 2016). Additional, Hicks et al. (2001) stated that HVLV manufacturers only have the opportunity to produce when receiving a specific customer order. Due to exposure to high uncertainties and, in general, driven by cyclical demand. Nonetheless, there is no clear definition or scope of what constitutes HVLV. Thus, HVLV is defined differently in the literature. Some base it on the supply chain structures and Customer Order Decoupling (CODP) (Buetfering et al., 2016), while others describe it as non-repetitive manufacturing (Portioli-Staudacher & Tantardini, 2012). The manufacturing value chains can be categorised when looking at the COPD or Order Penetration Point (OPP). This refers to where in the value chain the customers are involved; see figure 4. HVLV is commonly divided into four stages: Engineering-to-order (ETO), Make-To-Order (MTO), Assemble-to-order (ATO), and Make-to-stock (MTS). The CODP in HVLV manufacturing is typically ETO or MTO (Olhager, 2003)

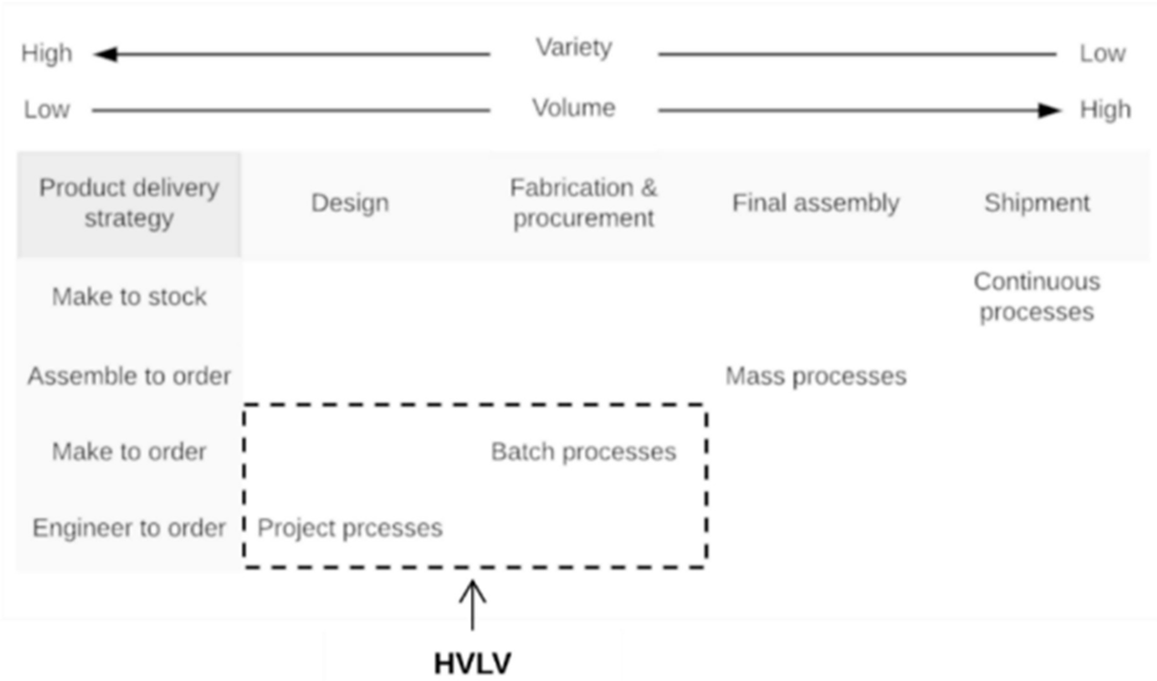

Figure 4. Types of production regarding CODP (Austefjord & Opsahl, 2020; Olhager, 2003)

Furthermore, the difference between ETO and MTO is distinguished by who is doing the engineering and design process, either the manufacturing or the customer, respectively (Amaro et al., 1999). MTO is defined as the customer delivering complete drawings for the manufacturing to produce, while ETO is when the manufacturing performs the engineering process. According to Jina et al. (1997), HVLV manufacturer is more prone to turbulence, whereas described "turbulence" has the variation and uncertainty regarding inputs within the manufacturing (Jina et al., 1996).

3.3 Information flow

When looking further into the HVLV environment, one can find the flow of information between actors, systems and machines. The literature has many definitions of information flow, but some were pointed out regarding the HVLV manufacturing environment. These are displayed in table 2.

Table 2. General overview of definitions of information flow

Definition of information flow	Source
Verbal, written, recorded, and computer data, whether it could be visual or not.	Muller et al. (2017); Thomas (1993)
A set of data semantics.	Lee and Lee (1999)
It can also require synergy between the modern organisation and computer systems, and viewed as a signal	Mentzas et al. (2001) Lueg (2001)

Interaction between humans and computer systems, a human-machine relation.	Hinton (2002)
Data and documents describe the communication between production and the control of the production process as well as between actors and the services of a company.	Alabdul Razzak et al. (2018); Durugbo et al. (2013)
The shared communication between a working team.	Stapel and Schneider (2014).
Information as communication is a part of information technology.	Sundram et al. (2020)
A substantial amount of the day-to-day communication in any business is spoken communication between individuals (face-to-face communication) or between individuals and a small group (committee work, oral reporting to a board, instruction given to a group of subordinates). Highlighted in a more modern aspect, it could also include the communication between machine-to-human	Little in Puvanasvaran et al. (2009)

As a result, one can consider the information flow as the movement of old or new value (information) between all actors, systems and machines. Furthermore, a vital aspect is the quality of the information, which impacts its reception and interpretation (Ballou et al., 1998). Therefore, poor quality information flow can be detrimental to the company (Kehoe et al., 1992). However, the quality of information can be separated into transparency, granularity and timelessness. Firstly, transparency describes the capability of workers to understand the information delivered to the concerned. Secondly, granularity refers to the level of detail of the information. Finally, the timeless describes the availability of information when required (Ballou et al., 1998; Durugbo et al., 2010; Hanafizadeh & Harati Nik, 2020; Tomanek & Schröder, 2017). The ever-increasing volume of information is driven by variety and diversity in this new world. Thus, the number of sources, tools, and methods for generating information increases (Hicks, 2007). Consequently, the HVLV-environment creates a massive volume of information, leading to poor quality and waste. Hicks (2007) evaluated the challenges concerning the information flow and elucidated four fundamental causes of waste.

1. Firstly, the information cannot flow because it has not been generated, a broken process, or a critical process is unavailable.

2. Secondly, information cannot flow because it cannot be identified and flow activated, or shred processes are incompatible.
3. Thirdly, excessive information is generated and maintained, or excessive information flows. Consequently, the most appropriate and accurate information is not easily identified.
4. Finally, inaccurate information flows result in inappropriate downstream activities, corrective action or verification.

Further, these four causes of waste give a corresponding type of waste (Hicks, 2007). Table 3 display these waste categories.

Table 3. Categories of waste in information flow

Waste	Description
Failure demand	The necessary resources and activities to overcome a lack of information. It also includes generating new information or acquiring additional information.
Flow demand	The time and resources are spent identifying the information elements that need flow.
Flow excess	The time and resources are necessary to overcome excessive information, i.e., information overload (Edmunds & Morris, 2000).
Flawed flow	The unneeded or inappropriate activities that result from its use.

Accordingly, resource flow or constraint is essential in production planning and scheduling (Koskela, 1999). Thus, Puvanasvaran et al. (2009) stated it is essential to use technical knowledge to explore a problem and suggest solutions. For that reason, one must be able to assemble information, analyse it as well as report the findings in such a way that it will lead to a more efficient procedure and better ways of doing things. (Puvanasvaran et al., 2009). Hence, the information status of these constraints is required throughout the task lifetime, starting from the production schedule process (i.e., when the task is planned). Then, to the make-ready process (i.e., when the constraints are removed). Lastly, up to the execution process (i.e., when the task is executed in the field (Dave et al., 2016). Therefore, the information flow is related to these activities and depends strongly on the project, supply chain, and information system (IS) type (Dave et al., 2016).

3.4 The development of Lean

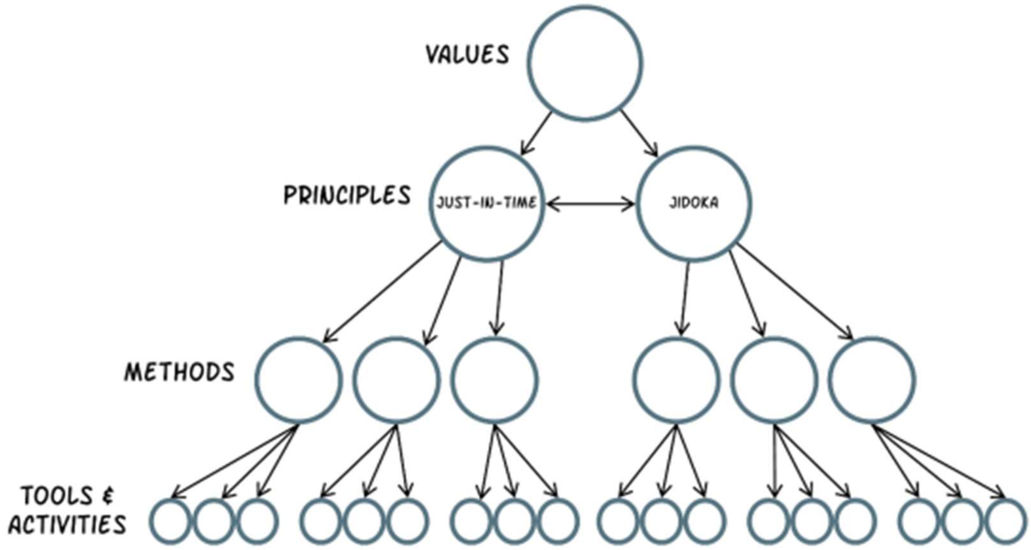

Figure 5. The hierarchy of the Toyota Production System
(Austefjord & Opsahl, 2020; Modig & Åhlström, 2012)

Over the years, the implementation of Lean has been rising. However, many companies have been struggling to understand the means of their industry (Womack & Jones, 1997), especially industries operating in the HVLV-environment (Bicheno & Holweg, 2016). Consequently, companies fail to recognise that Toyota Production System is not a toolbox but a philosophy. According to Modig and Åhlström (2012), it is a long-term vision philosophy where the result will yield when the right processes within this philosophy are followed. Hence, establishing Lean is not about implementing tools but a philosophy throughout the organisation. With this in mind, the difficulties appear when every organisation is and do different, which equals different needs. Thus, it is essential to recognise which elements contribute to emphasising the flow of information. As a result, Clegg et al. (2010) express the concerns around implementing the lean philosophy, where the lack of understanding could lead to myopic approaches to the situation. To avoid such situations, Lander and Liker (2007) suggested that creating a culture for continuous improvement was the key to achieving a lean culture and enhancing the business processes.

3.4.1 Lean in HVLV Manufacturing

Lean has earlier been perceived as not suitable for HVLV manufacturers. However, research has found that introducing lean in these environments has positively affected productivity (Birkie & Trucco, 2016; Jina et al., 1997; Powell et al., 2014). Nevertheless, the misconception is not without reason; the variation and uncertainty found in HVLV manufacturing have proven to cause challenges for lean implementation (Alfnes et al., 2016; Jina et al., 1997). Additionally, Buetfering et al. (2016) express that the research concerning lean in HVLV environments is still inadequate. Jina et al. (1997) stated three main obstacles to implementing Lean in HVLV manufacturers. First, the HVLV environment lacks a clear definition and scope of what it constitutes. Due to different volumes, complexity and various industrial structures, it is not easy to achieve a general strategy that embraces a consensus for all manufacturing structures (Austefjord & Opsahl, 2020). The second is that HVLV manufacturers are more prone to turbulence because of the high rate of bespoken products, contributing to higher variability and uncertainty of inputs and outputs. Lastly, the HVLV manufacturing system is exposed, which causes turbulence in the internal as well as outbound supply chain (Austefjord & Opsahl, 2020).

Moreover, according to Hines et al. (2004), lean can be separated into strategic and operational. The strategic level is about lean thinking, while the operation level uses lean production tools and methods. However, both emphasise the importance of understanding to achieve optimal lean implementation. When considering the information flow, the variability, complexity, and turbulence in the HVLV-environment provide the same challenges. Extracting the correct information, at the right time, in the right amount, is a difficult challenge, even in a stable environment (Alfnes et al., 2016).

3.4.2 Lean Thinking (HVLV manufacturing)

According to Womack and Jones (2003), "Lean thinking" is the philosophy of creating more exceptional value for the customer and eliminating waste.

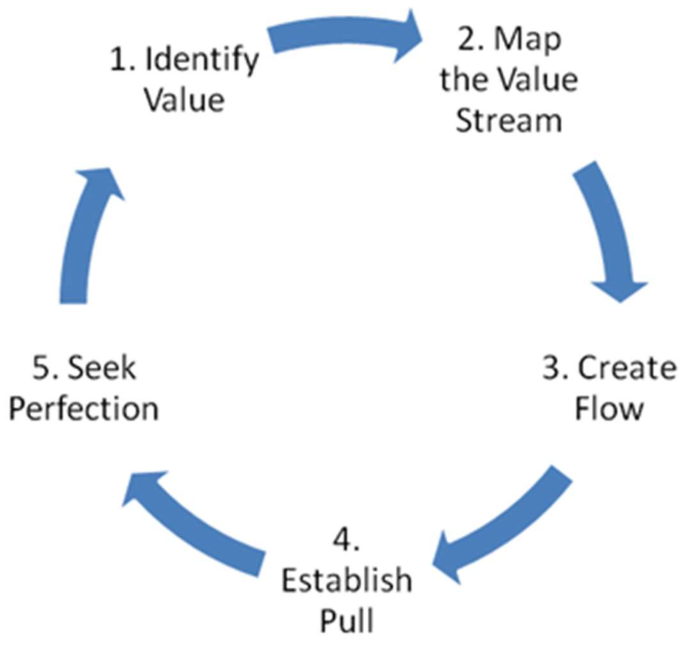

Figure 6. The principles of lean thinking (Womack & Jones, 2003)

The book of Womack and Jones (2003), *Lean Thinking*, has five principles;

1. Identify Value.
2. Map the Value Stream.
3. Create Flow.
4. Establish Pull.
5. Seek Perfection

These principles were created to provide a guideline for improving the work process flow, such as information flow and simultaneous creating customer value by eliminating waste (Buetfering et al., 2016).

Specify value

When specifying a value, often referred to as the value of the customer. However, in this context, the value is specified as the value in the information. Hence, according to Womack and Jones (2003, pp. 29-36), the base of lean thinking starts with a value that the end-user can only define. However, contradicting the definition of Womack & Jones, Powell et al. (2014) stated that the value of HVLV has to be extended to all major stakeholders. This is due to the complex end products in HVLV manufacturing, which creates a varied and undefined information environment.

Regarding the information flow, the value can be seen as the quality of the information transferred to the receiver. Further, Powell et al. (2014) express that customisation should be seen as a strategic source of generating value. Hence, it is vital to create a specified information flow that supports the flexibility inHVLV manufacturing.

Value stream

When the value is specified, one has to identify the value stream. The value stream has some different interpretations. For example, Womack and Jones (2003) stated that the value stream is all actions required to bring a product from the concept to the delivery of the customer. On the other hand, Rother and Shook (1999) express that all value-added and non-value-added activities are required for producing the product. When considering information flow, the definition of Rother and Shook (1999) makes it clear and transparent how to distinguish the information flow into value-added and non-value-added streams. Further, Womack and Jones (2003) proposed that all waste identified in the value stream should be challenged and improved to achieve a perfect system.

Flow

Next, the flow of the value stream needs to be defined. The literature defined flow by how the product and work progress from the beginning to the end. Accordingly, regarding how the information flows through management and production during the business processes, Womack and Jones (2003, pp. 21-24) express the importance of rearranging activities. The information can flow through the system with as little non-value creating time as possible to establish flow. Furthermore, both Jina et al. (1997) and Koskela (2000) emphasised building flexible and multifunctional work teams that quickly switch between tasks. The reason was to avoid hold-up problems due to the lack of skills to support flow in an HVLV manufacturer.

Pull

To achieve an optimal flow in HVLV-manufacturer, one must create a pull production (Buetfering et al., 2016). According to Hopp and Spearman (2004), a pull production is when the amount of work-in-progress (WIP) is limited within the production. Further, this means that no new product can be manufactured or processed before another product has been finished. Therefore, controlling the amount of WIP can contribute to a shorter lead time, more visibility and higher quality (Hopp & Spearman, 2004) and create a more defined and limited information flow (Buetfering et al., 2016). Based on this, the concept of pull is that work is released based on the status of the system (Bicheno & Holweg, 2016, pp. 15-16). There are three potential systems that Netland and Powell (2016, pp. 292-296) suggested being used in HVLV environments to create pull:

1. Kanban Cards
2. Constant work-in-progress (ConWIP)
3. Paired-cell Overlapping Loops of Cards with Authorisation (POLCA).

Further, Sugimori et al. (1977) presented three clear advantages of the Kanban cards:

(i) the cost of processing information was reduced,
(ii) the process for capturing and expressing the information in a dynamic environment was enhanced.
(iii) Lastly, the tasks for all units were synchronised.

However, the use of Kanban cards is set to be limited in HVLV. On the other hand, POLCA-system is considered to be more suitable for HVLV-environment and is based on the Kanban cards in the form of it is card-based as well as pull-motivated (Suri & Krishnamurthy, 2003). Therefore, POLCA-cards will be elaborated further in section 3.4.3.

Perfection

Lastly, and probably the most important, is the search for perfection. It originated from the well-known Japanese word "Kaizen", which contains the concept of "continuous improvement" (Austefjord & Opsahl, 2020). According to Liker and Convis (2012, p. 36), the concept of Kaizen is "*at the root of kaizen is the idea that nothing is perfect, and everything can be improved*". Hence, the mindset of Kaizen seeks continuous improvement at all levels of an organisation to achieve an everlasting effort to become better (Bicheno & Holweg, 2016, pp. 62-64). For this reason, Netland and Powell (2016, p. 291) emphasise the importance of daily continuous improvement activities to create a continuous process flow. In addition, another Japanese word that is a necessary term related to Kaizen is "Gemba". Bicheno and Holweg (2016, p. 15) described it as "*the place of action*". The interpretation is that the person operating the process has the best knowledge of improving it. Concerning the information, the operator would know the required and desirable information. Another term is the concept of breakthrough improvement, which includes significant improvements in processes (Harrington, 1995). Thus, significant recurring problems are solved by the direct allocation of resources. Figure 7 illustrates the difference between continuous and breakthrough improvements (Wang & Ahmed, 2003).

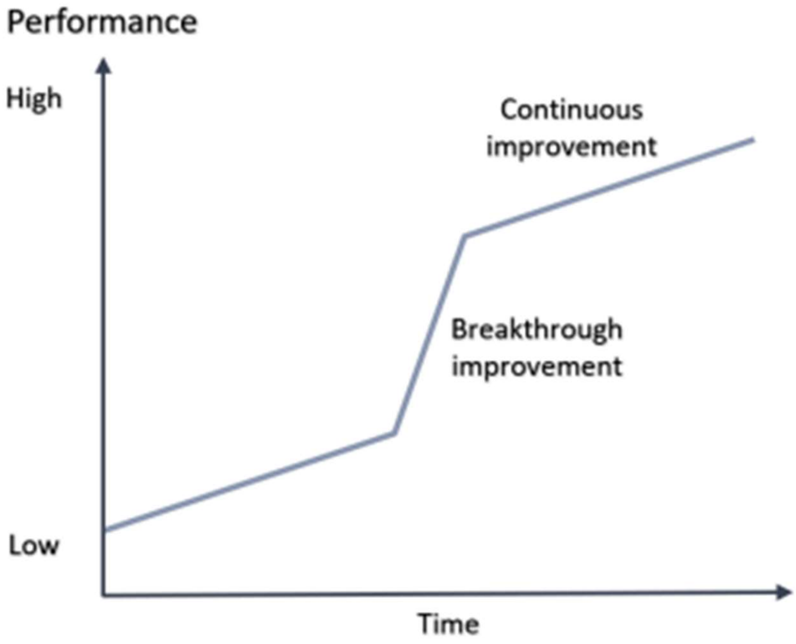

Figure 7. Difference between continuous and breakthrough improvements (Austefjord & Opsahl, 2020; Harrington, 1995)

Continuously seeking to learn as an organisation is profoundly related to continuous improvement. By having a learning culture, the organisation can quickly adapt to new changing situations (Nonaka, 2009; Wang & Ahmed, 2003). Furthermore, to optimise organisational learning, there should be a focus on creating a dedicated team culture. Every team member needs to work to learn and generate knowledge for the organisation to stay competitive (Wang & Ahmed, 2003)

3.4.3 Lean tools for the HVLV environment

5S

A well-known and used lean tool is 5S. The tool creates workflow in the workplace (Austefjord & Opsahl, 2020; Omogbai & Salonitis, 2017) by implementing a set of principles. These principles are set out of the five S's, which represent a step in the process: (1) Sort, (2) Set in order, (3) Shine, (4) Standardise and (5) Sustain. These steps involve going through everything in the production, deciding what is necessary and not necessary, then putting things in order, cleaning, and setting up procedures for performing these tasks regularly.

Bicheno and Holweg (2016, pp. 136-139) emphasise the importance of introducing the 5S correctly. Furthermore, an important aspect is to realise that it is a mindset to create a more organised working environment and not avoid a messy workplace. However, this implementation will not directly influence the information flow. Instead, it will create a better foundation for implementing other tools.

VisiLean

The following tool, VisiLean, is based on the Internet of Things. High abstraction-level communication interfaces are of the utmost importance to leverage inter-and intra-enterprise information systems (Dave et al., 2016). In other words, the purpose of VisiLean is to align or integrate functions with other systems at a high abstraction level to exploit systems within the organisation as well as systems with other organisations. Moreover, it is a superior tool that enables other tools, such as the Last Planner (LP) System or Value Stream Mapping. In addition, it visualises the production planning process (LP System workflow) and the one-to-one mapping of each task in the organisation (Dave et al., 2016). This visualisation improves planning reliability as the planning processes executed in LP System provide the most complete and up-to-date information on production in a single interface during planning and execution (Dave et al., 2016). In addition, visual controls and information in production support the "pull" based method by directly visually providing an interface. Hence, visual management, such as VisiLean, is built upon the principles of Kanban and Andon (Tezel, 2011). VisiLean creates a platform where the product information is updated in real-time to minimise the waiting time during processes and the reaction time if the status of the process changes (Dave et al., 2016).

Last Planner – Plan-Do-Check-Act

Further, planning an ever-changing and order-dependent production is a demanding task—nevertheless, a crucial aspect. Hence, implementing the Last Planner (LP) System could support this aspect where LP is a production control system for production management (Ballard & Tommelein, 2016; Øystese, 2019). During planning, more information is constantly obtained as plans unfold. Hence more detailed planning leads to more incorrect plans (Frandson et al., 2014). Therefore, the LP system can improve plan reliability by decomposing planning into specific processes with different levels of detail (Ballard, 2000). The system is divided into several sections and phases, where each section/phase has a particular purpose. Milestone Planning and Phase Planning aim to identify what, when, and whom (Ballard & Tommelein, 2016). The next phase is Look-ahead Planning which identifies potential work that can be done by including constraints for activities (Frandson et al., 2014). The next phase, Weekly work planning, is where what will be done and commences the production control (Emblemsvåg, 2014b). In addition, to control the progress in the processes, Percent Planned Complete (PPC) is used. PPC measures the per cent of activities completed as planned (Jünge et al., 2015) and is further used to measure reliability. Lastly, it will rise when commitments are made to the processes (Ballard & Tommelein, 2016). As a final phase, the Learning phase compares what was done against what was supposed to be done. This can help identify deviations and analyse them to learn and prevent reoccurrence (Øystese, 2019). Furthermore, techniques such as the five whys can identify root causes and countermeasures. In contrast, Plan-Do-Check-Act (PDCA) is used to test the effect of the countermeasures (Ballard & Tommelein, 2016). Nevertheless, Emblemsvåg (2014a) stated that LP systems cant handle advanced engineering design.

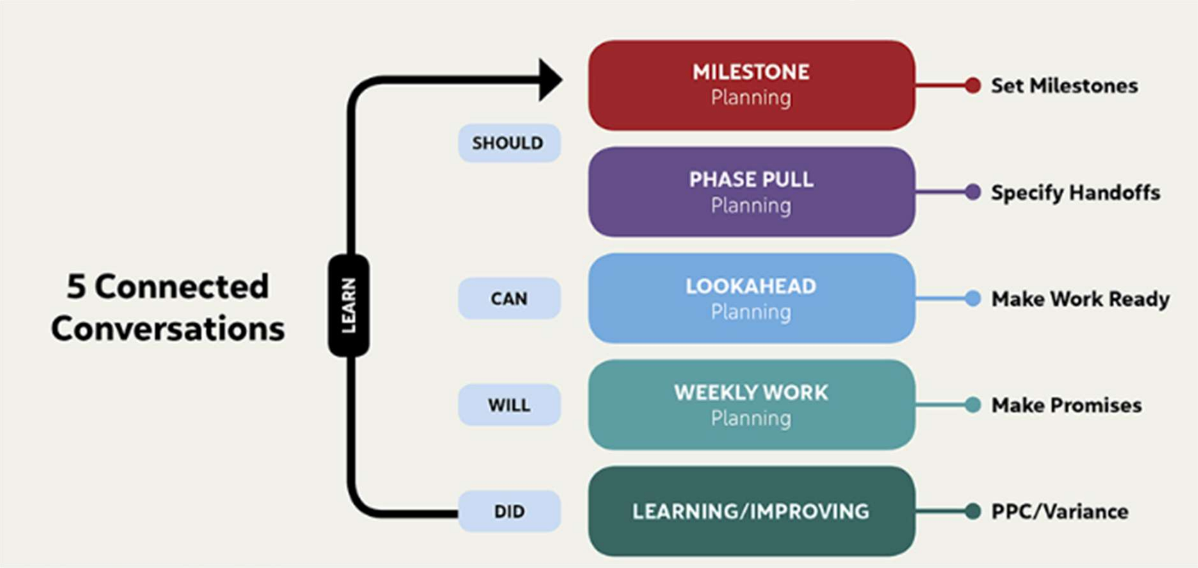

Figure 8. The Last Planner overview.
(Casey, 2018)

Business Process Modelling Notation

As an aid to LP, Business Process Modelling Notation allows the identification, analysis, and specification of business processes (Aguilar-Saven, 2004; Awadid, 2017) and characterises the flow between the internal environments of a company (Ouali et al., 2016). In connection with this, BPMN 2.0 arises, according to Chinosi and Trombetta (2012), as an understandable modelling notation that shows the properties and execution information of the process as well as a graphical readable language. Using graphical notation such as BPMN makes it easier to identify the location of inefficient information flows (Arromba et al., 2019). The purpose of BPMN is to support business process management for the internal environment in an organisation by notation models the steps of a planned business process from beginning to end (Chinosi & Trombetta, 2012). Furthermore, it is a visual modelling language that allows the notation to be graphical and visualise the information flow between actors and processes in the business workflows (Arromba et al., 2019).

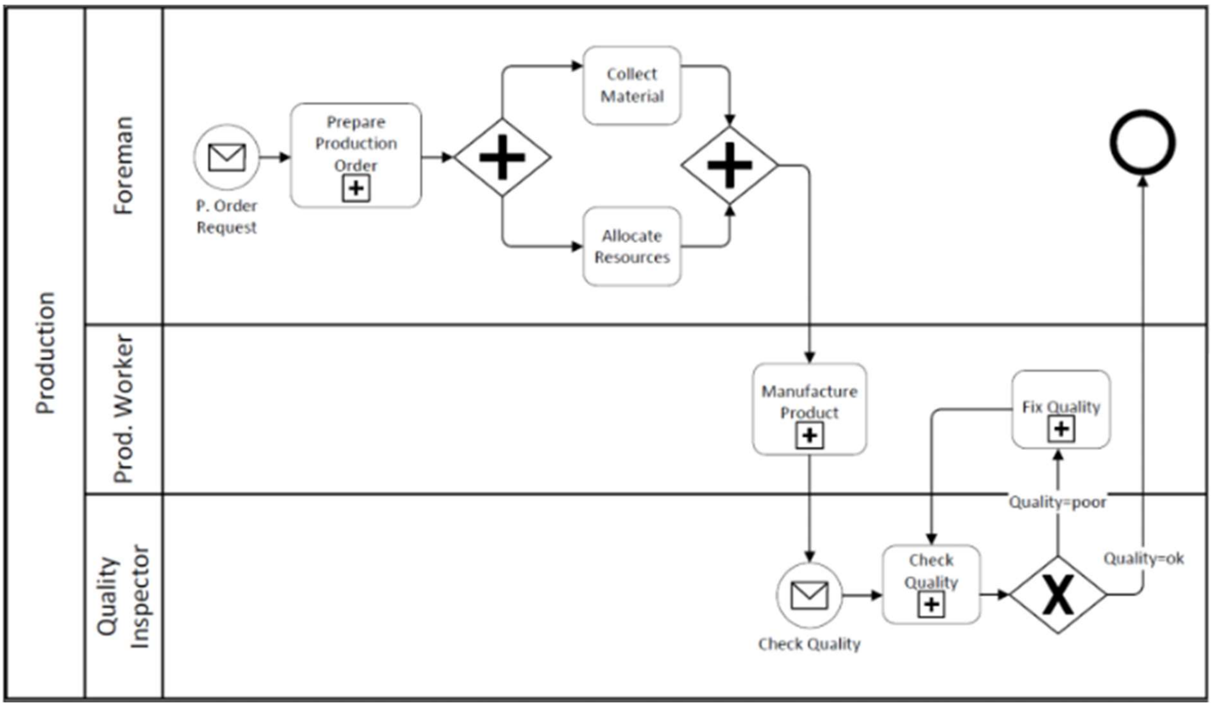

Figure 9. An example of a business process modelling notation.
(Lodhi et al., 2018)

POLCA-cards

A tool that affects the activities of the production is POLCA-cards. Suri and Krishnamurthy (2003) convey that POLCA-cards are a suitable version of Kanban cards to be implemented in the HVLV-environment. A POLCA-system is based upon the Kanban system, a card-based and pull-motivated system (Suri & Krishnamurthy, 2003). It focuses not internally at each station but between stations. Hence, minimising the interface between stations is vital to keep the company competitive. The potential lies in a precise and well-defined production process - an exact statement of where one lies in the process and production line. Another aspect is that by involving digitisation, such implementation can make it possible to visualise the process and statement. POLCA-cards can be a method that ensures that the station only works with components which shall further in the production line in the nearest future. However, POLCA is a capacity signal and not an inventory signal, which further emphasises the information flow by showing which station has free capacity. Also, Suri and Krishnamurthy (2003) communicated the scope of POLCA-cards is more extensive and more flexible between stations. If implemented completely, communication, better planning, and work-in-progress control benefit POLCA (Buetfering et al., 2016; Suri & Krishnamurthy, 2003).

Single Minute Exchange of Dies

Another tool that affects production is the Single Minute Exchange of Dies (SMED). SMED is a tool that focuses mainly on identifying internal and external activities (Ulutas, 2011). Hence, SMED is mainly concerned with minimising internal activities and transferring as many as possible to external activities. In other words, the purpose of SMED is to minimise the changeover or setup time in the process (Ulutas, 2011). For example, in HVLV-manufacturing, the time it takes to change the production is vital due to the non-added value process. Thus, SMED creates explicit and defined information and processes on how the changeover or setup should occur (Ulutas, 2011). As a result, this will enhance how the production can convey how and when the production is ready for the following value-added process. Additionally, the information that will soar through the company during a changeover or setup time could often be indistinct and overloaded.

Value Stream Mapping

Perhaps the most used lean tool is Value stream mapping (VSM). Likewise, it is considered the starting point of the lean implementation process (Hartmann et al., 2018). The tool is a lean manufacturing technique to analyse, design and manage the flow of materials and information required to bring a product to a customer (Rother & Shook, 1999). Furthermore, it is a tool to help understand material and information flow by employing a flowchart documenting every step in a process (Rother & Shook, 1999). VSM is a fundamental tool for identifying waste, reducing process cycle times, and implementing process improvement. However, due to operating in a turbulent environment, the flow is disrupted by variation, which creates some challenges for implementation in HVLV manufacturers (Alfnes et al., 2016). Thus, Jina et al. (1997) specified that when the system's turbulence increases, it becomes more challenging to implement VSM.

Consequently, Alfnes et al. (2016) emphasised that the turbulence has to be reduced to a moderate level, even for a modified version, to be applicable. A fundamental concept in mapping repeatable production and flow is takt time (Bicheno & Holweg, 2016). However, the concept is based on creating a fixed pace by regulating the production relative to the available work time divided by demand (Slomp et al., 2009). Hence, the concepts become problematic when considering the HVLV environment due to high turbulence. As a measure, Alfnes et al. (2016) communicated the possibility of establishing a pace based on more extended periods. With the base of Alfnes et al. (2016) statement, takt time is considered the rate at which the process needs to complete the required information to meet the end-users demand. In addition, digitalisation can enhance the VSM through the real-time collection of data (Meudt et al., 2017; Mrugalska & Wyrwicka, 2017). The digital version of VSM was introduced by Meudt et al. (2017) as "Value Stream Mapping 4.0". The method mainly focuses on information logistics and uses it for detecting waste in the information flow.

Further, a real-time VSM system can automatically create value stream maps by automatise data collection. As a result, this will help to reduce both the time spent on collecting data and the probability of error. Also, it will create a dynamic visual picture of the shop floor. Thus, it will enhance the visibility of the information and supply the management or decision-makers with accurate and real-time information (Hartmann et al., 2018; Hicks, 2007).

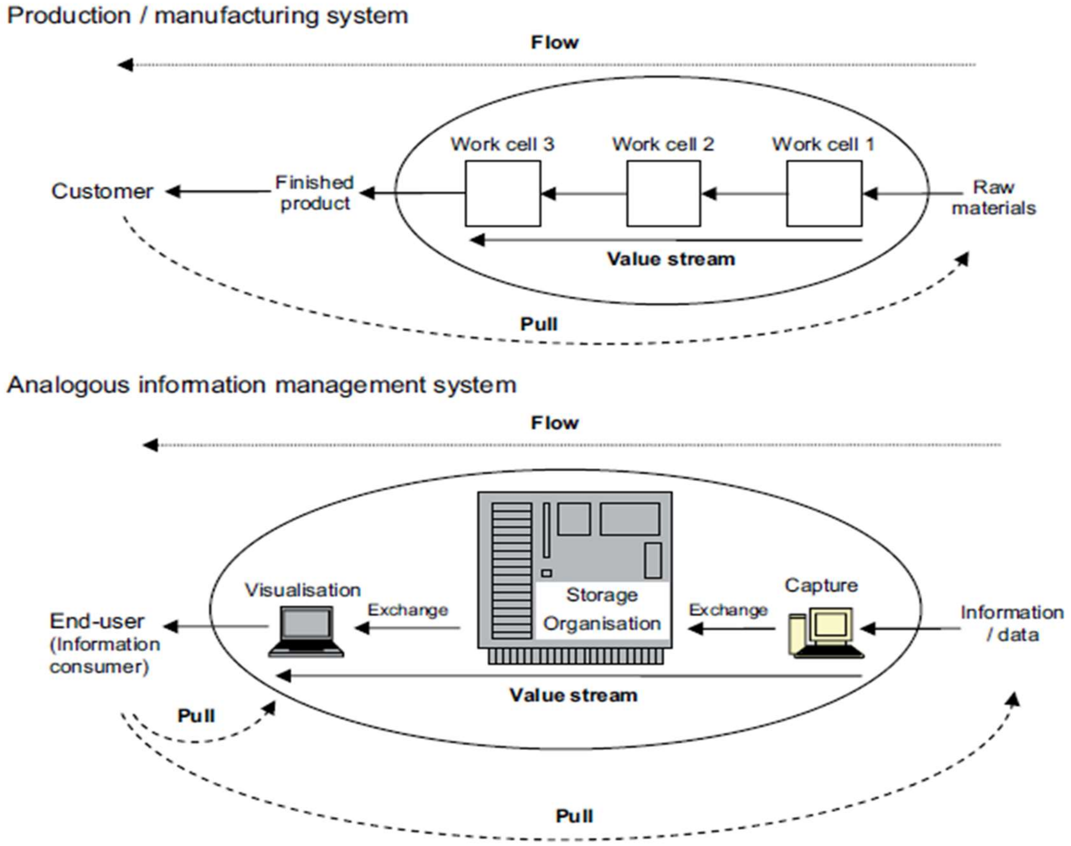

Figure 10. The value model for the production and management (Hicks, 2007)

3.5 Digitalisation

Digital has become a significant factor in recent years. The development and interest in the digital approach have increased rapidly. This has led to the transformation of digital companies and digital solutions. This increased digitalisation of manufacturing operations has created an expectation to cause disruptive changes in industrial manufacturing (Buer et al., 2021). The purpose is to facilitate new and more efficient processes, products and services (OECD, 2017). In addition, it has been expected to achieve significant changes in organisational structures, business models, supply chains, and the manufacturing environment (Hahn, 2020; Lasi et al., 2014). Furthermore, Buer, Fragapane, et al. (2018, p. 1036) commented that digitalisation of production could be defined as “the use of digital data and technology to automate data handling and optimise process”. Hence, digitalisation is mainly related to autonomous collection, analysis and the interconnection between products, processes, and people (Buer, Strandhagen, et al., 2018; Pfohl et al., 2017; Sjøbakk, 2018).

Furthermore, the digitalisation of the production floor is creating context-aware systems. Additionally, it supports people and machines in executing production activities by utilising information from the physical and the digital or virtual world (Zheng et al., 2018). Thus, providing production floor digitalisation creates a vital link for integrating the physical components and resources with the digital world and information processing. As a result, the field of Information and Communications technology (ICT) encompasses technical devices. These devices can convert digitally, process, store and transmit information, any data exchange and communication (Kolberg et al., 2017; Meissner et al., 2018). In addition, machines and production objects are more frequently interlinked, and humans are taking over the planning and monitoring activities. Also, the communication between machine-to-machine and human-to-machine gained a more prominent aspect of the literature and practitioners' attention (Hoellthaler et al., 2020). In addition, a general design principle for flow is 6r-axiom. It applies to all logistics objects likewise information (Hoellthaler et al., 2020). Thus, in terms of information, the 6r-axiom demands digital technologies to provide the right information, at the right time, at the right place, in the right amount, with the right quality, and at the right costs (Hoellthaler et al., 2020).

3.5.1 Information System infrastructure

An essential aspect of digital transformation is the digital infrastructure - which creates the foundation of digital development and other digital implementation. The digital infrastructure can be considered an IS infrastructure. The IS provides the systems and processes that are the base for the company's operations. Therefore, it is fundamental for the foundation and success of any company (Buer, Strandhagen, et al., 2018; Hicks, 2007). IS could be referred to as a range of technologies and devices, systems and applications, conventions and standards that the individual user or the collective rely on to work on different organisational tasks and processes (Buer, Fragapane, et al., 2018; Hicks, 2007). Moreover, it may include various IT, hardware, and software systems.

From an organisation's perspective, managing the information ensures that valuable information is acquired and applied to its fullest extent (Dietel, 2000; Hicks, 2007). But on the other hand, if the systems or the software application are not well aligned with the company's values and the IS infrastructure, it can have a significant detrimental effect (Hicks, 2007).

3.5.2 Data-driven information process

Digital technology uses computer technology methods and tools to replace or streamline manual or physical tasks. In other words, digitalisation is to facilitate the generation of digital information as well as the handling and utilisation of the information using information technology. ICT system is an information technology that consists of hardware, software, data and the operator(s). It contains digital technology to enhance regular, everyday tasks (Buer, Fragapane, et al., 2018). However, a "by-product" of such transformation and solutions is a large amount of unstructured data. Such data contain vital information as well as waste. The purpose of digital technology is to handle a large amount of unstructured data because of the capability to discover patterns and analyse the data. Thus, a data-driven information process is essential for converting the flow of information into a digital stage. On the other hand, it can be compared with the six sigma and be seen as an adjustment to the information flow. The data-driven information process can be divided into five steps (Buer, Fragapane, et al., 2018).

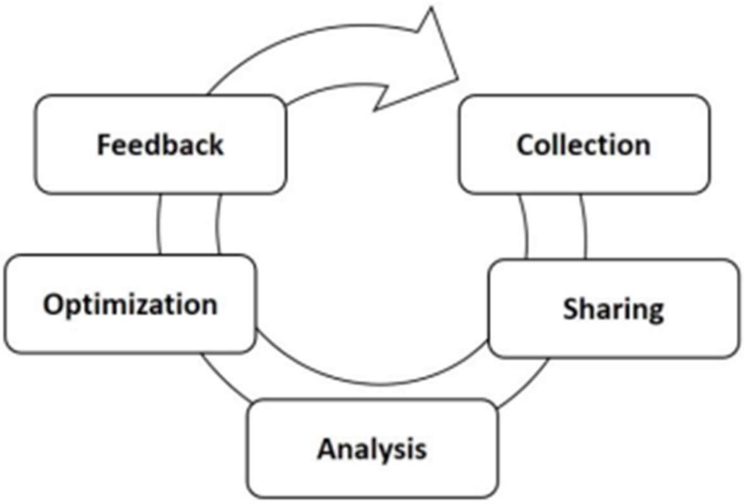

Figure 11. The data-driven process (Buer, Fragapane, et al., 2018)

1. Collection
2. Sharing
3. Analysis
4. Optimisation
5. Feedback

Collection

The collection of data is the foundation and a fundamental process. Because without data, the decision-makers have no baseline. Hence, collecting data is an essential process in every organisation. In HVLV-environment, data is collected sporadic, periodic or continuous and appears in both physical and digital formats as well as collected with or without human intervention. When obtaining the data input, it is transformed into shareable data (Buer, Fragapane, et al., 2018).

Sharing

When the data is collected, the next phase is to share the data. It involves sharing the data with the right actors that will process this data further, ranging from paper-based documents between people to digital transmission between a machine and the IS. With the advancing technology, the possibilities of sharing data have increased connectivity and data sharing velocity, leading to higher data availability (Gantz & Reinsel, 2011; McAfee et al., 2012). In other words, the sharing step describes how the data is exchanged between different actors (Buer, Fragapane, et al., 2018).

Analysis
When the right actors have retrieved the data, the data analysis starts. This phase concerns the process of data inspection, cleaning, transforming, and modelling in order to discover useful information. During the analyse, the data goes through the first quality control (inspection) regarding whether the data can be read in the first place or not. After that, data cleaning checks the data for errors in terms of completeness. As a result, identifying and removing errors and inconsistencies improves the data quality (Rahm & Do, 2000).

Further, the transformation is to find a deterministic mathematical function for each point in a dataset. Then, finally, the data object and its relationship to other data object as analysed in the data modelling. The modelling process starts by developing a conceptual model specifying how data relate to each other and then transferring to a mathematical model (Rahm & Do, 2000).

Optimisation
When the data is analysed and the relationship is discovered, the data is adjusted. The optimisation phase is an adjustment process of changing a specified set of parameters to find an optimal or near-optimal solution without violating any restrictions (Rothlauf, 2011). The mathematical model established in step 3 is the basis of the optimisation process. The optimisation algorithms are getting more advanced, increasing the solution quality and considering the information quality. Nevertheless, the basis of deciding is the result of the optimisation step. Further, it must be integrated back into the system (Buer, Fragapane, et al., 2018).

Feedback
The result and collected information from the previous step are transformed, shared, and implemented in order to ensure feedback on the process. In addition, this step ensures that the information collected and transferred further has the required and desirable characteristics.

3.6 Summary of literature
Lean is a vague concept which is interpreted differently depending on the setting. Also, with the rapid and enormous development of digital solutions, one has to be up to date. As a result, an extensive literature has been reviewed concerning the use of Lean and digital solutions in several environments dealing with high variety and low volumes of productions. For that reason, to find out how it can be applied in OPS. The summary is presented in table 4. Also, the result from the literature are then complimented with the findings from OPS in section 5

Table 4. Summary of the literature

Topic	Literature	Source
Information flow	A vital aspect is the quality of the information, which impacts its reception and interpretation.	(Ballou et al., 1998)
	Information volume is driven by variety and diversity, where the number of sources, tools, and methods for generating information increases.	(Hicks, 2007)
	Four causes of waste give a corresponding type of waste: Failure demand, Flow demand, Flow excess, and Flawed flow.	(Edmunds & Morris, 2000; Hicks, 2007)
Lean in HVLV	HVLV manufacturers often contain a distinct setting, which implies a lack of understanding of Lean philosophy.	(Lander & Liker, 2007)
	Turbulence from variation and uncertainty may restrict some aspects of Lean.	(Alfnes et al., 2016; Jina et al., 1997)
	The research on lean in HVLV manufacturing is encountered to be insufficient.	(Buetfering et al., 2016)
Lean thinking	Lean thinking aspires to develop a more excellent value for the customer while simultaneously eliminating waste.	(Womack & Jones, 2003)
	Lean thinking is said to arise from repetitive high-volume manufacturing. Some have critiqued the concept of not being eligible for manufacturing with high variation.	(Hines et al., 2004; Koskela, 2004; Powell et al., 2014)
Value	The perspective of the ultimate customer is viewed to be the value in Lean. As a result, it has been expressed a need to expand the principle to include all major stakeholders.	(Netland & Powell, 2016; Womack & Jones, 2003)
	Variation from customisation should be seen as a strategic source of generating customer value in HVLV manufacturing.	(Netland & Powell, 2016)

Value stream	A value stream consists of all value-added and non-value-added activities.	(Womack & Jones, 2003)
	Value streams in HVLV are prone to variation and iterations between different processes.	(Netland & Powell, 2016)
	The application of VSM is restricted by turbulence.	(Alfnes et al., 2016)
Flow	Turbulence from variation and uncertainty in the value stream creates challenges for continuous flow.	(Alfnes et al., 2016; Jina et al., 1997)
	Focus on building flexible and multifunctional work teams that can switch quickly between tasks to avoid hold-up problems due to lack of skills.	(Jina et al., 1997; Koskela, 2000)
	Rearranging activities such that the information can flow through the system with as little non-value creating time as possible to establish flow.	(Womack & Jones, 2003)
Pull	Pull means that the amount of WIP is restricted within the production.	(Hopp & Spearman, 2004)
	Visual POLCA boards can be used in HVLV manufacturing as pull systems.	(Suri & Krishnamurthy, 2003)
Perfection	There are two types of improvements: continuous and breakthrough. Both are essential in the concept of Kaizen.	(Harrington, 1995; Netland & Powell, 2016)
	A strong team culture should be formed where knowledge can be shared between the members to optimise learning.	(Wang & Ahmed, 2003)
	The information must be redundantly flowing in the organisation to create new knowledge.	(Nonaka, 2009)
Tools and methods	An important aspect is that tools and methods should be applied with caution. They should be selected or designed to the principles and consequently not as a quick fix.	(Lander & Liker, 2007; Skaar, 2019)

	There is a shortage of HVLV-specific tools.	(Netland & Powell, 2016)
Digital solutions	This increased digitalisation of manufacturing operations has created an expectation to cause disruptive changes in industrial manufacturing.	(Buer et al., 2021)
	Digitalisation is mainly related to autonomous collection, analysis and the interconnection between products, processes, and people.	(Buer, Strandhagen, et al., 2018; Pfohl et al., 2017; Sjøbakk, 2018)
	Data-driven information is essential for converting the flow of information into a digital stage.	(Buer, Fragapane, et al., 2018)

4. Methodology

This chapter presents a scientific theory about the method in research projects. Also, it explains the methodical choices made in the thesis. According to the master thesis, the work is divided into four parts: case study, literature review, interviews, and observation. The procedure for these methods will be presented below.

4.1 Research design

Scientific research is a way of presenting clear answers to problems. Research design can be used in multiple areas, such as finding rules, testing and discussing finding or collecting objective data (L Mitchell & M Jolley, 2010, p. 3). Research design is used to give a systematic presentation of data, such that it is possible to discuss and conclude within a problem statement or hypothesis. Research design starts with deciding which methods should be used to collect and analyse data.

4.1.1 Choice of method

There are many methods of collecting data to answer a problem statement. Hence, the choice of method must be justified based on the problem statement (Dalland, 2017, p. 225). In research, one distinguishes between two methods, qualitative and quantitative.

Qualitative methods aim to capture opinions and experience, which is challenging to measure or quantify (Dalland, 2017, p. 52). Thus, the method best clarifies what lies in characterising a phenomenon or term. This applies if there is restricted available knowledge about the phenomena to be examined (Jacobsen, 2005, p. 131). Further, The advantage of the qualitative method is the little restriction on what data can be collected. Besides, it shall present a phenomenon or answer a problem statement "correct", such that it represents the real world. The qualitative approach is also a flexible method with iterative processes. In this way, the problem statement and method can change along the process (Jacobsen, 2005, p. 128), which is helpful if one investigates a new or unknown phenomenon.

On the other hand, a downside of qualitative methods is that they are often resource-demanding and can collect a large amount of information. The collected data often has high nuance richness and can present as complex. In addition, the data can often be built on a few respondents. In that way, it can be challenging to draw generalisable conclusions. Another aspect is the danger of getting a "research effect" with qualitative methods. The actual survey affects the findings from the studied phenomena and hence the results (Jacobsen, 2005, p. 130).

Quantitative methods give data in the form of measurable findings (Dalland, 2017, p. 52). The method is suitable for examining a phenomenon that is already known and when one has a clear problem statement. The reason is that the examinator needs to know what kind of data and how it shall be categorised before starting the data collection. Further, the quantitative method best describes the frequency or scope of phenomena (Jacobsen, 2005, p. 134). Quantitative methods benefit from standardising and structuring information, making it easier to process. Often the method is also less laborious and makes it easier for respondents to participate, making the possibility to generalise the result bigger (Jacobsen, 2005, p. 132). A potential pit with the quantitative method is that it could present a result with a superficial touch. By measuring simple conditions that are standardised, we can miss out on nuances in the data. Also, a danger that the examiner has decided which relevant factors to get answers to before the examination starts. Quantitative methods are also more rigid and give less room for flexibility compared to qualitative (Jacobsen, 2005, p. 133).

This thesis has been chosen based on a qualitative case study according to Hartley (2004), Yin (1994) and Gripsrud et al. (2016)**.** The choice is justified by Yin (1994) article, which states that case studies seek a deeper meaning and understanding of actual circumstances in an organisation. To answer the problem statement, one needs to explore the possible influences of two different initiatives, which both are new and, to a small degree, studied previously. The qualitative method allows performing a thorough analysis of a field. Also, the method's flexibility has permitted the thesis to change and elucidate along the process. Further, this has been extremely useful since significant associations have been exposed during the data collection. In addition, the thesis aims to capture expectations and attitudes which necessary cannot be quantified.

Further, a design triangulation has been used to ensure theoretical and statistical generalisation. In design triangulation, one combines an intensive case survey with an extensive sample study. There are two different methods: case study before sample study and sample study before case study. In this thesis, it was conducted a case study before the sample study, where one uses the "close to reality" description to get a good understanding of phenomena and their connection. After that, this knowledge is used to test out if these findings exist in a larger context. The reason was to use the strengths in one survey design to compensate for weaknesses (Jacobsen, 2015, p. 121).

4.1.2 Method triangulation

A vital balancing with research work is if one shall utilise existing data or accumulate new data in the field (T Thagaard, 2018, p. 53). Method triangulation is an easy way of validating the results. Further, this involves using several approaches of methodological angles to answer the problem statement. Further, this qualitative research method is used to create credibility. Suppose one gain the same results with different approaches; its strengths are the validity of the result(Jacobsen, 2005, p. 216). Also, triangulation reduces the risk of bias, which can occur if one only uses one method. As a result, this protects the author from being accused of only using one method or the author's bias(Bowen, 2009). The thesis uses several methods to illuminate the problem statement, both through existing data and data from the field. This is done to collect and capture data from different areas and respondents with variable knowledge about the studied phenomena.

In addition, by triangulation, one desires to study if there is some agreement across disciplines or not. Figure 12 illustrates the thesis method triangulation.

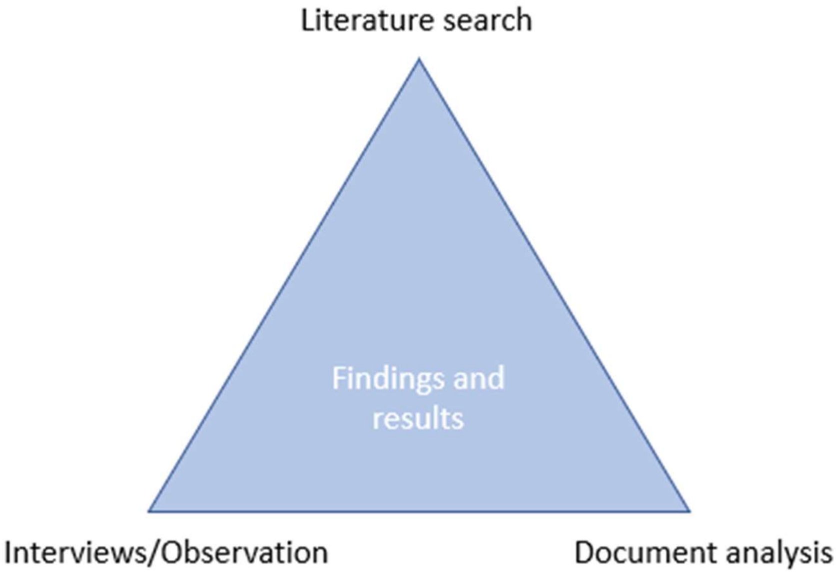

Figure 12. Master-thesis method triangulation

4.1.3 Validity, reliability, and objectivity

Research work needs to secure validity, reliability, and objectivity to have high credibility. Validity is how one can draw valid conclusions from the research. It is done by explaining the decisions made along the way and explaining that the research is transparent (Tove Thagaard, 2018, p. 200). Furthermore, the collected data must be quality assured to ensure validity. Reliability shows if the research is credible and trustworthy (Dalland, 2017, p. 55). Hence, one can achieve reliability by explaining how the data is collected and showing possible sources of errors. In addition, it can be strengthened by giving insight to the reader about the motivation behind exploring the chosen data (Dalland, 2017, p. 55). Objectivity concerns that the research and results are presented in a transparent and verifiable way. Additionally, one must consider that subjective conditions can affect the sources of the information collected. Thus, one can compare objectivity with being impartial (Tjora & Tjora, 2021, p. 263).

4.2 Literature review

A literature study is known as qualitative research. Also, it is a suitable method for giving an overview of the present research within a field or uncovering further research needs (Tjora & Tjora, 2021).

4.2.1 Search engines

Further, several search engines were used to find relevant literature for the literature study. It is possible to use Boolean operators to minimise the search in all search engines. Operator "OR" has been used to widen possible hits. Also, the operator "..." is used to achieve results containing the exactly written phrase. Finally, the truncation mark (*) is used to achieve different variants of the word (Skriv, 2022)

Web of science

The search engine has a large amount of data, which allows considering articles through statistics to the article, author(s), and publication. In addition, it is many possibilities to limit the search. These characteristics make it a good search engine for an overview of the theme. An independent board elects the database content.

Google Scholar

The second search engine contains articles, books, dissertations, and other literature. Google Scholar is a valuable search engine because it gives a high number of results and ranks these after where it has been published, who the author(s) are and how many citations it has. It also has different tools to exclude or include results, such as the time of publication (Scholar, u.å.). On the other hand, a weakness of this search engine is the lack of distinction between peer-reviewed articles and not. It could also be problematic that the search engines are too wide in the search and prevent finding relevant literature.

Oria

The last search engine gives access to all the collected resources from the UIA university library, electronic or paper-based (Unit, 2020). Oria can delimit peer-reviewed articles, which is helpful. Further, it has several filters to delimit the result, such as language, time of publication, medium type and faculty.

4.2.2 Selection of literature

Academic articles

A challenging process was finding academic articles that explicitly review the use of lean and digital technologies in the information flow. Another aspect is that both phenomena have been developed and revised over time. Therefore, the danger of articles that review the phenomena is already outdated. However, articles in scientific journals have an editorial staff that should ensure the given publication's quality. Additionally, they get independent professionals to ensure that the article has the required standard (Dalland, 2017, p. 154). Nevertheless, articles in this literature study are all collected from peer-reviewed journals and ensure that the impact factor is greater or equal to one. The Impact factor is a number that shows the average number of citations in a journal and is calculated on behalf of the previous years (Oslo, 2019).

Snowball method

Further, “backwards snowballing” and “forward snowballing” were used. The “backwards snowballing” is a method where one goes into the reference list on the literature collected to find more articles that may have explored relevant aspects of the thesis. The “forward snowballing” is when one finds newer literature by looking at the literature cited in the chosen article (Wohlin, 2014).

Constriction
In order to avoid overload with articles, a constriction process was performed. However, some originating articles have been used. The rationale for using older literature is because the literature originates from these articles as well as a large number of citations. Consequently, the widespread of articles are chosen to achieve the originated articles of fundamental aspects as well as the newer input and state-of-art literature. As such, the background for the concept design has to be built on updated information as well as reflect the newest findings in these fields. For example, the use of Lean has been reviewed many times; however, the review in the HVLV environment is sparse.

Further, it has been reviewed a significant amount when considering digital technologies. Still, the overall has left many definitions and interpretations. In addition, the specific direction of lean and digital technologies in information flow has not been researched to the author's knowledge. So, therefore by combining Lean and digital technologies regarding the information flow, the research direction has been concrete and specific.

4.2.3 Validity, reliability, and objectivity
Securing the selected articles has emphasised several aspects that make the information reliable, among other things, by using peer-reviewed journals and considering the impact factor. In addition, it is important to use information that is not outdated or does not originate from the rudimentary articles. Thus, such an attempt to shed light on today's attitudes and practices. The selected articles are considered valid by filling in or embroidering definitions, methods or trends that give essential background information to discuss the potential of the effect of lean and digital technologies. Keywords and content were assessed to the extent the research article has been cited further to ensure that the chosen literature is relevant and trustworthy. A point that weakens the validation of the literature dealing with lean and digitalisation is that the articles have not been reviewed in the information flow, making the discussed theme in this article a hypothesis. In addition, it has been pursued to use different search databases and variants of search phrases as well as delimitation to ensure that the literature is the most suitable to ensure objectivity. Further, it is also focused on presenting the collection of literature in a verifiable manner.

4.3 Interviews
Another method to collect data was an interview. Briefly said, interviews "aim to collect qualitative knowledge, express with normal language" (Dalland, 2017, p. 68). In this thesis, open, individual interviews have mainly been conducted. Hence, six interviews were conducted in OPS Solutions and three with other companies, so nine interviews.

4.3.1 Interview form and interview guide

When conducting an interview, the approach is to determine the topics but ensure flexibility to formulate questions along the way and follow up on topics the interview objects talk about but which are not planned (Tove Thagaard, 2018, p. 91). The method was chosen with the background that both Lean and digitalisation have sparse literature research. Also, it was relatively unknown to the authors at the start of the process. In addition, there was varying knowledge about the phenomena of the interviewees. Thus, there was a high probability of topics in the interview process that had not been captured. Further, the interviewees also got the opportunity to address any other points. Which allowed the interviewee to express important topics if they thought something was not covered in the interview. It is helpful to use an interview guide due to the preparations of the interview both professionally as well as mentally (Dalland, 2017, p. 78). Hence, one interview guide was prepared and used as a base for the interviews. The interview guide was relatively short in the first place and adjusted to every interview. Hence, to some extent, it was a variation in the theme due to the interview's expertise.

Further, because of the iterative nature of the thesis, some themes also changed during the interview process. As a result, the first interviews provided insight into aspects that were not reflected in the original interview guide. An example was the theme of information flow tied to the organisation and how the flow affects the company. Thus, questions about the flow of information between production and management were added in the later interviews.

4.3.2 Selection of interview objects

The choice of interview objects has been made through a strategic selection. One systematic chooses the persons with the desired knowledge or characteristics, which is strategic to answer the problem statement (Tove Thagaard, 2018, p. 54). In addition, the interview selection can be categorised as unique since all objects have been contacted regarding knowledge about Lean or Digitalisation. Further, some possible interview objects were approached. However, they declined the request due to the fear of adverse effects. Therefore, the contemplated consideration was the possibility of a biased answer to speak on their behalf or opinions but not talk ill about the company or other employees. Also, the snowball method was used to find interview objects. As a result, the authors have contacted candidates that were considered relevant but are referred further to other candidates (Tove Thagaard, 2018, p. 56). This development can be considered unfortunate since the candidate referred to does not give a confirmed consent before being approached (Tove Thagaard, 2018, p. 56).

Nonetheless, this is not perceived as a problem for this study. The interviewees have been contacted on behalf of their position or workplace. As a result, no personal information has been obtained other than their educational background, position, and attitudes to the investigated phenomena.

4.3.3 Conducting an interview

Further, the period of conducting the interviews was through the period of 07. Mars to 22. April. The relatively long interview period is due to the long response time to agree on an interview time and holiday settlement at Easter. Further, most of the interview was conducted in person, but some were conducted through video calls using Microsoft teams. A video call falls under the category of synchronous interview (Tove Thagaard, 2018, p. 110). Hence, the video calls gave a similar opportunity as a face-to-face interview for direct response and spontaneous interaction. It also provides the ability to analyse the tone and body language of the interviewee. From this, one can get several factors to evaluate the answers. Another advantage of synchronous interviews is that the interview objects are accessible even within a geographical distance(Tove Thagaard, 2018, p. 110). Figure 13 shows a presentation of the layout of the interviews. Before the interviews, the companies' purpose or practice was examined so they could be informed in advance of the interview. All interviews lasted between 30 - 60 minutes, depending on the time the candidate(s) had at their disposal and how long it took to get through the questions in the interview guide.

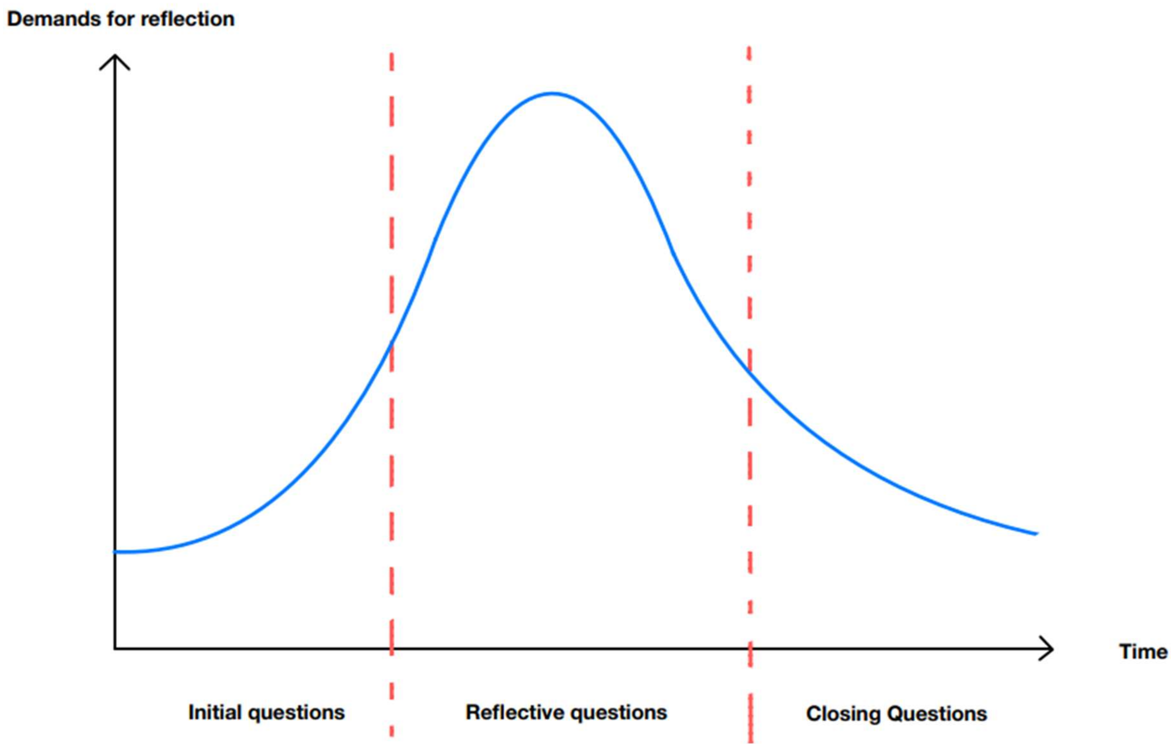

Figure 13. Setup of interviews
(Tjora & Tjora, 2021, p. 147)

4.3.4 Analyse the interviews

One is imposed when writing a thesis for UIA to follow the guidelines to NSD for privacy. Therefore, all interviewees had received a statement of consent that must be approved before being used as a result. Further, all interviews were recorded because it is considered the most complimentary process of getting information about the dialogue between the interviewer and the interview object (Tove Thagaard, 2018, p. 111). After that, the author transcribed the recordings and not by tools. Jacobsen (2005, p. 186) claims that qualitative data analysis treats raw data by; first describing, then systemising and categorising, and finally connecting. The raw data description was done by transcribing all the interviews and reviewing notes taken during the interview. After this process, the categorisation of data began. The categorisation is a way to simplify detailed and rich data material. This is done by systematising statements and sentences into categories based on set criteria. These categories must be relevant to the problem and conceptually sensible (Jacobsen, 2005, p. 193). By using interview guides, parts of the categorisation are set in advance.

Further, the results from the interviews were then arranged according to topics addressed by the various respondents and informants—figures 14, 15 and 16 show how the information was systematised for Lean and Digitalisation, respectively. Finally, an analysis was made of the statements within each category, which were assigned themes.

4.3.5 Validity, reliability, and objectivity

In order to present findings from the interviews in a transparent way, it has been reflected around several moments in the data collection. First, it was the pursuit of objectivity by posing open questions, so the interrogation was not affected by own attitudes. Generally, it is reasonable to assume that validity is ensured in the interviews by preparing an interview guide in advance and preparing the relevant topics before conducting the interview. This secure that one asks questions under the same theme for all interviewees and can illuminate which findings are repetitive and divergent. As a result, this strengthens the validation and makes it possible to conclude to a higher degree. Finally, the interviewees in this thesis are anonymised. Still, one can assume that their views and attitudes during the given interview time were independent of the purpose of the interview. Hence, this strengthens the reliability.

Nevertheless, OPS knowledge about Lean and Digitalisation is limited, making it reasonable to assume that the interviewees can change their attitudes as their knowledge about the phenomena rises. As a result, this weakens the reliability. In addition, a limited number of interviews in OPS Solutions was conducted due to some repetitive requests, refusal to participate and the possible bias of not answering based on own opinions. All this weakens the validation as well as reliability.

4.4 Observation

Finally, the last method that was used to collect data was observation. According to Baker (2006), there is difficult to find definitions of observation. However, since the observation happens over a longer period, the most appropriate definition was expressed by Becker & Geer in Baker (2006). The definition was that participant observation is either a covert or overt activity. Further, "in which the observer participates in the daily life of the people under study . . . observing things that happen, listening to what is said, and questioning people, over some length of time" (Baker, 2006).

4.4.1 Observation method

Observation involves examining what humans do in different social situations, where it is a matter of registering the behaviour of individuals and groups (Jacobsen, 2015, p. 165). Hence the method will only look at how people act and not what they subjective experience or believe, which leads to a small extent of capturing those not directly observable phenomena. Thus, it will often be connected to a form of an interview (Jacobsen, 2015, p. 166). Jacobsen (2015, p. 166) stated that it is challenging to separate observations. Nevertheless, he separated it into covert or overt observation. Covert observation (the unit does not know if they are exanimated) has the advantage of achieving a normal situation. The reason is that when people know they are being studied, they tend to change their behaviour.

For example, they are trying to satisfy the investigator or deliberately trying to avoid doing something that may be perceived as stupid (Jacobsen, 2015, p. 166). Further, the observation itself creates an observer effect. This effect means that many researchers will prefer covert observation. Also, many people assume that the reliability improves when the observation is covert (Jacobsen, 2015, p. 166). But covert observation presents us with an ethical problem: Is it right to examine people without their consent to be observed? It appears to have no clear answer, and the researcher himself must understand the situation and its requirements. Another aspect of observation is the role of the researcher. Where roles have been defined as "the characteristic posture(s), researchers assume in their relationship with the people whom they are studying" (Baker, 2006). Moreover, the role is considered the second separation between participatory and non-participatory observation (Jacobsen, 2015, p. 167). Participatory observation implies that the researcher is participating equally in the examination.

An example could be an employee who examines the working environment in their organisation. Non-participatory observation involves that the examinator keeps a distance from the people that are being observed (Jacobsen, 2015, p. 167). Participatory observation will first and foremost be relevant if one is to investigate what happens over time in a group. The big problem with participatory observation is that the researcher influences the result strongly, which means that the reliability decreases (Jacobsen, 2015, p. 167). Further, Jacobsen (2015, p. 168) stated *where*, *when* and *how long* should one observe as relevant factors. W*here* could be divided into two main types: Observation in natural surroundings and observation in artificial surroundings, where artificial surroundings are also referred to as laboratory study. In natural surroundings, a phenomenon is studied in its natural context, often for observation(Jacobsen, 2015, p. 168). The second question is *when* one should make the observation. All observation is a section of a unique era. Therefore, the time one selects will probably have significant consequences on what we observe (Jacobsen, 2015). Finally, *how long* should the observation last. In general, Jacobsen (2015, p. 168) stated that the longer the period, the more reliable the information becomes. A more extended period means one achieves different times and observes more relations. Moreover, according to Thomas (2017), one can also separate observation into two types: unstructured and structured observation. The unstructured is not systemic and unplanned, while structured is a planned observation of a phenomenon, where it follows specific patterns, rules, and design.

4.4.2 Selecting of observation

When applying observation as a method, the element of which situations one shall observe people is essential (Jacobsen, 2015, p. 186). Thus, one should think critically about the kind of situation one chooses. First, the critical aspect of where the observation should occur must be determined. For example, the place was prominent due to employment close to the problem statement (Jacobsen, 2015, p. 187). Next is the choice of the observation period. Since the period significantly impacts the result, the period has to be carefully considered. As a result, the chosen period was approximately three months. Finally, one needs to consider if any specific characteristics within the given period make the situation one studies typical or atypical (Jacobsen, 2015, p. 187). As a result, the observation was conducted over three months to achieve a more reliable and typical situation.

Further, observation methods have been made strategically (Tove Thagaard, 2018, p. 54). In addition, the selection can also be categorised as a specific selection. The reason is that the observation is done in a single case study, explicitly chosen due to the environment and access. Furthermore, the selection of observation method was an unstructured covert observation. The reason was due to the normal work situation of the observer, where the observer was an employee (researcher role) during the observation period (Baker, 2006; Jacobsen, 2015, p. 166). Since the observer was an employee during the observation period, it can be categorised as participatory observation, which Jacobsen (2015, p. 167) used as an example above.

Also, when considering the environment, it can be seen as natural surroundings to observe the synergy between production and management. Finally, *when* and *how long* the observation took place was the beginning of February until the end of April. As a result of the limited time scope for this study, the observation period had restrictions (Jacobsen, 2015, p. 168). As a result

4.4.3 Conducting observation

As such, the observation in this study was conducted over three months through employment. During this period, it was intended to observe to collect specific data by being a participating factor in these processes; the data were collected through a typical work situation. However, since the observer was conducting in a normal situation, it can be unfortunate due to the lack of awareness around other sequences outside the daily tasks. As a result, this could harm the result due to the possibility of not noticing essential aspects in the information flow. On the other hand, it can also contribute to achieving a typical situation where the observer acts normal. Accordingly, this could reduce the researcher's influence on the result. The observer is actively immersed in the production setting, observing the processes without engaging the employees or progressing to receive the most status quo of the production processes and management. The purpose was to get a realistic view of the information flow through the production and management as well as the synergy in the flow.

4.4.4 Analyse observation

After conducting the observation, the vital process of analysing the data starts. However, when conducting an observation, it is impossible to collect everything that happens at a given time. Even though one tries to start with an open mind as possible, one will always make a selection of data (Jacobsen, 2015, p. 203). Trying to approach completely without aids or a certain amount of preparation will never lead to getting all the relevant information instead of making an unconscious selection of data. In most cases, it will be best to make this selection explicit. Meaning before the observation takes place, to a certain extent, it makes it clear to ourselves (and others) what we want to focus on (Jacobsen, 2015, p. 203). As a result, the content of the observation can exclude that all relevant information was collected. The reason is the lack of an observation guide. Nevertheless, except for the missing observation guide, the explicit selection was made through the focus on Lean and Digitalisation. As a result, the observation was specific and flexible to some extent.

Nevertheless, according to Jacobsen (2015, p. 199), qualitative data analysis is about processing raw data by; first describing, so systematising, then categories, and finally connecting the data. The description of raw data collected was done to the best of the author's ability to transcript the relevant information obtained during the observation and systemise the information. After that, the data categorisation was done to simplify and define a large amount of data material. These categories need to be relevant to the problem statement and conceptually sensible. Since it was not used any observation guide or explicit selection in advance, the determination of the categories was done after collecting and systemising the data. The result from the observation was then arranged after the theme that the researcher collected - figures 14, 15 and 16 show the systemised data.

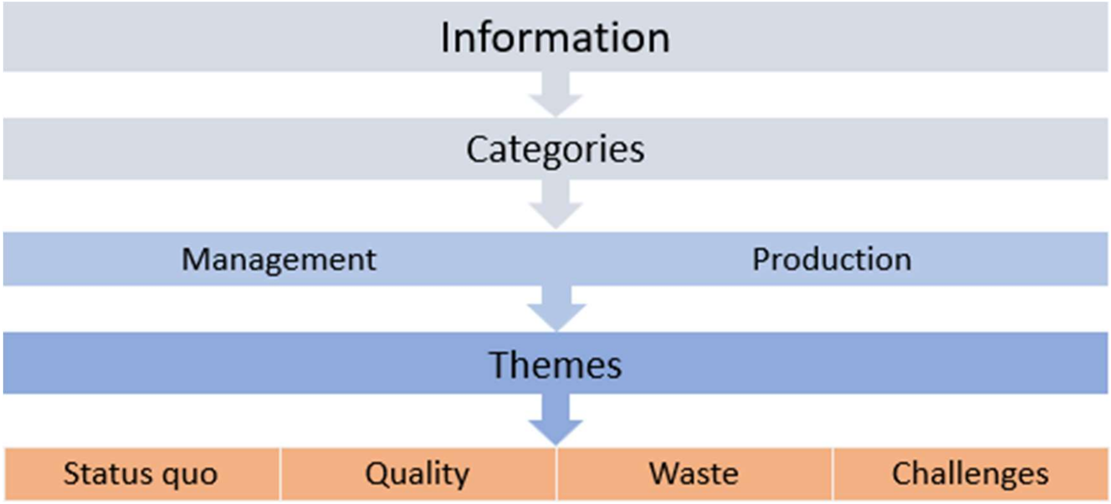

Figure 14. Information flow categories and themes

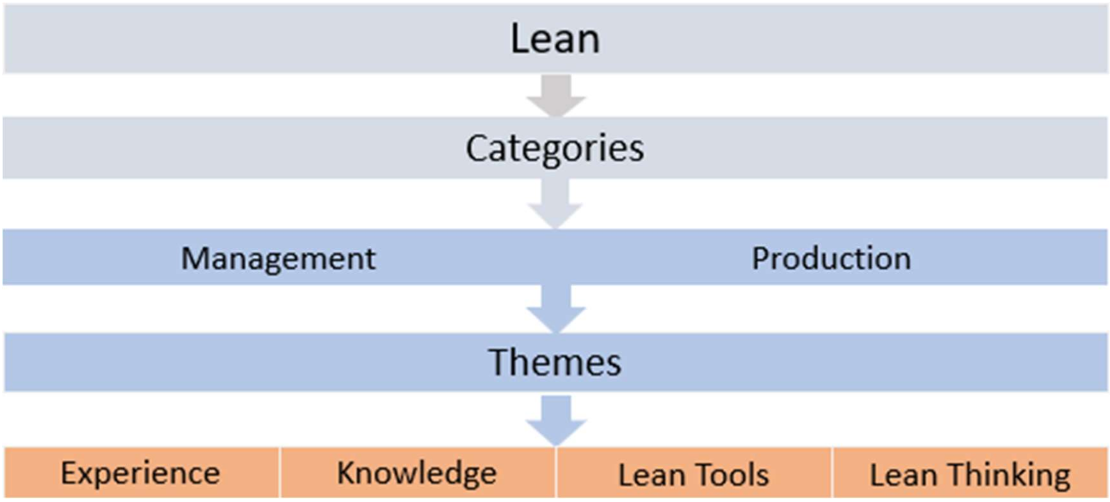

Figure 15. Lean categories and themes

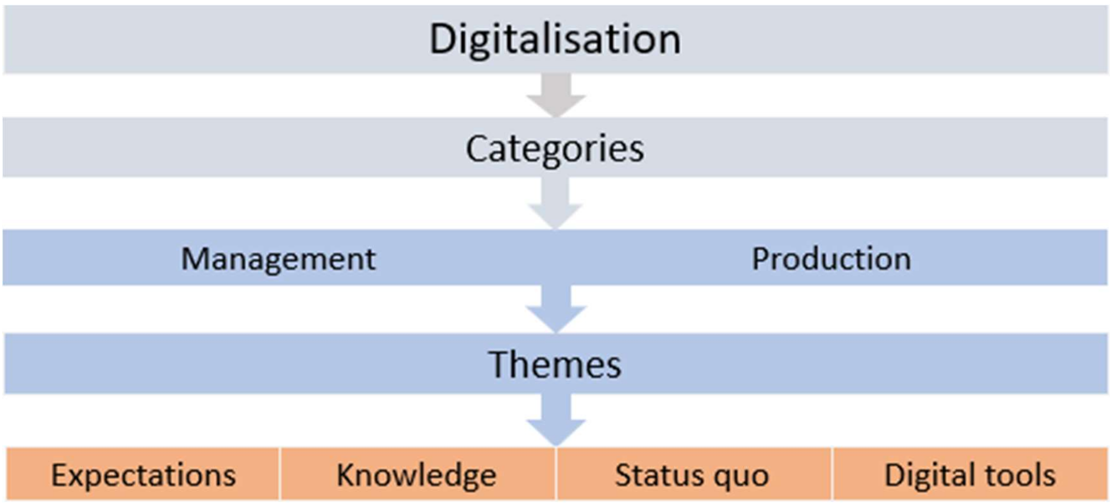

Figure 16. Digitalisation categories and themes

4.4.5 Validity, reliability, and objectivity

As mentioned in the interview section, it has been reflected around several moments in data collection to present the findings transparently. Further, a problematic aspect is ensuring objectivity in an unstructured-participatory observation. The reason is due to researcher engagement during the process. Also, engagement is an effect of the researcher's role, which reduces the objectivity of the observation. In addition, the validation can be reduced due to the lack of an observation guide. On the other hand, it could be argued that it may lead to other possibilities and areas due to an open mind. Thus, as a result, information flow was discovered in the observation by considering the specific area.

Nevertheless, Jacobsen (2015, p. 245) expresses that the quality of the data collected will never get better than the quality one manages to registerer. However, he stated also that human memory is not built to store a large amount of detailed information with utility value. On the other hand, one could also consider the period as a maturity process, where the researcher gains more knowledge through the process, with that becoming able to select more relevant data. However, when comparing the findings upon the interviews, one can illuminate which findings are repetitive and divergent. This strengthens the validation because one may say that when two persons achieve the same result, one may assume that the result can be trusted (Jacobsen, 2015, p. 243). Further, it makes it possible to conclude to a greater extent.

Furthermore, in the observer effect, one could assume that those observed in their normal state at the given time are independent of the purpose of the observation. As a result, this strengthens the reliability. Another effect is the context effect, where the observation occurs in a natural context (Jacobsen, 2015, pp. 242-243). However, Jacobsen (2015, p. 243). However, Jacobsen (2015, p. 243) expresses no clear answer to which context is good or bad. Still, one will prefer to conduct surveys in a natural context, so people don't change behaviour according to the environment.

5. Result

Further, in this chapter, the results from the triangulation method are presented. The method has provided empirical findings that will be discussed further. Also, the results will be discussed in connection with the research questions. Furthermore, there are some repetitive results when analysing the results from the literature, observation, and interviews. These results are displayed in table 5 to create an overview of the findings through observation and interviews, as well as the description of the problem.

Table 5. Empirical findings through data collection for information flow in OPS

Findings	Description	Data collection
IS infrastructure	Inability to exchange information between systems. Inability to exchange data automatically. Unable to generate real-time as well as monitor time, WIP and shop floor processes. The identification and location of files on computers and servers as well as partial documented information. Multiple instances of information make it challenging to identify the most accurate/up to date.	Observation
Centralised organisation	Inadequate strategic planning. Unclear strategy and business plan. Top hierarchy, which develops into a hierarchy in the information.	Observation Interview
Groupings	Different prioritising regarding projects. Self-centred mindset.	Interview
Time pressure	Create stress in the workplace.	Observation
Changing focus	The priority list of projects is in a constantly changing cycle. Employees have to shift focus and often get different priorities from people in the management.	Interview
Undefined tasks	Tasks are poorly described and often vague.	Interview Observation

In addition, to provide further insight into the challenges, these challenges are connected to the four causes of waste introduced by Hicks (2007). The challenges displayed in table 6 are classified concerning the waste categories.

Table 6. Classification of information flow challenges concerning waste

Challenges	Implications of waste	Waste category
IS infrastructure	- The inability to automatically exchange information and enable value to flow; thus, other processes are necessary to overcome this lack of functionality/poorly functioning process.	- Flow demand
	- Inability to perform certain functions to support the management and flow of information. Hence, require additional resources.	- Failure demand
	- Excessive information is stored—partly because of a lack of understanding of potential value.	- Flow excess
	- Time and effort are necessary to identify information to flow and the unavailability of processes to sustain flow.	- Flow demand & failure demand
	- Out-of-date or inaccurate information requires additional effort to verify and update information.	- Flawed flow
	- A lack of understanding of the value of information and its flow across the organisation. As a result, it can be a poorly performing system and arguably waste.	- Value and waste
Centralised organisation	- Inadequate strategic planning.	- Failure demand
	- Unclear strategy and business plan.	- Flawed flow
	- Top hierarchy leads to a poorly information-based decision.	- Flow excess
	- Long response time.	- Flow excess
Groupings	- Different priorities in the management affect the production floor and create groupings in the production.	- Flawed demand
	- Creates a self-centred mindset in the organisation, where each employee thinks of their well-being and not the organisation.	- Failure demand
Time pressure	- Creates a chaotic atmosphere where the ripple effect can be significant.	- Flow excess and demand and Flawed flow
Changing focus	- Changing the priority cycle, which leads to undefined information flow.	- Failure demand and flow, and flow demand and excess

6. Discussion

This section looks at similar challenges in an HVLV and develops the key principles inspired by Hicks (2007) of a digital Lean approach for the information flow. This approach applies to an HVLV manufacturer environment. In particular, the five fundamental principles identified by Womack and Jones (1997) and discussed in the theoretical background are elucidated concerning the flow of information. These principles are summarised in table 7 and discussed in the following sections.

Table 7. Key principles for an enhanced information flow

Principle	Description
Value	Information and functionality must supply value to the end-user. 1. Only manage valuable information - information that must be managed as well as information that supports the core business activities. 2. Depictions of a system that only offers direct value or understands the indirect value, i.e., for another department.
Value stream	1. Ensure that the information delivered by process and activities are mapped. This includes processes that support the capture, representation, exchange, organise, retrieval and visualisation of information. 2. Ensure that the sequence (network) of processes that support information flow are integrated.
Flow	1. Information should be available in real-time – as soon as it is generated. 2. Ensure that all information and support processes occur in the shortest possible time. 3. Procedures and processes should be invoked and performed in the simplest way possible. 4. Minimise duplication of information between the management and production. 5. Minimise the amount of out-of-date or unnecessary information between the management and production.
Pull	1. Information and additional functionality should only be delivered as demanded by the end-users. 2. The interfaces, methodology and procedures need to be consistent across the organisation to facilitate pull. 3. Minimise the dependency on IT staff and programmers for implementation. Support users to undertake local customisation and promote ownership—end-user developed systems.
Continuous improvement	1. Regularly review infrastructure and processes—remember information systems, business processes, and processes that support products and services change. As such, opportunities for improvement will also change. 2. Support rapid implementation and training. This is the time from system acquisition to full implementation and integration with the business processes.

6.1 Which similar challenges has HVLV-environment in the information flow?

In order to discover similarities regarding challenges in the information flow in an HVLV-manufacturing environment, one has to look for both repetitive solutions and challenges. Further, to address the first research question, the findings from the observation were used as a basis. The reason was due to the apparent challenges at OPS Solutions. One of these challenges was the IS infrastructure. It was a central and significant problem where the lack of a functional and defined infrastructure contributed to a disrupted and divergent flow of information.

"*The company needs better systems for systematising data and communication*" (Interview Object 1)

In contrast, Company A, B and C all had a thriving IS infrastructure. They all emphasised the importance of having a IS infrastructure that suited the company. In addition, they agreed on the statement that having a well-functional and suitable IS infrastructure was the main challenge for companies for HVLV manufacturers due to the complexity and variation in the information. They also added that it was not an easy process but a crucial and necessary one. It was a constant learning process. Thus, when comparing OPS Solutions to the other companies, it becomes evident that the foundation and the primary challenge is having a well-functional IS infrastructure. The next challenge that was discovered was centralised bureaucratic organisation. As a result, it was the root of other challenges, such as groupings and changing focus. Through observation and interviews, it was clear that every decision had to go through the top management—interview-object one oneorroborated by referring the organisation to micro-control.
Further, companies A and B also emphasised the importance of a flatter organisation, where decision-making was decentralised as much as possible.

"We have team leaders that manage the project and take decisions within their framework during the projects. These frameworks are created by the top management together with the team leaders in order to have a suitable framework" (Company A)

The ideal is to achieve a more thorough and smoother flow. Also, key employees feel a sense of belonging and ownership. As a result, employees will take more responsibility and seek continuously learning to contribute to achieving the goals. Additionally, they stated that continuous learning and improving decentralisation was the utmost important factor in increasing competitiveness. One of the most significant challenges regarding decentralisation was to trust other employees to make the right decision. However, the centralised organisation was considered a significant problem and, as a result, would harm competitiveness, flexibility, and responsiveness. Hence, it was emphasised through company A, objects 1 and 2, that in a centralised organisation, the management must make decisions based on narrow information.

*"The response time it takes the top management to achieve, most likely the same answer, is just a waste of time. It is like everything stops" (*Interview object 2).

As a result, this led to long decision time, which led to time pressure and developed into groupings. Grouping occurred because different sections in the production had different prioritising and consequently worked on different projects. Interview object 4 emphasised this observation by stating that it was an extinguish fire mentality.

"It's all man to the pumps when it burns, and so on. Always lying behind" (interview object 4)

Also, interview object 2 added that every project is often in arrears. Compared to the other companies, high time pressure was recurring, which was expected due to the HVLV-environment.

However, only company B had some similarities to groupings. A repetitive factor where OPS and company B had a more centralised organisation. Nevertheless, the other companies agree that the HVLV-environment could struggle with groupings. Another aspect that could cause grouping was the order of priority projects. The focus often changed along with the priority of orders. As a result, company A emphasised the crucial aspect of having a priority list developed by the top management, which had to be constantly updated due to the changing environment. Lastly, undefined tasks often occur in the HVLV environment since time pressure and high variation lead to quick changes. The companies and interviews further agreed upon this. Yet, company B stated that it is not the environment that is the cause of undefined tasks. But, it is the lack of planning, such as going into process and project details.

Nevertheless, both the observation and interview of companies A and B showed a trend of struggling in detailed planning. The reason was the constantly changing schedule and the priority in the production. Further, the three companies had clearly defined tasks compared to OPS. To some extent, the reason was that all companies had successfully IS infrastructure. As a result, it created a better foundation to plan accurately ahead. In addition, a repetitive factor was just poor communication between humans which is a constant influential factor in the flow of information.

6.2 Can a digital approach to the lean principles enhance the information flow?

To enhance the information flow between the management and the production, one must fulfil the key principles displayed in table 7. These principles create the foundation and take the challenges in the information flow for an HVLV manufacturing company and try to solve them.

Value

Value is essential in every aspect; therefore, it is crucial to specify the value for the given process. Further, in the HVLV environment, the high turbulence results from responding to the market's need by offering one-of-a-kind products. As a result, an enormous and divergent flow of information occurs between management and production, leading to poor information flow. However, the flexibility and variation from customisation are essential strategic sources of generating customer value (Ballou et al., 1998; Hicks, 2007). Thus, it is vital to emphasise the flexibility in the information flow. An element detected during the observation was the challenge of separating the waste from the value in the information flow.

Further, the value in information is set to be the information the end-user receives. Consequently, the value has to be flexible and specific to the end-user, regarding it is a human or machine. In order to achieve such a result, the foundation lies in the IS infrastructure. A result of an inadequately IS infrastructure in OPS led to inaccurate information (Mbakop et al., 2021). This information was out-of-date and often extensive. Hence, it takes considerable time and effort to identify the desirable value. To avoid such waste, one has to achieve a successful IS infrastructure. A successful IS infrastructure is where the information is collected, identified, exchanged and updated automatically (Laudon & Laudon, 1997). This will create a standardise flow process but still flexible to enhance the value in an MTO- and HVLV-company. As a measure to achieve such IS infrastructure, a digital approach as the data-driven process would ensure this process. Through this process, the information is distinguished. The value in the information is separated from the waste – which further enhances the quality in a way that would not be possible for humans (Buer, Fragapane, et al., 2018). As a result, the information can be extracted at any given time, at any given level of detail, and is transparent. However, the overall strategy and business plan significantly influence the selected value. Hence, it is vital to involve key employees in an early stage to be able to detect the actual and optimal value (Porter, 1985).

Once the IS infrastructure is set and functional, one can enhance it further by implementing the Lean tool LP system. Since planning was critically emphasised in the interviews, a fundamental element is to achieve a planning schedule even though it is considered a significant challenge in a turbulent environment (Gran & Alfnes, 2019).

However, LP System has been a valuable tool in the construction environment. Still, it is considered to be falling short in changing environments.

Nevertheless, with a digital approach driven by automatic data collection, one can visualise the information during the planning phase. This makes it possible to decompose the planning into specific processes, making it easier to detect the value (Ballard & Tommelein, 2016; Ballard, 2000). In addition, only the valuable information gets managed as well as the information that supports the core activities. Since the number of changes that happen during the planning phases is large, it can be challenging to ensure that the valuable information along with the information that supports core activities are managed (Frandson et al., 2014). As a measure, a data-driven process will continuously search and update so that the planning phase always has real-time information regardless of the changes. Accordingly, one can ensure that the desired value is identified and set the correct base for further steps. Additional, with a digital approach to LP systems, a large tablet will be installed so, at any given time, the desirable real-time information is displayed.

Further, it will also make it easier to filter out which information one desires to show and address. Another aspect is the giant paper traces the traditional LP System leaves behind (Ballard, 2000). Therefore, the risk of losing some papers will always be presented and, as a result, make up an additional risk. In addition, to LP System, Key performers indicator files can be used as interconnection with the LP System, where the specific information is stored in a file (Meier et al., 2013). The LP system will provide the files with real-time information at any time, so the operator will be able to base the decision on the best possible foundation. Such development will contribute to making the organisation more decentralised. Since employees "closer" to the process are provided with essential information, and not only the management. In addition, they are included in fundamental processes during the planning phase. Hence, provide the management with the safety necessary to ensure that the operator bases the decision on the correct information. Also, these files will be available for the operator at any time; the operator only needs a technology device like a tablet or smartphone. Lastly, an LP system creates an overview of the company and all its processes, which makes it possible to achieve a deception of a specific system and all systems in the company. As a result, this will create a visual display over which systems offer direct value or understand the indirect value. As such, it will be helpful for the employees to get a total overview of the company's processes as well as procedures, which will reduce the requirement for additional resources. Without the aid of a data-driven cycle, this will be an extremely time and resource-consuming aspect, making it a nonprofit element. Therefore, the data-driven cycle will avoid additional time and resources to keep up with the changes.

Value stream

The next phase ensures the optimal value stream when the given value is determined. Hence, the VSM is the most used method within lean because it is an essential process to achieve better information and flow. Therefore, it is crucial to be able to implement VSM even though it is an HVLV environment (Alfnes et al.; Tobro, 2017). However, mapping the delivered information by every process and activity in a constantly changing environment is complicated and often considered senseless due to an unclear takt time. Nonetheless, when using a digital approach to the VSM, referred to as "VSM 4" by Meudt et al. (2017), one can see a transparent adaptation process.

Furthermore, the data-driven process creates the foundation for a real-time VSM that can automatically create value stream maps because of continuous data collection. This dynamic visual picture of the shop floor enhances the visibility of the information throughout the organisation and ensures mapping in real-time (Hartmann et al., 2018; Meudt et al., 2017). So, even in a constantly changing environment, one can be secure that the information delivered by every process or activity is up-to-date. In addition, it supplies the management or decision-makers with accurate and real-time information. Furthermore, VSM can collaborate with the LP system through the data-driven process cycle. This leads to a sequence of integrated processes that support the information flow, which provides a smoother flow through the organisation. This is elaborated further in the Flow section. Figure 17 displays an example of a digital VSM process.

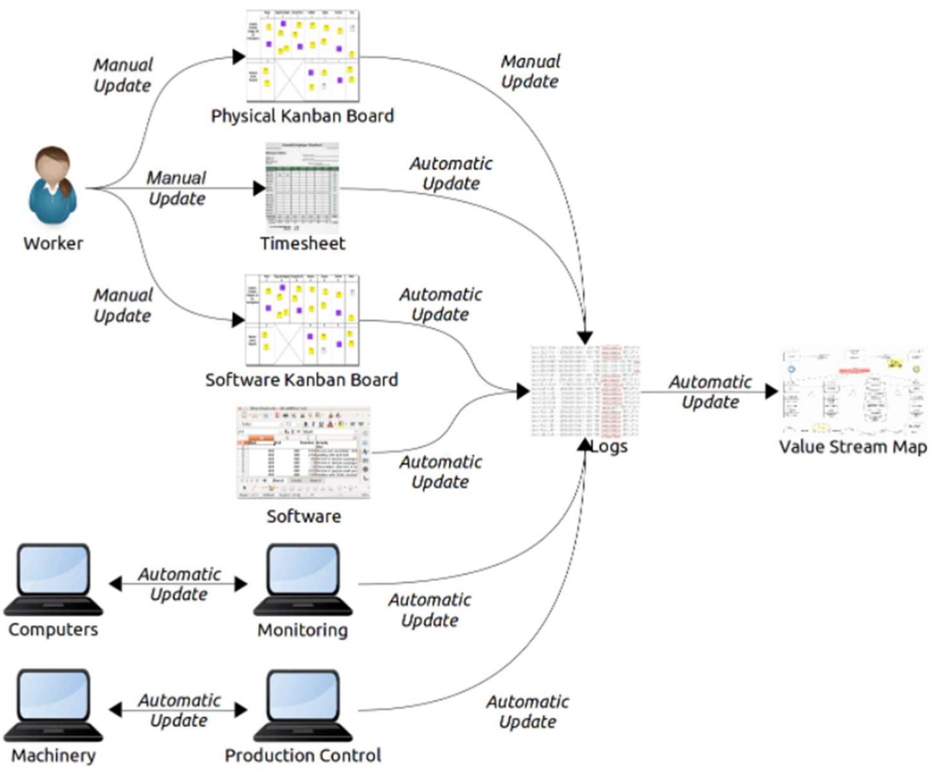

Figure 17. An example of digital VSM process (Falkowitz, 2020)

In order to have a digital VSM, the IS infrastructure is essential to achieve the data collection in a constant and the shortest possible way to have a real-time VSM. In addition, to automatically collect data, one is also dependent on manual updates of given processes. However, having tablets and a straightforward procedure for manual updates becomes a more manageable and straightforward process, contributing to making employees do the manual updates. Further, another Lean tool that can contribute to the process is BPMN, which shows the processes' properties and execution information as well as converts it into a graphical readable language (Chinosi & Trombetta, 2012). As such, this tool is more corrected against the planning aspect of the organisation by modelling notation of the steps of the planned business process from start to end. As a result, it creates a more specified notation of a planning process. This will contribute by creating a graphical language of the different sequences the information goes through. So, for example, one can see which actors are involved as well as which elements the information goes through, such as departments and machines. Also, it enables the visualisation of the sequences of processes that support the given information flow (Arromba et al., 2019). With this visualisation, the waste becomes separate from the value because one can easier see which processes are non-added and added-value. Hence, in an HVLV, the separation and visualisation of these processes can be a fundamental tool to achieve accurate value stream mapping. Further, this ensures the integration of these processes because it makes it clear due to the visualisation that if some process fails.

Nevertheless, LP, VSM and BPMN tools also contribute to the flow principle. In addition, these tools help to achieve information in a real-time state as soon it is generated. Further, the procedures and processes are invoked and performed in a simple way. In addition, to some extent, such tools will minimise the unneeded or out-of-date information as well as avoid duplicate effort between the management and production due to the data-driven process cycle. However, these tools are dependent on human intervention and other information sources. Thus, it can enhance the flow when used correctly; if not, it can harm the organisation.

Flow

When the value is specified and the stream is highlighted, the flow must be defined. The information flow is how the value progresses from the beginning to the end. An optimal flow is as few as possible non-value processes that interfere with the flow (Womack & Jones, 2003). Often one desires a rigid and standardised flow. Still, since flexibility is considered a value-generating process in HVLV, one needs a system that sustains flexibility in the flow. Hence, Dave et al. (2016) introduced "Visilean". A tool that will align or integrate the systems within the company with the use of the Internet of Things (IoT). The reason is to solve the problem expressed by interview object one. To enable a connection between the system and enhance the flow between the different systems as well as the steps in the data-driven process cycle. As a result, this will provide the information as soon as it is generated because all information and support processes occur constantly and are automated.

Further, this leads to procedures and processes being invoked and performed most shortly and simply as possible. However, Visilean is built upon the principles of Kanban, which is considered to be restricted in the HVLV environment (Dave et al., 2016). Therefore, VisiLean must be adapted to the HVLV-environment and adjusted to POLCA-principles. Since VisiLean is based upon the IoT, having a functional IS infrastructure is required. Because VisiLean will not enhance the system, only the connection between the systems (Dave et al., 2016). If implemented correctly, it will provide an enhanced flow and enable tools like LP and VSM. For LP and VSM to get an optimal effect, these are dependent on receiving the most complete and up-to-date information from the management and production. As a result, VisiLean will minimise the duplication of information since it is based upon the IoT. Additionally, this will connect with the IS infrastructure, where all data is collected and shared further. Thus, no duplicated information is sent further.

Another aspect is the production floor – where the production floor is constantly changing. In order to enhance the flow between projects, one has to establish procedures and defined tasks. By implementing SMED, the production will enhance the change-over between projects. Furthermore, since operating in an HVLV environment, it can be complicated to separate the activities from each other and know which activities belong to which processes. Therefore, SMED contributes to identifying and separating these activities, so the production floor gets a more transparent overview (Ulutas, 2011).

Further, this will contribute to establishing a flow that sustains the necessary flexibility to enhance the information. Also, the information quality will be improved since when identifying the internal and external activities, the required information to execute the change-over is well defined and elaborated to the employees (Ulutas, 2011). Nonetheless, the basis for information flow lies in the IS infrastructure and the connections. It is the desired condition that all information has an assembly point. Hence, the assembly point is where the data is collected automatised. It is then shared with other systems regarding the element; for example, the employee will fill out the procedure on a tablet if a discrepancy has occurred. This procedure is collected at the assembly point. Further, the data-driven cycle identifies its identity and shares the information with the respondent system, the HR system. From there, the HR responsible has real-time information about the discrepancy and can do the necessary processes to take care of it. During this process, the HR system analyses it and optimises the result. As a result, the flexibility will be emphasised because the system will constantly collect real-time information. Therefore, the receiving ends will be updated when changes will take place. At the same time, having an assembly point of all information will enable it to be quality assured before it is shared with other systems.

PULL

In addition, to the data-driven IS, an essential aspect of creating optimal flow is to create a pull production. As Hopp and Spearman (2004) expressed, the amount of WIP is limited. When considering information, one can look at the information as the work. Thus, a pull system will contribute to limiting the flow of information and avoiding flow excess. As a result, the information flowing at the given time is real-time and the information regarding the occurred processes. Also, this will make the information quality higher as well as transparent. Hence, the production floor is a vital aspect that affects the flow. For this purpose, tools with a physical impact are considered like 5S and POLCA-cards.

Further, implementing 5S will create the possibility to enhance the production floor by creating a better workflow. In other words, 5S will create a foundation for a smoother product flow and will exclude unnecessary processes and influences. Thus, implementing 5S creates a better base for implementing POLCA-cards as well as other tools. However, due to different projects of different forms, it is not easy to standardise the production itself (Bicheno & Holweg, 2016, pp. 136-139; Omogbai & Salonitis, 2017).

Nonetheless, one measure may be implementing a principle that ensures flow between the production stages. There may be some control over the production process by standardising who can contribute to the next stage. Having one station relate to one «supplier» and one «consumer» could lead to better communication. For example, station K1 will take over the unit for processing from A1. When K1 has finished its process, the station will look for new work at A1.

On the other hand, this can weaken the production flow where A1 cannot deliver new work to K1. Hence, the workers must be up to date on different parts of the production to use spare capacity for something else. This ConWIP approach will be able to create a push in production. Combination with the POLCA card will provide an overview of the available capacity at the various stations (Suri & Krishnamurthy, 2003). When introducing the POLCA cards, a QR code will be recommended. As a result, this can streamline communication and reduce the interface by cutting unnecessary channels and intermediaries. In addition, the QR code provides relevant and concrete information about what has been completed and what will be done at the new start-up, see figure 18.

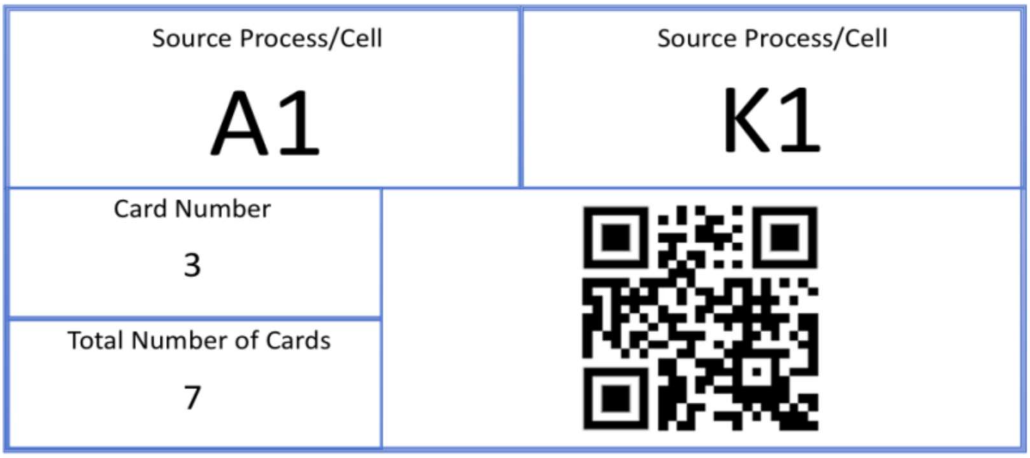

Figure 18. An example on a POLCA card that shows the flow between stations

Further, an essential aspect of pull production is to ensure the dependency on IT staff for implementation (Buetfering et al., 2016). Therefore, using a simple and digital approach like POLCA-cards supports the user in promoting ownership. It will contribute to making employees take more responsibility and actively engage in the process's development. In addition, by having a defined and digital procedure, the operator will have defined points to fill out. As a result, it will remove the risk of self-assessment regarding the PPC since all operators have the same milestones to follow. In collaboration with an Andon system (a notification system), the system will automatically notify the relevant personnel when the process (machine) reaches a milestone (Cole, 2019). As a result, the collected information will be reliable because operators can't interpret the PPC, and the milestones lead the PPC.

Continuous improvement

A critical aspect of Lean and digital development is searching for improvement (Netland & Powell, 2016, p. 291). As seen in recent years, the rapid development of digital technology emphasises the importance of staying up to date. Further, when discussing the information flow, one must strive for continuous learning. Information flow is an element that will never go away, but the surrounding is constantly changing. Further, the operators are improving as problems occur due to the constantly changing environment. However, the improvement process appears in an unstructured process.

Further, this leads to a disadvantage. It is difficult for the organisation to follow up on the processes, hence learning from them (Nonaka, 2009). In addition, the operator has to be empowered to take responsibility for the improvement process. Also, one has to see the need for improving the processes, which is not always the case (Elving, 2005; Wang & Ahmed, 2003).

> *The operators, who execute the daily tasks, should give input on improving solutions and how we work continuously. It is discussed different aspects of the production. Still, we see that the improvement loop can be shorter and more efficient and, most importantly, be done by the people who do the job.* (interview object 6)

In order to mitigate the effects of continuous improvement, a focus should be on creating a strong team culture where knowledge is shared (Wang & Ahmed, 2003). In addition, it should focus on creating transparent information (Nonaka, 2009), for example, by using a digital approach of the Lean tools or visual management (Bicheno & Holweg, 2016).

7. Conclusion

This master thesis deals with developing a new approach for supporting the improvement of information flow and, in particular, the performance of digital embossed Lean tools in an HVLV manufacturing environment. The increasing demand for customised products creates a highly competitive environment. In addition, the ever-increasing technology development forces companies to a modern approach. Thus, in a modern organisation, the information flow is a vital element of the company's processes and product development (Eppinger, 2001). Therefore, the manufacturing industry is evolving towards digitalisation. As a result, an increasing interest in digital Lean in HVLV manufacturers (Agrifoglio et al., 2017). But so far, the research on his area seems to be sparse (Olhager & Prajogo, 2012; Tomašević et al., 2021). Thus this master thesis highlights the challenges that occur in the information flow in an HVLV manufacturer. Also, the Lean tools that are adaptable to the HVLV-environment are present. Finally, the opportunities of implementing the discovered Lean tools with a digital approach to enhance the information flow between the management and production.

Further, the author identified challenges and elaborated on key principles using the literature on the topic. In collaboration with these challenges and key principles, lean tools were discovered that were adaptable to the HVLV environment while at the same time providing opportunities to enhance the flow of information. Further, challenges were discovered with IS infrastructure, centralised bureaucratic organisation, groupings, time pressure, changing focus and undefined tasks. These challenges create a vague and divergent flow of information between the management and production. Since improving the information flow can yield significant benefits to all areas of an organisation (Dietel, 2000; Hicks, 2007), the digital approach of the Lean tools is set out to make the flow of information more direct and transparent. In addition, it can enhance by providing more defined and desirable information to the receiver. As a result, the thesis found the principles behind Lean Thinking applicable in HVLV environments as well as contribute to the information flow. Still, the principles must be interpreted and adapted. Managing the information flow can involve adding value to the information by virtue of how it is organised, visualised and represented; and enabling information (and hence value) to flow to the end-user (information consumer) through the exchange, sharing and collaboration processes (Hicks, 2007). The potential benefits and extent of applying lean principles are discussed, and fundamental challenges for its application to enhance the information flow are highlighted. These include the need to characterise the nature of waste and establish the five principles of; value, value stream, flow, pull and continuous improvement in enhancing the information flow. In order to characterise the waste, the findings from the reported study Hicks (2007) are used as the basis for elaborating on the various types of waste and their causes. This revealed four types of waste in information flow; failure demand, flow demand, flow excess, and flawed demand.

A conceptual framework for a set of lean principles within the context of information flow is proposed using the characterisation of waste and the understanding gained from the study. These principles include the traditional elements of value, value stream, flow, pull, and continuous improvement. It is argued that the framework and the understanding of waste offer a unique and generic approach for supporting the retrospective improvement of processes and systems that manage information. In particular, the principles aim to support a continuous programme of improvement concerned with the efficiency, quality and overall management of the processes. It is further argued that, as has been the case for manufacturing systems, such improvements are likely to have wider organisational benefits. These may include a more excellent capability to undertake core activities, improved responsiveness and increased competitiveness. Hence, creating processes aligned with the company values and philosophy enhances the strategic resource for generating value.

Furthermore, an essential aspect of the HVLV-environment is flexibility (Olhager, 2003). Thus, the information flow has to enhance and contribute to the need for flexibility which creates a necessary transformation (Fatorachian & Kazemi, 2018). As a result, the data-driven process cycle is essential in making the digital embossed Lean tools adaptable to the HVLV-environment. Furthermore, the data-driven process cycle enables the Lean tools with real-time information as well as detail adjustable. Accordingly, this enhances that the end-users information is up to date and status-quo information, making the decision based upon reliable information. Nevertheless, this master thesis forms a hypothesis for further action research by confirming or denying if the digital approach of Lean tools can be implemented and enhance the information flow. In addition, this would contribute to further scientific research in this field.

8. Further research

This research has investigated how lean and digital technologies can enhance the information in HVLV manufacturing, limiting the research to focus on the flow between management and production. Another limitation was to avoid the advanced technical background of digital technologies. Further, to get a more holistic view of the information flow, it is necessary to investigate the implications of advanced technology as well as the information flow regarding the whole organisation. The emphasis of this research has been on exploring HVLV manufacturing in the light of Lean thinking principles. However, there are many other principles and approaches which has not been explored. Also, the research is only based on one case study, limiting the generalisation of the findings. As a result of achieving a broader basis for generalisation, more research on the subject and other studies are needed to verify the findings.

Further research could be to use action research in the case study. The difference can be divided into “regular” research and action research: (1) the Action researcher is a participatory part, together with those who make up the units in the case. (2) the Action researcher is an active part in the sense that they implement changes and then study the effects. Therefore, the action researcher will thus act as a mixture between a “change agent” (one who initiates change) and a researcher (who measures the effects of the changes). With this approach, one could strengthen the result and elaborate on the hypothesis created under this study.

9. References

Agrifoglio, R., Cannavale, C., Laurenza, E., & Metallo, C. (2017). How emerging digital technologies affect operations management through co-creation. Empirical evidence from the maritime industry. *Production Planning & Control, 28*(16), 1298-1306.

Aguilar-Saven, R. S. (2004). Business process modelling: Review and framework. *International journal of production economics, 90*(2), 129-149.

Alabdul Razzak, M., Al-Kwifi, O. S., & Ahmed, Z. U. (2018). Rapid alignment of resources and capabilities in time-bound networks: A theoretical proposition. *Global Journal of Flexible Systems Management, 19*(4), 273-287.

Alfnes, E., Thomassen, M. K., & Gran, E. (2017). A Framework for Lean Flow in Turbulent High-Variety Low-Volume Manufacturing Environments.*IFIP Advances in Information and Communication Technology* Cham.

Alfnes, E., Thomassen, M. K., & Gran, E. (2016). A framework for lean flow in turbulent high-variety low-volume manufacturing environments. IFIP International Conference on Advances in Production Management Systems,

Amaro, G., Hendry, L., & Kingsman, B. (1999). Competitive advantage, customisation and a new taxonomy for non make - to - stock companies. *International Journal of Operations & Production Management*.

Arromba, A. R., Teixeira, L., & Xambre, A. R. (2019). Information flows improvement in production planning using lean concepts and BPMN an exploratory study in industrial context. 2019 14th Iberian Conference on Information Systems and Technologies (CISTI),

Austefjord, B., & Opsahl, E. (2020). *Application of lean in high variety and low volume manufacturing: A qualitative casestudy in Norway* University of Agder].

Awadid, A. (2017). Supporting the consistency in multi-perspective Business Process Modeling: A mapping approach. 2017 11th International Conference on Research Challenges in Information Science (RCIS),

Baker, L. (2006). Observation: A complex research method. *Library trends, 55*(1), 171-189.

Ballard, G., & Tommelein, I. (2016). Current process benchmark for the last planner system. *Lean Construction Journal, 89*, 57-89.

Ballard, H. G. (2000). *The last planner system of production control* University of Birmingham].

Ballou, D., Wang, R., Pazer, H., & Tayi, G. K. (1998). Modeling information manufacturing systems to determine information product quality. *Management Science, 44*(4), 462-484.

Bicheno, J., & Holweg, M. (2016). *The lean toolbox: A handbook for lean transformation* (Vol. 5). PICSIE books Buckingham.

Birkie, S. E., & Trucco, P. (2016). Understanding dynamism and complexity factors in engineer-to-order and their influence on lean implementation strategy. *Production Planning & Control, 27*(5), 345-359.

Bowen, G. A. (2009). Document analysis as a qualitative research method. *Qualitative research journal*.

Buer, S.-V., Fragapane, G. I., & Strandhagen, J. O. (2018). The data-driven process improvement cycle: Using digitalization for continuous improvement. *IFAC-PapersOnLine, 51*(11), 1035-1040.

Buer, S.-V., Semini, M., Strandhagen, J. O., & Sgarbossa, F. (2021). The complementary effect of lean manufacturing and digitalisation on operational performance. *International Journal of Production Research, 59*(7), 1976-1992.

Buer, S.-V., Strandhagen, J. O., & Chan, F. T. (2018). The link between Industry 4.0 and lean manufacturing: mapping current research and establishing a research agenda. *International Journal of Production Research, 56*(8), 2924-2940.

Buetfering, B., van der Stoel, A., Sriram, P. K., Van Landeghem, H., Ickerott, I., Wiegel, V., & Alfnes, E. (2016). Lean in high variety, low volume production environments– A Literature Review and Maturity Model. *EurOMA 2016*.

Casey, S. (2018). *Working Backward to Plan Ahead: The Last Planner System* [Figure]. ELECTRICAL CONTRACTOR, Washington, D.C. https://www.ecmag.com/section/your-business/working-backward-plan-ahead-last-planner-system

Chinosi, M., & Trombetta, A. (2012). BPMN: An introduction to the standard. *Computer Standards & Interfaces, 34*(1), 124-134.

Clegg, B., Pepper, M., & Spedding, T. (2010). The evolution of lean Six Sigma. *International Journal of Quality & Reliability Management, 27*(2), 138-155.

Cole, J. (2019). Andon System Visualizes Machine Status Remotely. *Modern machine shop, 91*(11), 132.

Costa, F., & Portioli-Staudacher, A. (2021). Labor flexibility integration in workload control in Industry 4.0 era. *Operations management research, 14*(3-4), 420-433. https://doi.org/10.1007/s12063-021-00210-2

Dalland, O. (2017). Metode og oppgaveskriving (6. utg.)(1. opplag). *Oslo: Gyldendal Akademisk*.

Dave, B., Kubler, S., Främling, K., & Koskela, L. (2016). Opportunities for enhanced lean construction management using Internet of Things standards. *Automation in Construction, 61*, 86-97.

Dietel, J. E. (2000). Improving corporate performance. *Information Management, 34*(2), 18.

Durugbo, C., Tiwari, A., & Alcock, J. R. (2010). Managing information flows for product-service systems delivery.

Durugbo, C., Tiwari, A., & Alcock, J. R. (2013). Modelling information flow for organisations: A review of approaches and future challenges. *International journal of information management, 33*(3), 597-610.

Edmunds, A., & Morris, A. (2000). The problem of information overload in business organisations: a review of the literature. *International journal of information management, 20*(1), 17-28.

Elving, W. J. (2005). The role of communication in organisational change. *Corporate communications: an international journal*.

Emblemsvåg, J. (2014a). Lean project planning in shipbuilding. *Journal of Ship Production and Design, 30*(02), 79-88.

Emblemsvåg, J. (2014b). Lean project planning: Using lean principles in project planning. *International Journal of Construction Project Management, 6*(2), 185-207.

Eppinger, S. D. (2001). Innovation at the speed of information. *Harvard business review, 79*(1), 149-158.

Falkowitz, R. (2020). *Automated Value Stream Maps* [Figure]. Con-cen-tric Circle Con-sult-ing, Jussy. https://www.3cs.ch/automated-value-stream-maps/

Fatorachian, H., & Kazemi, H. (2018). A critical investigation of Industry 4.0 in manufacturing: theoretical operationalisation framework. *Production Planning & Control, 29*(8), 633-644.

Forza, C., & Salvador, F. (2002). Managing for variety in the order acquisition and fulfilment process: The contribution of product configuration systems. *International journal of production economics, 76*(1), 87-98.

Frandson, A., Berghede, K., & Tommelein, I. D. (2014). Takt-time planning and the last planner. Proc. 22nd Ann. Conf. of the Int'l Group for Lean Construction. Group for Lean Const, Gantz, J., & Reinsel, D. (2011). Extracting value from chaos. *IDC iview, 1142*(2011), 1-12.

Gran, E., & Alfnes, E. (2019). Practical Guidelines for Production Planning and Control in HVLV Production. IFIP International Conference on Advances in Production Management Systems,

Gripsrud, G., Olsson, U. H., & Silkoset, R. (2016). *Metode og dataanalyse : beslutningsst?tte for bedrifter ved bruk av JMP, Excel og SPSS* (3. utg. ed.). Cappelen Damm akademisk.

Hahn, G. J. (2020). Industry 4.0: a supply chain innovation perspective. *International Journal of Production Research, 58*(5), 1425-1441.

Hanafizadeh, P., & Harati Nik, M. R. (2020). Configuration of data monetization: A review of literature with thematic analysis. *Global Journal of Flexible Systems Management, 21*(1), 17-34.

Harrington, H. J. (1995). Continuous versus breakthrough improvement: finding the right answer. *Business Process Re-engineering & Management Journal*.

Hartley, J. (2004). Case study research.

Hartmann, L., Meudt, T., Seifermann, S., & Metternich, J. (2018). Value stream method 4.0: holistic method to analyse and design value streams in the digital age. *Procedia cirp, 78*, 249-254.

Hicks, B. J. (2007). Lean information management: Understanding and eliminating waste. *International journal of information management, 27*(4), 233-249.

Hicks, C., McGovern, T., & Earl, C. F. (2001). A typology of UK engineer-to-order companies. *International Journal of Logistics, 4*(1), 43-56.

Hines, P., Holweg, M., & Rich, N. (2004). Learning to evolve: a review of contemporary lean thinking. *International Journal of Operations & Production Management*.

Hinton, C. M. (2002). Towards a pattern language for information-centred business change. *International journal of information management, 22*(5), 325-341.

Hoellthaler, G., Meister, F., Braunreuther, S., & Reinhart, G. (2020). Function framework for describing digital technologies in the context of lean production. *Procedia cirp, 88*, 167-172.

Hopp, W. J., & Spearman, M. L. (2004). To pull or not to pull: what is the question? *Manufacturing & service operations management, 6*(2), 133-148.

Jacobsen, D. I. (2005). *Hvordan gjennomføre undersøkelser?: innføring i samfunnsvitenskapelig metode* (Vol. 2). Høyskoleforlaget Kristiansand.

Jacobsen, D. I. (2015). *Hvordan gjennomføre undersøkelser? : innføring i samfunnsvitenskapelig metode* (3. utg. ed.). Cappelen Damm akademisk.

Jina, J., Bhattacharya, A. K., & Walton, A. D. (1996). A new perspective in manufacturing systems design: turbulence management and rapid re–invention. *International Journal of Technology Management, 12*(2), 144-162.

Jina, J., Bhattacharya, A. K., & Walton, A. D. (1997). Applying lean principles for high product variety and low volumes: some issues and propositions. *Logistics Information Management*.

Jünge, G. H., Kjersem, K., Shlopak, M., Alfnes, E., & Halse, L. L. (2015). From First Planner to Last Planner. IFIP International Conference on Advances in Production Management Systems,

Katic, M., & Agarwal, R. (2018). The Flexibility paradox: Achieving ambidexterity in high-variety, low-volume manufacturing. *Global Journal of Flexible Systems Management, 19*(1), 69-86.

Kehoe, D., Little, D., & Lyons, A. (1992). Measuring a company IQ. 1992 Third International Conference on Factory 2000,'Competitive Performance Through Advanced Technology',

Kolberg, D., Knobloch, J., & Zühlke, D. (2017). Towards a lean automation interface for workstations. *International Journal of Production Research, 55*(10), 2845-2856.

Koskela, L. (1999). Management of production in construction: a theoretical view. Proceedings of the 7th Annual Conference of the International Group for Lean Construction,

Koskela, L. (2000). *An exploration towards a production theory and its application to construction*. VTT Technical Research Centre of Finland.

Koskela, L. (2004). Moving on-beyond lean thinking. *Lean Construction Journal, 1*(1), 24-37.

Kroll, H., Horvat, D., & Jäger, A. (2018). *Effects of automatisation and digitalisation on manufacturing companies' production efficiency and innovation performance*.

L Mitchell, M., & M Jolley, J. (2010). *Research design explained*.

Lander, E., & Liker, J. K. (2007). The Toyota Production System and art: making highly customized and creative products the Toyota way. *International Journal of Production Research, 45*(16), 3681-3698.

Lasi, H., Fettke, P., Kemper, H.-G., Feld, T., & Hoffmann, M. (2014). Industry 4.0. *Business & information systems engineering, 6*(4), 239-242.

Laudon, K. C., & Laudon, J. P. (1997). *Management information systems: new approaches to organization and technology*. Prentice Hall PTR.

Le Vassan, M. (1994). Effectiveness of communication in business. *Journal of Educational Research, 4*(1), 35-47.

Lee, Y. T., & Lee, Y. T. (1999). *Initial manufacturing exchange specification (IMES): information model for the process plan-workstation level*. US Department of Commerce, Technology Administration, National Institute of ….

Liker, J. K., & Convis, G. L. (2012). *Toyota way to lean leadership: Achieving and sustaining excellence through leadership development*. McGraw-Hill Education.

Lodhi, A., Köppen, V., Saake, G., & Turowski, K. (2018). *STREAMLINING PROCESSES FOR DIGITALIZATION*.

Lueg, C. (2001). Information, knowledge, and networked minds. *Journal of Knowledge Management*.

Mbakop, A. M., Voufo, J., Biyeme, F., Ngozag, L. A., & Meva'a, L. (2021). Analysis of information flow characteristics in shop floor: state-of-the-art and future research directions for developing countries. *Global Journal of Flexible Systems Management, 22*(1), 43-53.

McAfee, A., Brynjolfsson, E., Davenport, T. H., Patil, D., & Barton, D. (2012). Big data: the management revolution. *Harvard business review, 90*(10), 60-68.

Meier, H., Lagemann, H., Morlock, F., & Rathmann, C. (2013). Key performance indicators for assessing the planning and delivery of industrial services. *Procedia cirp, 11*, 99-104.

Meissner, A., Müller, M., Hermann, A., & Metternich, J. (2018). Digitalization as a catalyst for lean production: A learning factory approach for digital shop floor management. *Procedia manufacturing, 23*, 81-86.

Mentzas, G., Halaris, C., & Kavadias, S. (2001). Modelling business processes with workflow systems: an evaluation of alternative approaches. *International journal of information management, 21*(2), 123-135.

Meudt, T., Metternich, J., & Abele, E. (2017). Value stream mapping 4.0: Holistic examination of value stream and information logistics in production. *CIRP Annals, 66*(1), 413-416.

Modig, N., & Åhlström, P. (2012). *This is lean: Resolving the efficiency paradox* (Vol. 41). Rheologica Stockholm.

Mrugalska, B., & Wyrwicka, M. K. (2017). Towards lean production in industry 4.0. *Procedia engineering, 182*, 466-473.

Muller, A., Schader, C., El-Hage Scialabba, N., Brüggemann, J., Isensee, A., Erb, K.-H., Smith, P., Klocke, P., Leiber, F., & Stolze, M. (2017). Strategies for feeding the world more sustainably with organic agriculture. *Nature communications, 8*(1), 1-13.

Netland, T. H., & Powell, D. J. (2016). *The Routledge companion to lean management*. Routledge.

NHO. (2020). *Næringslivet i Agder*. https://www.nho.no/regionkontor/nho-agder/om-nhoagder/naringslivet-i-agder/

NODE, G. (2020, Oktober 30). *CGE NODE - an industry-driven cluster for ocean technologies*. GCE NODE. https://gcenode.no/participant/

Nonaka, I. (2009). The knowledge-creating company. In *The economic impact of knowledge* (pp. 175-187). Routledge.

NTNU, S. f. f. k. (u.å.). *Oppgavens struktur* https://www.ntnu.no/sekom/oppgavens-struktur

OECD. (2017). *The next production revolution: implications for governments and business*. Organisation for Economic Co-operation and Development OECD.

Olhager, J. (2003). Strategic positioning of the order penetration point. *International journal of production economics, 85*(3), 319-329.

Olhager, J., & Prajogo, D. I. (2012). The impact of manufacturing and supply chain improvement initiatives: A survey comparing make-to-order and make-to-stock firms. *Omega, 40*(2), 159-165.

Omogbai, O., & Salonitis, K. (2017). The Implementation of 5S Lean Tool Using System Dynamics Approach. *Procedia cirp, 60*, 380-385. https://doi.org/10.1016/j.procir.2017.01.057

Oslo, U. o. (2019, 31.01.2019). *Hva er Impact factor*. University of Oslo. https://www.ub.uio.no/skrive-publisere/for-forskere/impact/beregn-impact-factor.html

Ouali, S., Mhiri, M., & Bouzguenda, L. (2016). A multidimensional knowledge model for business process modeling. *Procedia Computer Science, 96*, 654-663.

Pfohl, H.-C., Yahsi, B., & Kurnaz, T. (2017). Concept and diffusion-factors of industry 4.0 in the supply chain. In *Dynamics in Logistics* (pp. 381-390). Springer.

Porter, M. E. (1985). Competitive strategy: Creating and sustaining superior performance. *The free, New York*.

Porter, M. E., & Heppelmann, J. E. (2015). How smart, connected products are transforming companies. *Harvard business review, 93*(10), 96-114.

Portioli-Staudacher, A., & Tantardini, M. (2012). Lean implementation in non-repetitive companies: a survey and analysis. *International Journal of Services and Operations Management, 11*(4), 385-406.

Powell, D., Strandhagen, J. O., Tommelein, I., Ballard, G., & Rossi, M. (2014). A new set of principles for pursuing the lean ideal in engineer-to-order manufacturers. *Procedia cirp, 17*, 571-576.

Prajogo, D., Oke, A., & Olhager, J. (2016). Supply chain processes. *International Journal of Operations & Production Management*.

Puvanasvaran, P., Megat, H., Hong, T. S., & Razali, M. M. (2009). The roles of communication process for an effective lean manufacturing implementation. *Journal of industrial engineering and management, 2*(1), 128-152.

Rahm, E., & Do, H. H. (2000). Data cleaning: Problems and current approaches. *IEEE Data Eng. Bull., 23*(4), 3-13.

Richter, A., Vodanovich, S., Steinhüser, M., & Hannola, L. (2017). IT on the Shop Floor-Challenges of the Digitalization of manufacturing companies.

Rother, M., & Shook, J. (1999). Value Stream Mapping. *Learning to See: Value Stream Mapping to Add Value and Eliminate MUDA.[online]. Source: http://www. sahibkarol. biz/gen/html.(8 October 2014)*.

Rothlauf, F. (2011). *Design of modern heuristics: principles and application* (Vol. 8). Springer.

Samuel, D., Found, P., & Williams, S. J. (2015). How did the publication of the book The Machine That Changed The World change management thinking? Exploring 25 years of lean literature. *International Journal of Operations & Production Management*.

Scholar, G. (u.å.). *About Google Scholar*. https://scholar.google.no/intl/no/scholar/about.html

Sjøbakk, B. (2018). The strategic landscape of Industry 4.0. IFIP International Conference on Advances in Production Management Systems,

Skriv, S. o. (2022, 22.03.22). *Søketeknikker*. Søk og Skriv. https://www.sokogskriv.no/soking/soketeknikker.html#siteringss%C3%B8k

Skaar, J. (2019). The power of lean principles. Proc. 27th Annual Conference of the International Group for Lean Construction (IGLC),

Slomp, J., Bokhorst, J. A., & Germs, R. (2009). A lean production control system for high-variety/low-volume environments: a case study implementation. *Production Planning and Control, 20*(7), 586-595.

Solutions, O. (2020, 2020). *About*. OPS Solutions https://www.opssolutions.no/about

Stapel, K., & Schneider, K. (2014). Managing knowledge on communication and information flow in global software projects. *Expert Systems, 31*(3), 234-252.

Strandhagen, J. W., Vallandingham, L. R., Alfnes, E., & Strandhagen, J. O. (2018). Operationalizing lean principles for lead time reduction in engineer-to-order (ETO) operations: A case study. *IFAC-PapersOnLine, 51*(11), 128-133.

Sugimori, Y., Kusunoki, K., Cho, F., & UCHIKAWA, S. (1977). Toyota production system and kanban system materialization of just-in-time and respect-for-human system. *The international journal of production research, 15*(6), 553-564.

Sundram, V. P. K., Chhetri, P., & Bahrin, A. S. (2020). The consequences of information technology, information sharing and supply chain integration, towards supply chain performance and firm performance. *Journal of International Logistics and Trade, 18*(1), 15-31.

Suri, R., & Krishnamurthy, A. (2003). How to Plan and Implement POLCA: A Material Control System for High–Variety or Custom–Engineered Products. *Center for Quick Response management Technical Report*.

Tezel, B. A. (2011). *Visual management: an exploration of the concept and its implementation in construction* Salford: University of Salford].

Thagaard, T. (2018). *Systematikk og innlevelse : en innføring i kvalitative metoder* (5. utg. ed.). Fagbokforl.

Thagaard, T. (2018). Systematikk og innlevelse: en innføring i kvalitative metoder (5. utg.) Fagbokforlaget.

Thomas, G. (2017). *How to do your research project: A guide for students*. Sage.

Thomas, J. (1993). *Doing critical ethnography* (Vol. 26). Sage.

Tjora, A. H., & Tjora, A. H. (2021). *Kvalitative forskningsmetoder i praksis* (4. utgave. ed.). Gyldendal.

Tobro, R. L. (2017). *Applicability of Lean and Value Stream Mapping Techniques in Turbulent High-Variety, Low-Volume Manufacturing Environments-A Multiple Case Study* NTNU].

Tomanek, D. P., Hufnagl, C., & Schröder, J. (2020). Determining the digitalization degree of information flow in the context of industry 4.0 using the value added heat map. In *Integration of Information Flow for Greening Supply Chain Management* (pp. 159-179). Springer.

Tomanek, D. P., & Schröder, J. (2017). Analysing The Value Of Information Flow By Using The Value Added Heat Map. *Business Logistics in Modern Management*.

Tomašević, I., Stojanović, D., Slović, D., Simeunović, B., & Jovanović, I. (2021). Lean in High-Mix/Low-Volume industry: a systematic literature review. *Production Planning & Control, 32*(12), 1004-1019.

Ulutas, B. (2011). An application of SMED Methodology. *World academy of science, engineering and technology, 79*, 101.

Unit. (2020, 24.04.2020). *Hvordan bruke Oria*. UNIT. https://www.unit.no/hvordan-bruke-oria

Wang, C. L., & Ahmed, P. K. (2003). Organisational learning: a critical review. *The learning organization*.

Warren, T. L. (1985). *Technical Writing: Purpose, Process, and Form*. Wadsworth Publishing Company.

Wohlin, C. (2014). Guidelines for snowballing in systematic literature studies and a replication in software engineering. Proceedings of the 18th international conference on evaluation and assessment in software engineering,

Womack, J. P., & Jones, D. T. (1997). Lean thinking—banish waste and create wealth in your corporation. *Journal of the Operational Research Society, 48*(11), 1148-1148.

Womack, J. P., & Jones, D. T. (2003). *Lean thinking : banish waste and create wealth in your corporation* (Rev. and updated [ed.]. ed.). Free Press.

Yin, R. K. (1994). Discovering the future of the case study. Method in evaluation research. *Evaluation practice, 15*(3), 283-290.

Zangiacomi, A., Pessot, E., Fornasiero, R., Bertetti, M., & Sacco, M. (2020). Moving towards digitalization: a multiple case study in manufacturing. *Production Planning & Control, 31*(2-3), 143-157.

Zheng, P., Lin, T.-J., Chen, C.-H., & Xu, X. (2018). A systematic design approach for service innovation of smart product-service systems. *Journal of Cleaner Production, 201*, 657-667.

Øystese, H. (2019). *A Framework for the Implementation of Takt Time in High-Variety, Low-Volume Manufacturing Environments* NTNU].

Vedlegg A:

Intervjuguide

No.	Spørsmål	Oppfølgingsspørsmål
1	Hva er din arbeidstittel og posisjon i selskapet?	- Hvor lenge har du jobbet i denne produksjons bransjen?
2	Hvordan vil du kategorisere produksjons miljøet?	- Hvilke typer produkter produserer dere? - Er produktene variable og ofte lagd ut ifra spesifikasjoner fra kunden? - Størrelsen på bedriften?
3	Hvilke endringer har produksjon etterspørsel gjennomgått de siste 5 årene?	- Har dere økt fokus på tilbud av noen spesifikke tjenester/produkter? - Hvilke tjenester/produkter ser dere størst økning i utførelse av? - Ser dere økning i etterspørsel etter spesial produkter? - Har dere noen tjenester utover produksjon som dere har hovedfokus på?
4	Fins det tiltak som dere gjøre for å kunne være konkurransedyktige på pris?	-
5	Hvordan vil du beskrive informasjonsflyten mellom produksjonen og administrative-ledelsen?	- Hvilke prosesser syns du er velfungerende? - Hvilke utfordringer mener du selskapet har? -

6	I hvilken grad benytter selskapet deres digitale verktøy i informasjonsflyten? I hvilken grad benytter selskapet deres lean tankegang i organisasjonen?	- Gir denne bruken dere et konkurransefortrinn eventuelt en ulempe? - Er dette et fokusområde hos dere? - På hvilken måte påvirker det selskapet? - Har digitale verktøy ført til uønsket resultat eventuelt en misforståelse? - Hvordan er dine kunnskaper i forhold til Lean? - Tror du Lean ville være implementertbart i deres bedrift og eventuelt hvorfor? - -
7	Hvordan fungerer informasjonsflyten mellom produksjonen og administrative ledelsen gjennom prosjekt-prosessen?	- Er det mye feil-informasjon? - Overflødig informasjon? - Feil informasjon på feil plass? - Ventetid på informasjon? - Vanskelig tilgang til ønsket informasjon? - Vanskelig å dele informasjon? -
8	Anser dere et behov for å gjøre endringer / justere informasjonsflyten? Oppfølging til 12	- Ser dere nye muligheter her? - Hva er deres strategi for å håndtere endringene? - Vil det være like attraktivt å fortsette i samme fotspor?
9	Hvordan ser du for deg fremtidig utvikling innen lignende bedrifter når det gjelder den digitale verden?	- Tror du det vil bli endringer i hvordan produksjonen utføres? - Blir det mer etterspørsel etter andre tjenester enn spesial produksjon? - Hvor ser du at deres fokus vil ligge fremover?
10	Tror du det er ulik oppfattelse av, og fokus på, endringer i	- Tror du de store produksjonsselskapene har sterkere ressurser for å håndtere endringer?

	små/mellomstore versus store produksjonsselskaper?	- Hvordan oppfatter du konkurransesituasjonen i bransjen?
12	Hvilke endringer ser dere for dere at selskapet vil gjennomgå for å være konkurransedyktige?	- Hva slags kompetanse ser dere etter i ansettelsesprosesser? - Hvilket fokus har dere på etterutdanning og kompetanseheving? - Hva gjør dere for å bygge og fremme de intellektuelle ressursene som finnes i selskapet? - Gjør selskapet noe for å sikre de intellektuelle ressursene i selskapet? - Opplever du at andre selskaper får konkurransefortrinn som følge av ressursene de har tilgjengelig?
13	Hvordan ser du som leder på ditt ansvar for å bidra til utvikling av tjenester?	- I forhold til digitalisering? - Innovasjon? - I forhold til Lean? - Eller tror du at innovasjonen må komme fra andre hold enn ledelsen? - Hvordan gir du rom for å fremme innovasjon?
14	Har organisasjonen en overordnet strategi og forretningsplan som alle ansatte følger og «verdsetter»?	- Hvor det er en klar strategi gjennom alle ulike prosjekter? - En overordnet, men samtidig en prosjekt-strategi og mål?
15	Har du noe til slutt som du tenker kan være relevant som vi ikke har kommet inn på?	