Supply chain supporting build-to-print products in a small manufacturing company

Author: W.F.J.H. (Willem) van Sambeek
University of Twente, P.O. Box 217, 7500AE Enschede, The Netherlands

ABSTRACT

Business is conducted on a large economy scale these days. This puts tremendous pressure on manufacturing companies to adopt advanced manufacturing practices. However, the newest wave of digital customer engagement is developing in the manufacturing industry. Manufacturing companies offer consumers customized products at high speeds. Companies engage with customers online and invite them to customize and order products through a company website. Orders are produced quickly and delivered quickly. As with most IT changes and IT implementation, also the business has to change. The objective of this research is to investigate how the supply chain of HVL metal & technics has to change, to support their new online customer ordering system. It is academically relevant to study how academic theory and literature can play a role in determining a new supply chain within a manufacturing company. Within this research, it will be studied how different theories and literature on manufacturing processes can be combined. This research could also be academically relevant for companies working in the manufacturing industry which are looking to update their current supply chain to produce more custom products or companies which are having similar issues as the studied company within this research. This research will be practically relevant for HVL metal & technics. HVL can use this research as a basis for the change in their supply chain when the new online build-to-print service will be implemented. The basic structure for this research is based on the design science research process by Peffers. This is a model for producing and presenting information system research. This research concluded that theories and pre-defined processes usually do not hold in small manufacturing companies. These are often only partly, if at all, integrated. Small manufacturing companies work mostly out of their own knowledge and insights. When trying to get a complete and theory-based overview of the processes within a small manufacturing company, it is difficult to base this on only one existing theory. Therefore, it helps to look into multiple theories that could collectively describe the processes within a small manufacturing company. This way of exploring and expanding the existing literature is called an integrative literature study. For HVL metal & technics, this meant that their new ordering process will be based up on four different theories. These are: lean manufacturing, computer integrated manufacturing, high-speed bespoke supply chain and build-to-print service. This research discusses how these four theories can be combined and shows what the new ordering process will look like when HVL implement their online build-to-print service. The added value can be obtained through the following. For manufacturing companies, it is important to keep the focus within their ordering process, on what their manufacturing unit is built for. In order to maximize profit within a manufacturing company, all manufacturing machines should produce as many hours as possible. When a manufacturing company offers a wide variety of operations, it is key to keep their main focus on orders that include as many of these operations as possible. To keep your focus on the orders that offer the most value to the company as well as the customer, a clear split should be implemented between different types of orders. Therefore, a second supply chain should be set up, while keeping the base supply chain in place. In case of HVL metal & technics, their base supply chain will remain a lean supply chain and their sub-supply chain will become a high-speed bespoke supply chain.

Graduation Committee member: 1st examiner: DR.IR. A.A.M. SPIL, 2nd examiner: DR. P.C. SCHUUR

Keywords: HVL metaal & techniek, lean manufacturing, computer integrated manufacturing, build to print service, high-speed bespoke supply chain

Table of Contents

1. Problem identification and motivation

The first chapter will focus on defining the specific research problem and justifying the value of a solution. Along with the problem, also a research question will be presented. This research question is mentioned in section 1.3. The academic and practical relevance (section 1.5 and 1.6) also motivate the importance of this research. Chapter 1 about the problem identification and motivation can be seen as the introduction of this research. For small manufacturing companies, little theory can be found on ordering processes. This research will look into creating a theory-based ordering process for a small manufacturing company.

1.1 Situation and problem

Business is conducted on a large economy scale these days. This puts tremendous pressure on manufacturing companies to adopt advanced manufacturing practices. These adoptions are made to achieve sustainable competitive advantages for the sustainable development of the organization. The key to achieve sustainable development concerns the customer satisfaction. This is reached through: improved quality, reduced cost, reduced delivery lead and proper communication (Nejati, 2010). To improve customer satisfaction, the manufacturing company should select the suitable manufacturing system. This manufacturing system should optimize the available resources to produce a product that is valuable for the customer.

HVL metal and technics is also looking for a way to achieve sustainable development through improving customer satisfaction. HVL metal and technics is a company located in Liessel (the Netherlands) and is specialized in metal fabrication. The company was started by Hans Vervoordeldonk in 1994. Currently, HVL has more than 80 employees working in a facility of 12500m². HVL builds machines and modules from metal (HVL metaal & Techniek, 2021). The highest possible quality is the standard for all products produced by HVL. The company is also active with inventing smart solutions and systems that incorporate the capabilities of their fabrication process. This research will focus on one of these smart solutions.

HVL receives all sorts of different orders. The orders differ from simple metal components to large, complicated machines and products. An example of a simple order could be a 100mmx100mm stainless steel plate. An example of a complicated order could be a completely custom, stainless steel indoor swimming pool. Currently, the simple orders go through the same process as the complicated orders.

The problem is that within the current supply chain, it takes HVL too much effort and time for the simple orders. There is also lost effort and time, since the drawings of the customer, have to be re-drawn by HVL. HVL would like to solve this issue. The current supply chain will be further elaborated on in chapter 4. In section 1.2, a potential solution will be discussed.

1.2 Objectives of a solution

The newest wave of digital customer engagement is developing in the manufacturing industry. Manufacturing companies offer consumers customized products at high speeds. This is called mass customization (Jiao, Wang, & Tseng, 2017). Companies engage with customers online and invite them to customize and order products through a company website. Orders are produced quickly and delivered quickly. These new supply chains are called high-speed bespoke supply chains, because they provide both speed and product customization (Sodhi & Tang, 2017). Bespoke is a synonym for custom.

While the emergence of this new model is a phenomenon of manufacturing and fulfilment of personalized products, its value extends to rarely ordered products as well. These promising opportunities also bring new challenges for the manufacturer company. These companies need to strategically modify their supply chain model within their operations.

To solve the issue described in section 1.1, HVL wants to focus more on the mass customization trend. HVL wants to set up an online platform for their top customers where they can place orders. This online platform should solve the issue of the simple orders taking too much time and effort. The online customer ordering system should automate and digitalize the process from the arrival of a new order till the start of the

production. The new process will be beneficial for HVL and for HVL customers. It will save both parties: time, effort and money (Hobbs, 2004).

As with most IT changes and IT implementation, also business processes have to change (Elvin & Ward, 1999). The objective of this research is to investigate how the supply chain of HVL has to change, to support their new online customer ordering system. The combination of the online customer order system and a change within the supply chain should automate and digitalize the process from the arrival of a new order till the start of the production. To investigate what supply chain is needed, the design science research process by K. Peffers will be used (Peffers, et al., 2006). In chapter 3, an explanation on the methodology can be found.

1.3 Research Question

How can a small manufacturing company create a new supply chain that supports build-to-print products?

This research question will be answered through first answering the following sub-questions:

- What theories can be found on supply chain that support online build-to-print platforms? And could these theories be combined?

- What is the current supply chain for simple orders within HVL?

- What are the wishes, demands, vision, principals and constrains of HVL for the new supply chain that should support the online build-to-print service?

1.4 Theoretical Framework

In this section, the basics of four theories correlating with the research objective will be introduced. The findings within these theories will be used when answering the research question. These theories will be further elaborated on in chapter 3. In chapter 3.5, a combination of these theories is also included.

1.4.1 High-speed bespoke supply chain

The first theory that will be discussed is the high-speed bespoke supply chain. As the name itself already says, this type of supply chain focusses on high speeds of production and delivery. On top of that, all products are bespoke, which means they are a custom fit for a specific customer. A high-speed bespoke supply chains fit the needs of make-to-order products based on realized demand, not forecasts (Sodhi & Tang, 2017).

1.4.2 Computer integrated manufacturing

The second theory that will be described is Computer integrated manufacturing. Computer integrated manufacturing includes all engineering functions and all the business functions of a company. In an ideal computer integrated manufacturing system, computer technology is applied to all operational and information-processing functions of the company (Alavudeen & Venkateshwaran, 2010).

1.4.3 Build to spec vs. Build to print

The third theory that will be elaborated on is the difference between build to spec and build to print. In case of this research, we are focusing on the build to print principle. Build to print is a process in which a manufacturer produces products, equipment, or components according to the customer's exact specifications. The customer provides drawings and the manufacturer is responsible for producing the order to the correct spec, while using the correct materials (Elitesoh, 2014).

1.4.4 Lean manufacturing

The fourth theory that will be described is lean manufacturing. Lean manufacturing is a methodology that focuses on minimizing waste within manufacturing systems while simultaneously maximizing productivity. Waste is seen as anything that customers do not believe adds value and are not willing to pay for (Hobbs, 2004).

1.5 Academic Relevance

It is, in general, academically relevant to study how academic theory and literature can play a role in determining a new supply chain within a manufacturing company. Within this research, it will be studied how different theories and literature on manufacturing processes can be combined. These theories have never been combined before. The goal will be to combine the following four theories: high-speed bespoke supply chain, computer integrated manufacturing, build to print and lean manufacturing. Next, it will be attempted to apply this new combined theory to a small manufacturing company. This will be relevant for other researchers interested in supply chains that support custom products, within small manufacturing companies. It could also be academically relevant for companies working in the manufacturing industry which are looking to update their current supply chain to produce more custom products or companies which are having similar issues as the studied company within this research.

1.6 Practical Relevance

This research will be practically relevant for HVL metal & technics. HVL can use this research as a basis for the change in their supply chain when the new online build-to-print service will be implemented. The practical relevance for HVL also concerns solving the issues HVL is dealing with as described in section 1.1. This practical relevance also holds for the customers of HVL. For the customer, the ordering process will become more efficient as well. They will receive the price and delivery date directly. Beforehand, they had to wait a few days for it.

1.7 Research Design

The research question will be answered using primary and secondary data. The basic structure for this research will be based on the design science research process by K. Peffers. This is a model for producing and presenting information system research (Peffers, et al., 2006). This model consists of six different topics. These are:

1. Problem identification and motivation
2. Objectives of a solution
3. Design and development
4. Demonstration
5. Evaluation
6. Communication

Within these topics, some sub-topics are included. Within chapter 1, the problem identification and motivation are discussed. Within the objectives of a solution, a literature study is performed. The design and development topic includes the current supply chain of HVL and an internal research within HVL. In the demonstration topic an advice for the new supply chain will be given. With the combination of the learned theories, HVL's current ordering process and an internal research within HVL to know HVL's wishes, demands, vision, principals and constrains, it will be possible to create the new supply chain for HVL's online build-to-print service. In the evaluation section, chapter 6, the discussion and recommendation are presented. An elaborate explanation on the methodology can be found in chapter 2. The sub-questions are also included within the methodology.

2. Methodology

The basic structure for this research will be based on the design science research process by K. Peffers. This is a model for producing and presenting information system research (Peffers, et al., 2006). A visualization of the model is shown in figure 1. This model consists of six different topics. These topics are: problem identification & motivation, objectives of a solution, design & development, demonstration, evaluation and communication. Within this research, the six main topics are supported by multiple sub-topics. As can be seen in the model in figure 1, there are multiple approaches which can be used within this model. The model has four possible entry points: problem centered approach, objective centered approach, design & development centered approach and observing a solution. In the following six sub-sections (section 3.1 till 3.6), the methodology for each topic will be explained.

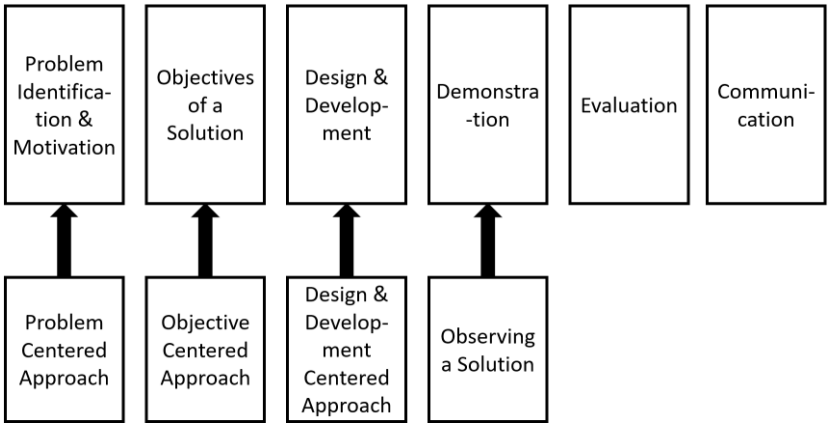


FIGURE 1

Within this research the problem centered approach was used. HVL has defined a clear problem, but the appropriate solution for the supply chain is still not clear. Therefore, this research will generate a solution to HVL's problem. This will be done by starting at the problem identification and motivation entry-point. After that the following steps will follow: objectives of a solution, design and development, demonstration, evaluation and communication. This research is, for example, not observing an already defined solution and is therefore not starting at the demonstration entry-point.

2.1 Problem identification and motivation

The first topic of the design science research model is: the problem identification and motivation. This should focus on defining the specific research problem and justifying the value of a solution. The problem and its motivations are presented in chapter 1. Along with the problem, also a research question has been created. This research question is mentioned in section 1.3. The academic and practical relevance (section 1.5 and 1.6) also motivate the importance of this research. Chapter 1 about the problem identification and motivation can be seen as the introduction of this research.

2.2 Objectives of a solution

The second topic of the design science research model is: the objectives of a solution. The objectives of a solution should be inferred from the problem description. The objectives of a solution are shortly presented in section 1.2 and section 1.4. The literature used is broadly elaborated on in chapter 3. This literature study will be done on different theories about manufacturing processes and it will be investigated whether it is possible to combine these different theories. This type of literature study is called an integrative literature review. An integrative literature review focuses on a pool of theory that focuses on an issue, concept or theory (Snyder, 2019). In case of this research, the theoretical literature study will focus on finding theories that could help set up a new supply chain that supports an online build-to-print service for HVL. An integrative literature review requires a more creative way of collecting data, as the purpose is not to cover all articles ever published on the topic, but to combine perspectives and insights (Snyder, 2019). This makes the integrative literature review a

distinctive form of research that generates new knowledge about the topic reviewed (Torraco, 2005).The research question for this section is: what theories can be found on supply chain that support online build-to-print platforms? And could these theories be combined?

2.3 Design and development

The third topic of the design science research model is: the design and development. In this section the architecture and desired functionalities should be discovered. This topic will be split in two sections. Each section has its own research question that will be answered in these sections.

2.3.1 Mapping out current supply chain of HVL

The first design and development sub-section consists of mapping out the current supply chain for the simple orders within HVL. This is presented in chapter 4.1. The current ordering process will be described step-by-step. This will be done through analyzing the complete process of a simple order placed by a customer. The research question that this section will focus on is: what is the current supply chain for simple orders within HVL?

2.3.2 Internal research within HVL

The second design and development sub-section consists of an internal research within HVL. This will be done through interviews, to get to know possible wishes and demands from different departments. In this internal research, also potential vision, principals and constrains of HVL should be considered. The results of these interviews are presented in chapter 4.2. These interviews will be semi-structured interviews. In this type of interview, the interviewer may prepare a list of questions but will not necessarily ask them all, or touch on them in any particular order. Instead, they are used to guide the conversation (Doyle, 2020). This type of interview was chosen, because within this interview type, follow-up questions can be asked based on the answers to the previous questions. The research question this section will focus on: is what are the wishes, demands, vision, principals and constrains of HVL for the new supply chain that should support the online build-to-print service?

2.4 Demonstration

The fourth topic of the design science research model is: the demonstration. In chapter 5, the new structure for HVL's supply chain will be presented. This will be done by using the gained knowledge in the objectives of a solution and the design and development phases. With the combination of the learned theories, the current ordering process and HVL's wishes, demands, vision, principals and constrains learned from the internal research, it will be possible to create the structure of the new supply chain that supports HVL's online build to print service. Also new tasks for some employees will be discussed.

2.5 Evaluation

The fifth topic of the design science research model is: the evaluation. This research is primarily a case study and is focused on HVL, however the conclusions could also be retrofit to other companies facing similar problems. Therefore, in this section, it will be concluded how well the presented new supply chain supports a solution to the problem for HVL. It will also be discussed whether this solution could be a solution to other companies facing similar problems. The research question will be answered within this section. Recommendations for further research and as well as discussions about this research are covered, within a sub-section.

2.6 Communication

The sixth topic of the design science research model is: the communication. The goal of the communication topic is to distribute the knowledge gained in the other five topics. The knowledge gained in this research will be communicated through this report. It will be shared with the University of Twente and with HVL metal & technics. When needed, it can also be shared with other interested people of practicing professionals. The

importance for communicating this report, are presented in the academic and practical relevance in section 1.5 and 1.6.

3. Objectives of a solution

During this research an integrative literature review was performed. An integrative literature review requires a more creative way of collecting data, as the purpose is not to cover all articles ever published on the topic, but to combine perspectives and insights (Snyder, 2019). This makes the integrative literature review a distinctive form of research that generates new knowledge about the topic reviewed (Torraco, 2005).

All searches for literature were performed on scientific literature platforms. In total 32 different articles were read on 7 different theories. Within this research, 4 of these 7 theories will be used and combined to create a new integrative theory. For these 4 theories, 17 references have been used. Next, the search terms for each theory will be mentioned.

During lectures, mass customization was often mentioned. In these lectures, Nike was often used as an example. Therefore, the following search terms were used: Nike shoe customization. While reading multiple articles about Nike's supply chain for their custom shoe production process, the High-speed bespoke supply chain theory by Sodhi and Tang was found. I came across this theory, because Nike was used as an example within this report by Sodhi and Tang.

Multiple prior conversations within HVL showed that HVL is current using lean manufacturing as their base supply chain. Therefore, the search terms that found the theory about lean manufacturing, were simply: lean manufacturing. When reading multiple other papers about lean, it became clear that the theory is originally created by Womack and Jones. Therefore, this reference is mostly used to describe the theory of lean manufacturing. Also, a report by Hobbs was used to describe the benefits. This report was found using the search terms: importance lean manufacturing.

During a conversation with A.A.M. Spil, computer integrated manufacturing came to the discussion. Since this discussion was interesting, this theory was further researched. The following search terms were used: computer integrated manufacturing. 4 reports or books were read in total, of which 2 are used within this research. The book by Alavudeen & Venkateshwaran was used to generally explain the theory. The book by Scheer was used to explain the three steps involved within computer integrated manufacturing.

In the search for the correct denomination for an online customer ordering platform for custom products, 4 different options were considered. Finally, the denomination settled on an online build-to-print service. The article that explained this was written by Elitesoh. This article was found using the following search terms: customer's specifications and service.

This section will first elaborate further on the, in section 1.4, shortly described four theories. After that, combinations of these theories found in existing literature will be discussed. Finally, the created integrative theory will be presented. The research question for this section is: what theories can be found on supply chain that support online build-to-print platforms? And could these theories be combined?

3.1 High-speed bespoke supply chain

Having the right type of base supply chain is well-understood by manufacturers. Two well-known options are: lean for cost-efficiency or agile for time-efficiency. It is a choice that depends on whether the products are functional goods for which cost matters most, or fashion goods (innovative products) for which time to market is critical. High-speed bespoke supply chains add a third option to these types of supply chains. Whether a company employs a lean supply chain, an agile supply chain or a combination of both, its operations are meant to be optimized for make-to-stock products based on forecasts. By contrast, high-speed bespoke supply chains fit the needs of make-to-order products based on realized demand, not forecasts (Sodhi & Tang, 2017). x

An advantage to extending the lean-agile framework with a high-speed bespoke supply chain: Supply chain managers gain a more cost-effective option for fulfilling low-volume items. Another advantage is that developing a high-speed bespoke supply chain allows a manufacturing company to add more product variety

with niche demand. A third advantage is that customers have shown their willingness to pay more for products they have shaped or customized themselves (Sodhi & Tang, 2017).

Although unit manufacturing costs in a high-speed bespoke supply chain are higher than in the base (lean or agile) supply chain, the total supply chain's cost per unit can be lower for products with low demand, because manufacturing-complexity related, inventory-related and transportation-related costs are greatly reduced. This is due to the fact that manufacturing facilities are build close to customers for quick delivery and therefore onshore. Thus, high-speed bespoke supply chains translate into in-country manufacturing facilities. The bulk of manufacturing however would remain in the base supply chains that originate in low-cost offshore locations, because custom unit sales will remain a small but valuable portion of overall unit sales (Sodhi & Tang, 2017).

3.2 Computer integrated manufacturing

The second theory that will be described is Computer integrated manufacturing. Computer integrated manufacturing includes all engineering functions and all the business functions of a company. These business functions include, among other functions, the following: design, analysis, planning, purchasing, cost accounting, inventory control and distribution (Alavudeen & Venkateshwaran, 2010).

In an ideal computer integrated manufacturing system, computer technology is applied to all operational and information-processing functions of the company, from customer order through design and production to product shipment and customer service. The scope of the computer system includes all activities that are concerned with manufacturing. In many ways, computer integrated manufacturing represents the highest level of automation in manufacturing. Once a product is designed, its production process can be outlined using computer-aided process planning systems that help select sequences of operations and machining conditions. This can enable manufacturing companies to produce small batches of simple products, where it was previously only profitable to mass produce identical objects (Alavudeen & Venkateshwaran, 2010).

Computer integrated manufacturing should at least involve the following three parts: an application-independent data organization, consistent process chains and small feedback loops (Scheer, 2012). Firstly, an application-independent data organization means that data structures are designed independent of their individual applications. They should be generalized that they can be used for various tasks. This is done through a database-oriented information system, often an ERP-system. Secondly, process chains are a characteristic of computer integrated manufacturing. Processes are considered in terms of their connectedness, independency of organizational structures and are supported by the database-oriented information system. Thirdly, small feedback loops means that, within any process, planned-actual comparisons are made continually (Scheer, 2012).

3.3 Build to spec vs. Build to print

The third theory that will be elaborated on is the difference between build to spec and build to print. Build to specification is when the customer needs a component of which the specific size and the specific parameters regarding its operation are known. The customer gives these specifications to a manufacturing company, which will manufacture the component. The actual degree of specifications of the component may vary, but the manufacturer has the liberty to utilize their design expertise and manufacturing skill to manufacture the part that will be supplied to the customer (Elitesoh, 2014).

On the other hand, there is the build to print principal. Build to print is a process in which a manufacturer produces products, equipment, or components according to the customer's exact specifications. The customer provides drawings and the manufacturer is responsible for producing the order to correct spec, while using the correct materials. This method requires a little more effort and development costs from the customer's side. An advantage for the customer is that the customer maintains control of the intellectual property right while having the flexibility to select the appropriate supplier to produce the components (Elitesoh, 2014).

3.4 Lean manufacturing

The fourth theory that will be described is lean manufacturing. Lean manufacturing is a methodology that focuses on minimizing waste within manufacturing systems while simultaneously maximizing productivity. Waste is seen as anything that customers do not believe adds value and are not willing to pay for. Some of the benefits of lean manufacturing can include reduced lead times, reduced operating costs and improved product quality (Hobbs, 2004).

Lean consists of five principles. These principles are: value, the value stream, flow, pull and perfection. These principles are used as the basis for lean implementation.

Firstly, value should be identified from the customer's perspective. Value is created by the manufacturer, but value is defined by the customer's needs (Womack & Jones, 1996).

Secondly, the value stream should be mapped out. This principle involves recording and analyzing the flow of information or materials required to produce a specific product or service with the intent of identifying waste and methods of improvement (Womack & Jones, 1996).

Thirdly, flow should be created. Eliminate functional barriers and identify ways to improve lead time. Lean manufacturing relies on preventing interruptions in the production process and enabling a harmonized and integrated set of processes in which activities move in a constant stream (Womack & Jones, 1996).

Fourthly, a pull system should be established. This means production is only started when there is demand for it. Lean manufacturing uses a pull system instead of a push system (Womack & Jones, 1996).

Fifthly, perfection should be pursued by continuous process improvement. Lean manufacturing rests on the concept of continuously striving for perfection. This involves targeting the root causes of issues and eliminating waste across the value stream (Womack & Jones, 1996).

3.5 Combining the four theories

The previous four sub-sections (section 3.1 till 3.4) were different theories about manufacturing processes. Next, it will be investigated whether possible combinations between these 4 theories already exist in the literature. After that, a possible combination between these different theories will be presented. (Snyder, 2019).

3.5.1 Existing combinations in literature

in the high-speed bespoke supply chain theory, lean is often mentioned. Besides that, no combination between two of the four discussed theories was found in other existing literature. However, a comparison between industry 4.0 and lean manufacturing was found. Industry 4.0 has not been discussed in this research, but it has a lot of similarities with computer integrated manufacturing. Therefore, this comparison will also be shortly discussed.

3.5.1.1 High-speed bespoke supply chain and lean manufacturing

This combination has already been discussed in the last paragraph of section 3.1. In this section, the combination between a high-speed bespoke supply chain and lean manufacturing will be further explained through an example of Adidas, mentioned in the paper of Sodhi and Tang. As mentioned before, a high-speed bespoke supply chain can be an addition to the base lean supply chain.

Sports clothing company Adidas offers customization of its shoes through its "MiAdidas" online platform. Adidas has built its first "speed-factory" in Germany to add high-speed manufacturing to its bespoke product offering (Sodhi & Tang, 2017). The company plans to open additional factories in western countries. This way, the factories are closer to the customers. The company will continue to order over 300 million standard pairs of shoes a year from its Asian contractors in its base lean supply chain. Besides its base supply chain, Adidas wants the new factories to be able to produce an estimated 1 million customer-designed pairs of shoes a year, to meet high-priced bespoke demand in western countries. Adidas plans to drastically shrink the time between custom orders and delivery with these new factories to four to five business days. Currently, it takes Adidas 4-6

weeks with MiAdidas to deliver these custom shoes. With this new high-speed bespoke supply chain, a customer would design and order a dream pair of shoes on Monday, and receive the pair on Friday.

3.5.1.2 Industry 4.0 and lean manufacturing

Industry 4.0 is all about using computer technology and artificial intelligence to improve production. This definition is similar to computer integrated manufacturing. Industry 4.0 is quite similar to lean manufacturing, but there are four differences. These four differences will be explained in this section (Roser, 2018).

Firstly, industry 4.0 purely focuses on computers, automation, and robotics. Lean mainly focusses on working with people and lean looks at their needs and how they interact with each other. Secondly, industry 4.0 focusses on computers, automation and networks. On the contrary, lean does not purely focus on solutions which involve computer technology. If the best solution includes a computer, lean manufacturing will happily use computers, automation, networks, and any other computer-related aspects too. Thirdly, there is a difference in speed of change. Within lean, it is possible to have easy and quick-fix solutions. industry 4.0 is hardware- and software-heavy. Any change always requires a programmer and technicians, which will take more time than a simple change within lean will. Finally, there is a difference when it comes to making improvements. Within lean, continuous improvement is one of the main aspects. However, due to the slower speed of changes and implementations in Industry 4.0, most Industry 4.0 applications are more static and not as flexible as lean manufacturing.

3.5.2 General integrative theory

The general integrative theory will be explained in this section. This integrative theory uses the following four theories: lean manufacturing, computer integrated manufacturing, high-speed bespoke supply chain and online build-to-print service.

Lean manufacturing is the basis for the integrative theory. Lean manufacturing is a methodology that focuses on minimizing waste within manufacturing systems while simultaneously maximizing productivity. Waste is seen as anything that customers do not believe adds value and are not willing to pay for. The opposite of waste is value. Value is created by the manufacturer, but value is defined by the customer's needs (Womack & Jones, 1996). Benefits of lean manufacturing are reduced lead times, reduced operating costs and improved product quality (Hobbs, 2004). These benefits add value to the customer and to the manufacturing company.

A way of eliminating waste, adding more value and thus becoming more lean, is to improve through computer integrated manufacturing. Computer integrated manufacturing includes all engineering functions and all the business functions of a company.

Computer integrated manufacturing purely focuses on solutions which involve computers, automation, and robotics. Lean also focusses on working with people and lean looks at their needs and how they interact with each other (Roser, 2018). It is important to keep lean as a basis, to not forget about the employees and the customers opinion. However, when an issue can be solved using computer technology, computer integrated manufacturing can be used.

In an ideal computer integrated manufacturing system, computer technology is applied to all operational and information-processing functions of the company. In many ways, computer integrated manufacturing represents the highest level of automation in manufacturing. Once a product is designed, many parts of its supply chain can be automated by computer-aided software. This can enable manufacturing companies to produce small batches of simple products, where it was previously only profitable to mass produce identical objects (Alavudeen & Venkateshwaran, 2010).

An example of such an operational and information-processing function that can be automated is the customer order process. A way to include computer technology within the customer order process, is to set up an online build-to-print service. Build-to-print is a process in which a manufacturer produces products, equipment, or components according to the customer's exact specifications. The customer provides drawings and the manufacturer is responsible for producing the order to the correct spec, while using the correct materials

(Elitesoh, 2014). It is often seen that the customer is able to share these drawings with the manufacturing company via a website provided by the manufacturing company.

The orders received through such an online build-to-print service are small make-to-order products. However, lean manufacturing is based around the make-to-stock principle. By contrast, high-speed bespoke supply chains fit the needs of make-to-order products based on realized demand, not forecasts (Sodhi & Tang, 2017). As the name itself already says, this type of supply chain focusses on high speeds of production and delivery. On top of that, all products are bespoke, which means that they are a custom fit for a specific customer. This fits the needs for the online build-to-print service. On top of that it also supports the principles of lean, because it reduces lead times, reduces operating costs for these make-to-order products (Hobbs, 2004).

The high-speed bespoke supply chain is often used as an extension to the base supply chain. This offers multiple advantages. Firstly, supply chain managers gain a more cost-effective option for fulfilling low-volume items. Secondly, developing a high-speed bespoke supply chain allows a manufacturing company to add more product variety with niche demand. Thirdly, customers have shown their willingness to pay more for products they have shaped or customized themselves (Sodhi & Tang, 2017).

Although unit manufacturing costs in a high-speed bespoke supply chain are higher than in the base lean supply chain, the total supply chain's cost per unit can be lower for products with low demand, because manufacturing-complexity related, inventory-related and transportation-related costs are greatly reduced (Sodhi & Tang, 2017).

3.5.3 Integrative theory visualized

In figure 2, a visualization of the integrative theory that was explained in section 3.5.2 is shown. In figure 2, it becomes clear that lean remains the base supply chain. Lean is extended by the high-speed bespoke supply chain to support the make-to-order products, because digital customer engagement is developing in the manufacturing industry. Manufacturing companies offer consumers customized products at high speeds via online customer order platforms. Currently, lean and high-speed bespoke supply chain still have a small connection, because both supply chains will share the same warehouse and some manufacturing units. The processes will only be split in the office. In the future, this may change. Then the high-speed bespoke supply chain may get its own manufacturing unit.

Within these modern manufacturing companies, computer integrated manufacturing is used to combine all engineering functions and all the business functions of a company. That explains why computer integrated manufacturing is equally connected to both types of supply chains. Computer integrated manufacturing offers the ERP system to the lean supply chain and to the high-speed bespoke supply chain. Computer integrated manufacturing is also used for the build-to-print service, since it will be set up using computer technology.

With this high-speed bespoke supply chain in place, it is possible to set up the online build-to-print service, to be able to deliver customized products at high speeds. This service will be the place where customers place their orders with the desired exact specifications. This build-to-print service automates the information-processing function of the customer order process. As mentioned before, for this online build-to-print service a second supply chain is needed. Which in this case, is the high-speed bespoke supply chain. This explains why there is an equal connection between build-to-print service and computer integrated manufacturing, and between build-to-print service and high-speed bespoke supply chain.

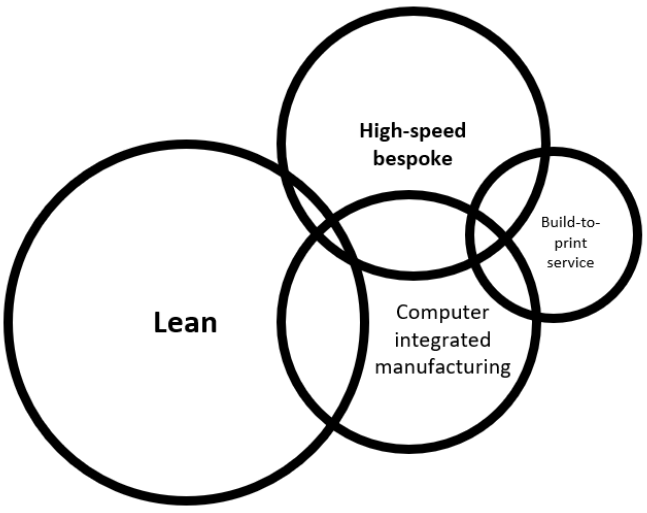


FIGURE 2

3.5.4 Integrative theory applied to HVL

In the ideal situation, the integrative theory may be applied to HVL in the following way. HVL is currently using lean manufacturing as their base supply chain. HVL wants to become more lean by eliminating more waste. They saw constrains within their ordering process for the simple orders. HVL wants to eliminate the waste of spending so much time on the simple orders and therefore making less profit on these simple products, because they are more expensive to produce. They want to do this by improving on their computer integrated manufacturing within the customer order process. This creates a better integration between the business and IT. To do this, they are planning on setting up an online build-to-print service. This online build-to-print service should allow customers to upload the drawing to an online website, instead of sending them via an E-mail. However, their current lean supply chain is not ideal for an online custom ordering platform. They need to extend their current supply chain with a second supply chain. This second supply chain will be a high-speed bespoke supply chain. This type of supply chain focuses on small quantities and custom orders delivered at high speeds through an online website available to its customers.

As mentioned before, this described situation would be the ideal way to apply the integrative theory within HVL. However, this will probably not go as smoothly. Within the high-speed bespoke supply chain theory, not only the tasks within the office changes, but also the complete production process. For companies that add a high-speed bespoke supply chain to their base supply chain, it is usual to build an entire new production facility specifically for this new supply chain. This is not expected to happen within HVL. HVL is planning on changing the ordering process for the small orders, by using an online build-to-print service. With the implementation of the online build-to-print service, they only change the tasks within the office, not the production tasks. HVL currently no plans to build an entirely new production facility for a high-speed bespoke supply chain. They plan on using the same production procedure they are currently using for their larger B and C orders. Only the tasks that are performed within the office in the ordering process for simple orders will change. However, HVL does believe that it will be possible to have two separate supply chains. The lean supply chain they are used to for the B and C-orders. The high-speed bespoke supply chain for the A-orders.

It is also expected that not every customer is willing to use the new online system, instead of using E-mails to place orders. Therefore, the online build-to-print system could also be used internally. For example, when some customers do not want to use the online build-to-print system, the sales department of HVL could use the new system themselves with the drawings send by the customer via E-mail. This way the sales department will immediately have a price and delivery date.

3.6 Summary objectives of a solution

Chapter 3, the objectives of a solution discussed four different theories and presented an integrative theory of these four theories. The discussed theories are: lean manufacturing, high-speed bespoke supply chain, computer integrated manufacturing and build-to-print service. First of all, lean manufacturing is a methodology that focuses on minimizing waste within manufacturing systems while simultaneously maximizing productivity. Secondly, the high-speed bespoke supply chain focusses on high speeds of production and delivery. On top of that, all products are bespoke, which means that they are a custom fit for a specific customer. Thirdly, computer integrated manufacturing includes all engineering functions and all the business functions of a company. In an ideal computer integrated manufacturing system, computer technology is applied to all operational and information-processing functions of the company. Finally, build to print is a process in which a manufacturer produces products, equipment, or components according to the customer's exact specifications. The customer provides drawings and the manufacturer is responsible for producing the order to correct spec, while using the correct materials.

In short, the integrative theory created with these four theories is as follows. Lean manufacturing is the basis for the integrative theory. A way of eliminating waste, adding more value and thus becoming more lean, is to improve on computer integrated manufacturing. An example of an operational and information-processing function that can be automated is the customer order process. A way to include computer technology within the customer order process, is to set up an online build-to-print service. The orders received through such an

online build-to-print service are small make-to-order products. A high-speed bespoke supply chains fit the needs of these make-to-order products much better than the base lean supply chain does. Therefore, a sub-supply chain, the high-speed bespoke supply chain, is added to the base lean supply chain.

4. Design and development

The fourth chapter is the design and development chapter. In this chapter the architecture and desired functionalities should be discovered. This topic will be split in two sections. In section 4.1 the current ordering process of HVL will be discussed. In section 4.2, the internal research within HVL will be elaborated on. This includes the wishes and demands for the new ordering process, as well as the value and vision of HVL. Also, it will be checked how the four previously discussed theories fit within HVL.

4.1 Current ordering process at HVL

In this chapter, the ordering process for the simple orders at HVL metal & technics will be described. All the information in this chapter was gathered through following an order through the complete ordering process through all the different departments. Every task of each department has been documented and will be elaborated on. This chapter will answer the following sub-research question: what is the current supply chain for simple orders within HVL?

4.1.1 Different types of orders

At the moment HVL is using MKG as their ERP system. This system is the basis for their ordering process. MKG is an ERP system specifically designed for the metal manufacturing industry (MKG, 2021). HVL receives three different types of orders. They have divided these different types of orders into three categories, named as A, B and C-orders.

A-orders are the simplest orders. Only laser cutting on sheet-metal laser and pressing on the press brake, is involved within the A-orders. There are no welding, assembly or other tasks involved within A-orders. Examples of these A-orders can be seen in figure 3.

FIGURE 3

An order becomes a B-order when there are, besides cutting and pressing, also welding and assembly tasks involved within the order. Also, tubes are included within B-orders. An order becomes a C-order, when it requires a lot of work. C-orders are the larger projects. For example, projects that require 60 hours of welding and assembly. An example of such a C-order is a custom indoor stainless-steel swimming pool. This can be seen in figure 4 and in figure 5 the underside of the pool can be seen.

FIGURE 4

FIGURE 5

HVL choose to divide the order types, for the task division within the product-engineering department. From all the staff at the product-engineering department, only one person is allowed to work on a C-order. This way not all employees are focusing on big orders and therefore the smaller A and B-orders do not stack up.

4.1.2 Focus on A-orders

The online build-to-print service will only support the A-orders. When orders start to include welding and assembly, it is much more difficult to automate this, because the welding robot needs different drawings. Also, within B and C orders, much more communication is happening between the different departments in the office and the production department in the manufacturing hall during the welding and assembly phase. With an online build-to-print service, the product-engineering department will be less involved with these simple orders. This is undesirable for the B and C orders, because these require communication between the product-engineering department and the welders and assemblers within the production department.

4.1.3 The ordering process

Next, the ordering process for the simple orders, type A-orders, within HVL metal & technics will be described. Each step will be discussed in detail. The ordering process has been made more visible in figure 6 and Appendix A.

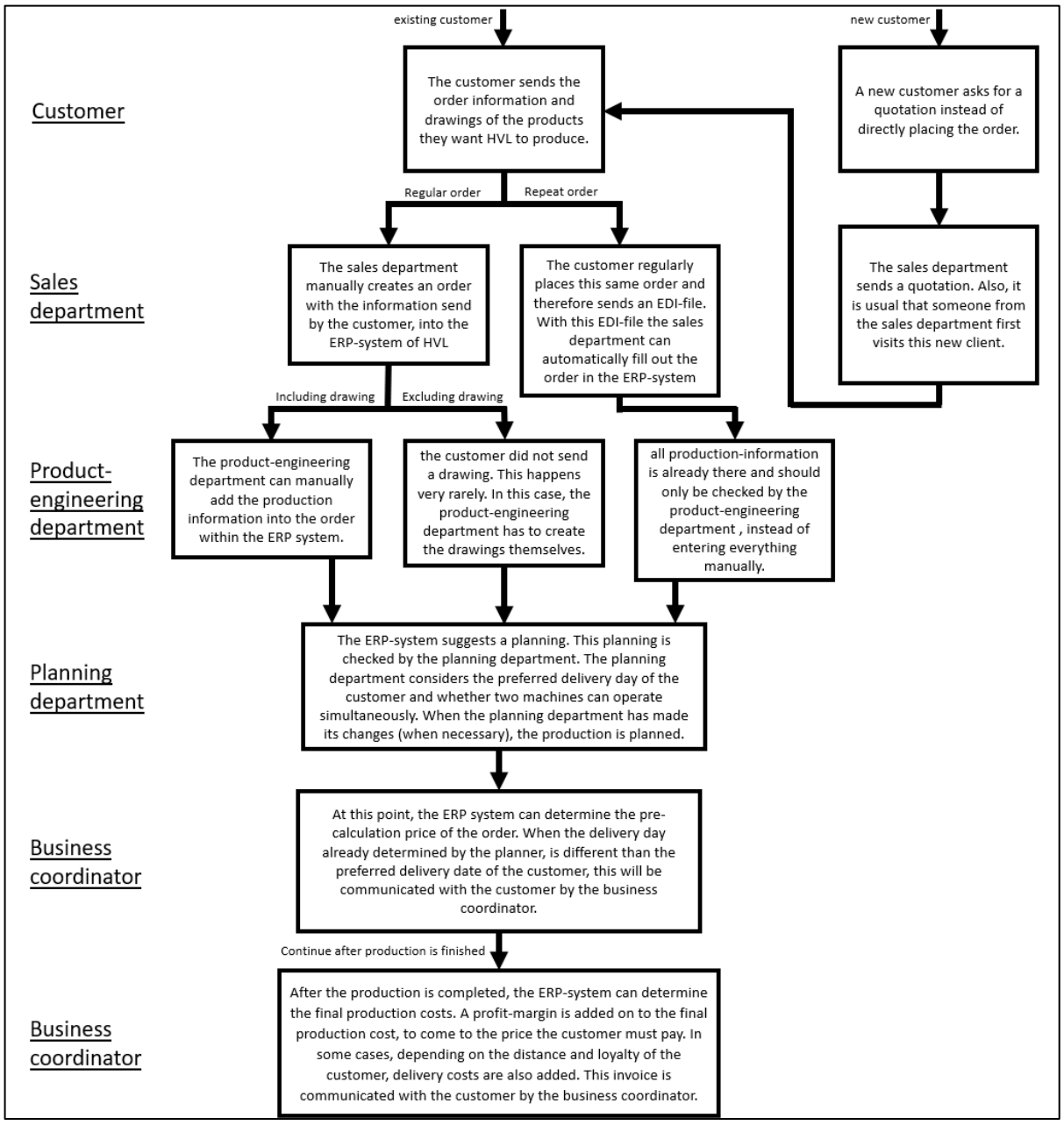


FIGURE 6

4.1.3.1 Step 1: Customer Sends Order

The customer sends the sales department of HVL an E-mail with the information about the order they want to place. The customer does this through sending a PDF with information about the order. This information includes: customer number, preferred delivery day, delivery address, quantities, revision numbers, drawing numbers and description of the products. The customer also attaches a drawing of the products they want HVL to produce in this order.

An exception to this usual situation is, when the customer is a new customer. Usually, new customers first ask for a quotation, instead of directly placing the order.

4.1.3.2 Step 2: Sales Department

This Email is received by the sales department. The most common procedure in step 2 is as follows. The sales department creates an order within the ERP system of HVL. The information within the PDF send by the customer, is manually put into this order within their ERP system by an employee at the sales department. Also, the drawings send by the customer are loaded into the ERP system. Information that should be included within the order is: customer number, product-type, preferred delivery day of the customer, revision numbers, quantities, drawing numbers and description of the products.

Firstly, each customer has its own customer number. Secondly, in case of these simple, A-orders, that this research focusses on, the product-type is always an end-product. These A-orders do not require welding or assembly of multiple semi-finished products to create the final finished end-product. Thirdly, when the customer asks for an unrealistic delivery day, the sales department will already change the estimated delivery day to a more reasonable delivery day. Fourthly, the customer should give the delivery address. Fifthly, when later on the planner does not agree with this delivery day, he will change it again. Fourthly, the revision number is included, in case that there are multiple versions of the same product. Sixthly, the quantities of the ordered products should be included. Seventhly, the number of the drawing that was mentioned within the PDF file, should be filled into the order within the ERP system.

There are two exceptional situations where step 2 differs. The first exceptional situation is when a client orders the same product on a regular basis. When this happens, the client sends an extra file (EDI-file) within their ordering E-mail. With this EDI-file, the sales department can automatically load the order within the ERP system. This way they automatically have all the information of the previous production. This includes, for example, drawings and previous production time.

The second exceptional situation is when a new customer asks for a quotation, instead of directly placing the order. It is usual that someone from the sales department visits the other company, before they start doing business together. When this introduction phase of the new customer is completed, the order follows the standard procedure.

4.1.3.3 Step 3: Product-engineering Department

When the sales department has entered all the sales information within the order. The product-engineering department can start adding the production information into the order within the ERP system. The time it takes the employees of the product-engineering department to fill out all the production information, is kept up by the ERP system itself. This spend time will later be used when determining the price.

Firstly, based on the drawing delivered by the customer, they will start filling in the needed list of materials. As previously mentioned, the simple A-orders are not an assembly. Therefore, they are only made out of one type of material. This can be steel, stainless steel or aluminum. All of these differ in quality and thickness. It also differs whether it is sheet-metal or a tube. Next, alle different proceedings have to be noted. The product-engineering department determines how much time is needed for each proceeding during the production. After that, the customer's drawing is checked for obvious mistakes. Also, all the measurements will be entered into the ERP system. Finally, when all the information is correct, the product-engineering department accepts the order. The sales information and the production information are both printed out and handed over to the planning department.

There are two exceptions where step 3 differs from the usual process. The first exceptional situation is when the ordered products have been ordered previously. In this case, all production-information is already there and should only be checked, instead of entering everything manually. An advantage is that the estimation of production time can be much more precise. The spend time was recorded during the previous production. Therefore, this time can be used as the estimation for this new production.

The second exceptional situation is when the customer did not send a drawing. This only happens very rarely for extremely simple products. In this case, the product-engineering department has to create the drawings themselves.

4.1.3.4 Step 4: Planning Department

After the product-engineering department is done with entering the product information, the planning department receives the production information and the sales information on paper from the product-engineering department.

First of all, the planning department searches for the order within the ERP system using the production number. The ERP system automatically suggests a planning, based on the needed proceedings provided by the product-engineering department and the capacity of each machine.

The planning is based on the last proceeding of the production process. HVL always tries to plan to finish the last production proceeding two days before delivery. Therefore, the last proceeding should take place, two days before delivery. All other proceedings are planned before this last proceeding. This way they create a two-day buffer, for when tasks take longer than expected or when mistakes are made. Also, after the production, the transportation department needs time to pack the products and bring them to the customer.

Secondly, this suggested planning is checked by the planner at the planning department. The planner considers the preferred delivery date of the customer. When it is not possible to deliver on the preferred day, the best alternative is used. Reasons for the preferred delivery date being impossible could be that the customer just puts the same date that the order was placed as the preferred delivery date. Or that the machines needed to produce the products are at full capacity before the preferred delivery date. Another reason could be that the needed type of material is not in stock and they have to wait for a third party to deliver.

Thirdly, the planner also considers whether certain machines can be run simultaneously, to speed up the production process. In case of the type A-orders, it could be that a first batch is already being pressed, while a second batch is still being cut.

Fourthly, the planner completes the planning. When everything is double checked, the planner puts the order in production. After this, the production can start at the planned time. This usually takes a few days or weeks. However, the client still has to be informed about the price and the delivery date. This will be done in step 5, by the business coordinator.

4.1.3.5 Step 5: Business Coordinator

With the information added by all three departments, the ERP system is able to determine the pre-calculation price of the order.

The ERP system uses the price per kilo of the used material and the measurements of the products to determine the price of the used material. This is combined with the time spend by the product-engineering department and the estimated time spend per proceeding during the production process. With combination of these three, the business coordinator is able to determine the pre-calculation.

When the delivery day determined by the planner, is different than the preferred delivery date of the customer, this will be communicated with the customer by the business coordinator. In almost all cases, this is accepted by the customer. In the few cases where the customer rejects the offer due to late delivery, the planner tries to shift within the planning to make the customer more satisfied with the offer.

After the production is completed and the final production times are known. The ERP-system is able to determine the final production costs. A profit-margin is added on to this final production cost, to come to the price the customer has to pay. In some cases, depending on the distance and loyalty of the customer, delivery costs are added. This final price is sent by the business coordinator in an invoice to the customer.

4.2 Internal research within HVL

The author performed an internal research within HVL. This research was done to get an understanding of several different topics that are related to this research. The internal research consisted out of seven interviews. Also, information was conducted through regular talks with employees and watching their work. The interviews were conducted with the following types of employees: salesman, planner, engineer, commercial manager, business coordinator, CFO and CEO. This section will consist of three general topics related to HVL and the relation between the four theories and HVL.

4.2.1 Lessons learned from previous online build-to-print service within HVL

From 2015 till 2019, HVL metal & technics already had an online build-to-print service. Customers could upload their drawings to an online website. They also had to give the material-type and the needed amount per product. When this information was all filled in correctly, they would press a button which send the information to the sales department of HVL. The sales department would check the quotation for mistakes and then send it to the customer. Several issues raised during the operating time of this online build-to-print service. These issues will be discussed in this section.

The commonly used file-type for the drawings is called a step-file. 7 years ago, this file type was not as intelligent, as it is nowadays. Back in 2015, HVL wanted the online build-to-print service to handle products that needed only laser-cutting and pressing. However, when a customer loaded in a heavy file which included pressing, the server would crash in many cases.

Secondly, many customers were messy with their drawings. Lots of customers uploaded corrupted drawings. This included drawings which had: open lines within the drawing, wrong plate thicknesses, wrong measurements and irrelevant information. There was no filtering whether the correct file-type was sent, with the correct specifications. This also made the server crash. The fact that step-files were not as intelligent as nowadays and the fact that customers were messy with their drawings, made it that 90% of the orders which included pressing, would crash the system.

A third issues was that there was no filtering. There was no filtering on the area the customer lived in. This meant that the online build-to-print service available was for the whole world. There was also no filtering on minimum order size. This meant that very small products could also be ordered, even though it was impossible for HVL to make profit on these very small orders. For example: a customer in South-Afrika asking for a house number sign, would receive a quotation just like every other customer.

A fourth issue was that the online build-to-print service did not take the planning and availability of certain materials into account. This resulted in difficulties with fulfilling the promised delivery date.

The fifth issue raised when the online build-to-print service was finally working well for orders that only included laser-cutting. Customers and other businesses started to use HVL's online service as a calculation tool. This resulted in HVL creating hundreds of quotations, but never receiving an order.

The online build-to-print service worked well for orders only including laser-cutting, but did not work well for orders that included pressing. In general, the previous online build-to-print service was implemented when the system was still premature. This made the system maintenance intensive. For these reasons HVL never implemented their old online build-to-print service when they switched from ERP-system.

4.2.2 Value within HVL

The core values within HVL are quality, speed and diversity. Firstly, HVL only produces products of the highest quality possible. Secondly, they want to deliver as fast as possible. Thirdly, they have a diverse set of operations that can be used to produce the products. In the Netherlands there are many small companies only focusing on one operation. Examples of these small companies are: machineries, injection molders, assemblers, welders. The diversity within HVL is the fact that HVL performs all these operations and many more. HVL also does all the purchasing strategy for the customers. This way, HVL completely relieves the customer from the moment the customer finishes the drawings, till the end-product is finished.

These three core values have to be reflected within the new online build-to-print service.

With the speed the current economy is running, customers expect to receive a reaction as soon as possible. Currently, it takes HVL approximately 2 days to deliver a quotation. The new online build-to-print service should increase the speed of all business-related tasks from the ordering process. With the new online build-to-print service HVL should be able to deliver a quotation within an hour. The production process will not be affected by the online build-to-print service and stay the same.

The online build-to-print service will focus on the simple A-orders. Currently, these take up a lot of time for the product-engineering department. The new service will save the product-engineering department a lot of time. This time can be used to focus more on the larger, more complicated orders. This way, the quality of these larger orders will increase.

It is also possible that new customers will be attracted by the new online build-to-print service, because HVL will be able to deliver smaller orders at higher speeds. This way the diversity is also increased, because they will be able to compete better with companies online, focusing on laser-cutting and pressing. Also HVL will spend more time on the more diverse B and C-orders, because all A-orders will be automatically processes and be handled much quicker throughout the whole process. This will also increase the diversity, since the B and C-orders require much more operations within the production department.

4.2.3 Effect on customers of HVL

The main goal of the online build-to-print service would be to please your customers. The ordering process should become easier, quicker and more effective for the customer.

Within the previous online build-to-print service, the opinion of the customers were divided. Customers without its own ERP-system, liked the online service. They would immediately receive whether it is possible to produce its order, what it would cost. They could also place orders outside of working hours. For these customers it did not matter time and effort wise, whether they uploaded their drawings and order information into an E-mail or the HVL portal.

For customers with their own ERP-system, using HVL's online service meant more work for the customer. Within the customer's ERP-system placing an order at HVL, involving many simple parts, was only a few clicks. When they wanted to place the same order within HVL's online build-to-print service, it meant that every part had to be uploaded individually. This made it that customers with their own ERP-system did not use the old version of the online build-to-print service.

4.2.4 Functionalities of new build-to-print service within HVL

First of all, an online build-to-print service could be used for two different purposes in the metal fabrication industry. The first option is to open up the service to the whole world and become a price fighter for the small A-orders. The second option is to only open the service for existing customers and this way offer more value to the current customers.

HVL wants the new online build-to-print service to be a combination of reducing the time spend per order by automating the ordering process, while still maintaining a personal touch to each order, to still be able to give extra value to each order.

The previous online build-to-print service was open to the whole world. This new online service should online be open to only existing customers. The customer should be able to place their order on a website provided by HVL, but also be able to place their order via an old-fashioned E-mail. Both of these orders will go through the same build-to-print service internally. This build-to-print service will automatically calculate the price, provide all the different drawings needed for each machine in the production and automatically plan the order within the production. Within the office an employee will quickly check the quotation provided by the build-to-print service and send it back to the customer.

HVL is already looking into a software package that will work with their current ERP system. This internal build-to-print service behind the online website is already in the test-phase within HVL. During a test, a step-file with

520 parts was loaded into the software package. The software was able to calculate a perfect price and planning, except for two parts. The software was also able to prepare all drawings and information for the production by itself. The two missing parts that the software did not recognize, would have to be entered manually by the employee checking each order coming in. Currently, all 520 parts would have to be entered in manually. Therefore, this new build-to-print service save HVL a lot of time. They will be able to respond to a customer much quicker. For an order with 520 parts, it would currently take 3 days to calculate a price. With the new software solution, it would take HVL an hour to respond to the customer.

The new software package would be able to do everything by itself. However, HVL wants to maintain the personal touch to each order. With a small check by an employee, each order still has the personal touch. They want to put in the extra effort, to make sure the quality of the product is perfect. Also, to make sure the quality of the calculated price is perfect.

As mentioned before, HVL does not want the new online build-to-print service to be open for the whole world, but only for their current customers. HVL believes that offering more speed and value, while still maintaining a personal touch with each order to their current customers, will bring more than receiving a lot of really small simple orders from hundreds of different customers.

Currently, HVL is not planning on integrating an order-history within their new online platform. With the current metal prices fluctuating rapidly, they believe it could raise a lot of questions when the customers have too much insight in previous orders. However, an order-history function, could always be added later, because it is supported within the new software package.

4.2.5 Lean within HVL

HVL metal & technics says often that they are using lean to improve their production process. During the internal research, it became clear that HVL is not fully committed to the lean principles. They are constantly trying to delete waste out of the whole process. For example, they are currently busy with the transition to work paperless. However, HVL does not follow the 5-step plan of lean provided by Womack and Jones. They work out of their own insights, instead of continually improving using the 5 steps of lean.

On top of that, the basic principles of lean are only known in the top-layer of the company. The top-layer of the company recognizes the waste and plans for the improvement. Lower down in the company, people are not familiar with lean. They are also not actively involved in improving the process and eliminating waste. For example, some employees believe that working lean is just keeping the production facility clean. On the contrary, in some cases certain waste was recognized by employees and communicated with the management. These cases considered small problems that were only related to the tasks of that specific employee and not related to the overall production process.

The CEO believes that the involvement of the employees regarding eliminating waste should be improved. The CEO gave two reasons for the lack of involvement at the moment. First reason could be that the employees are not aware of the fact that waste could be removed or do not bother to put in the effort of communicating the issue. Second reason could be that the management team does push their employees enough to actively eliminate waste or communicate about the waste they determined.

4.2.6 Computer integrated manufacturing within HVL

HVL metal & technics is doing well with using computer technology to support their manufacturing process. They are currently using one central ERP-system throughout the whole manufacturing process. This ERP-system will soon be supported by a sub-system that will do most of the offices tasks for the simple A-orders. The sub-system will calculate the price, provide all the different drawings needed for each machine in the production and automatically plan the order within the production.

There are a few small steps within the production process that are still not digital or automated. Firstly, the drawings that go through the production facility are still not digital, but on paper. HVL is currently planning on making the production process completely paperless.

Secondly, the packing list that has to be signed by the customer, is still signed on paper and later scanned into the computer. This could be done completely digital by using, for example, a tablet.

Thirdly, when employees in the production department see improvements that could be made for a specific product, they write this down on a piece of paper, instead of directly typing the note into the ERP-system. Later this note is added into the ERP by an employee of the product engineering department. This seems like double work, because two employees type or write the same note. However, HVL choose for this method, because they want the notes to be filtered. When 70 different people within the production department have the opportunity to write notes within the ERP-system, it could become a mess. They want to have their drawings, revisions and product information clean within their ERP-system.

Outside of the production process, the customer relation management is still not centrally organized. This is currently done using an excel-file, instead of a central customer relation management system. The current ERP-system includes tools for customer relation management, but these are currently not used.

In general, HVL believes that using computer technology within their production process could bring a lot of benefits, for both HVL and their customers. However, automating everything is overdone. HVL wants to maintain the feeling with each order or production, in order to be able to give each product the extra value they believe they offer.

4.2.7 Opportunities for a high-speed bespoke supply chain within HVL

There are three options for a variation of the high-speed bespoke within HVL. The first option is to create a second supply chain for the simple custom orders, only in the office. In the production department the supply chain of the simple A-orders and the supply chain of the larger B and C-orders would merge again. This means that the planning and capacity of the laser-cutter and press-machines are shared between the A, B and C-orders. The calculation, preparation and planning of the simple orders could completely be automated by the new software package HVL is planning to use. This way the employees within the office have more time to focus on the larger orders, since these orders deserve the time and effort. As mentioned before, the high-speed supply chain and the base-supply chain would merge again during the production phase. Therefore, the orders are planned into the same planning.

The second option is to create a second supply chain for the simple custom orders, in the office and partly in the production. In the production department the supply chain of the simple A-orders and the supply chain of the larger B and C-orders will each have its own part of the capacity of the laser-cutter. The calculation, preparation and planning of the simple orders could completely be automated by the new software package HVL is planning to use. This way the employees within the office have more time to focus on the larger orders, since these orders deserve the time and effort. As mentioned before, in this option the high-speed supply chain and the base-supply chain will have separated capacity of the laser-cutter. The laser-cutter will spend a set percentage of its time on A orders each day and the rest of the time on B and C orders. For example: 30% of the capacity will be used for A-orders and 70% will be used for B and C-orders. This way, the planning of the A-orders can also be separated from the B and C-orders. Also, the A-orders do not have to wait for all the other handlings of the B and C-orders. The A-orders can directly go to the transport department after being cut and pressed. This offers even more speed to the A-orders.

A third option could be to completely separate both supply chains. The production department would need a separate production cell with its own laser cutter and pressing bench. As it was in the first and second option, the order process within the office would also be separated for the small orders and the larger orders. When also separating the complete production process within both supply chains, the small orders could go through the whole process even quicker than in the second option, because they have much more capacity than in the second option.

The question is however whether HVL wants to put so much focus into these simple orders. As mentioned before, HVL offers a large variety of handlings, where most metal fabrications only offer one of these handlings. HVL puts in the extra effort therefore increases its product quality. There are many other companies in the Netherlands that could produce these simple products. There are, however, only a few companies that are able

to produce complete assemblies like HVL does within their B and C-orders. That is why HVL doubts whether they want to put so much focus in these small simple orders, because that is not really where their ambitions are.

On the contrary, it could safe HVL a lot of time. Currently, a simple order that takes 4 hours of effective production time, takes 1 week to produce. The week is divided as follows: 2 days of calculation and product engineering, the third day 1 hour of laser cutting, the fourth day 1 hour of pressing and 1 day to pack and ship the order. When these simple orders could be separated from the base supply chain, these orders could be offered much quicker to the customers. This way HVL could compete better with other companies purely focusing on this type of work.

When HVL thinks about the ideal factory, they mention a self-made term: the dark factory. In the future they would like to see certain machines within their factory the produce 24 hours a day. So also, during the nights when the lights are turned off. That explains the name: the dark factory. This dark factory would produce all simple products during the night automatically.

In general, there are definitely opportunities within HVL for a variation of the high-speed bespoke supply chain. However, HVL itself is currently not certain whether they want to put so much emphasis on the simple orders, because they want to offer extra value to the customer in comparison to other companies. They are unsure how they could add this extra value within these simple orders and therefore want to focus mainly on the B and C-orders.

4.3 Summary design and development

The fourth chapter discussed the current ordering process within HVL. Also, the internal research performed by the author was discussed in this design and development chapter.

An order within HVL goes through the following process. The customer sends the sales department of HVL an E-mail with the information about the order they want to place. This Email is received by the sales department of HVL and the sales department creates an order within the ERP system of HVL. When the sales department has entered all the sales information within the order, the product-engineering department can start adding the production information into the order within the ERP system. After the product-engineering department is done with entering the product information, the planning department receives the production information and checks the suggested planning generated by the ERP-system. After this, the production is planned. After the production is completed and the final production times are known, the final price can be communicated with the customer by the business coordinator.

The internal research discovered the wishes, demands, vision and value of HVL. Also, it looked into the application of the four different theories within HVL. Next, a summary will follow of what was learned from the internal research within HVL.

From 2015 till 2019, HVL metal & technics already had an online build-to-print service. However, this had many issues and for that reason, it was taken down in 2019.

The core values within HVL are quality, speed and diversity. These three core values must be reflected within the new online build-to-print service. Firstly, the online build-to-print service will focus on the simple A-orders. Currently, these take up a lot of time for the product-engineering department. Secondly, the new service will save the product-engineering department a lot of time. This time can be used to focus more on the larger, more complicated orders. This way, the quality of these larger orders will increase. Thirdly, it is also possible that new customers will be attracted by the new online build-to-print service, because HVL will be able to deliver smaller orders at higher speeds. This way the diversity is also increased, because they will be able to compete better with companies online, focusing on laser-cutting and pressing.

The main goal of the online build-to-print service would be to satisfy the customers. The ordering process should become easier, quicker and more effective for the customer. HVL wants the new online build-to-print service to be a combination of reducing the time spend per order by automating the ordering process, while still maintaining a personal touch to each order, to still be able to give extra value to each order.

HVL metal & technics often says that they are using lean to improve their production process. During the internal research, it became clear that HVL is not fully committed to the lean principles. They are constantly trying to delete waste out of the whole process, but are not following the 5-steps of lean.

HVL metal & technics is doing well with using computer technology to support their manufacturing process. They are currently using one central ERP-system throughout the whole manufacturing process. This ERP-system will soon be supported by a sub-system that will do most of the offices tasks for the simple A-orders.

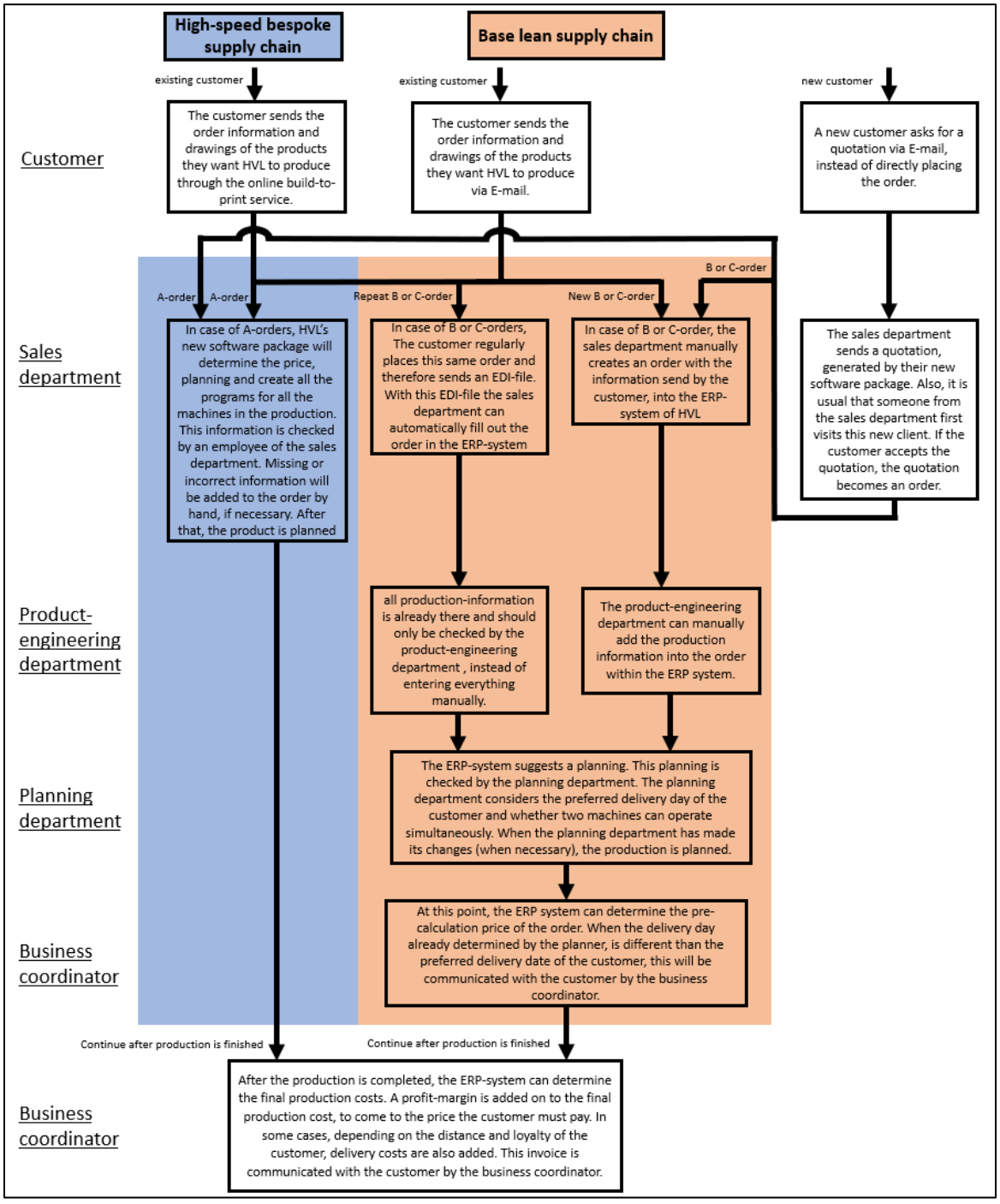
A variation of the high-speed bespoke within HVL could be applied. There are three options for a variation of the high-speed bespoke within HVL. The first option is to create a second supply chain for the simple custom orders, only in the office. In the production department the supply chain of the simple A-orders and the supply chain of the larger B and C-orders would merge again. The second option is to create a second supply chain for the simple custom orders, in the office and partly in the production. In the production department the supply chain of the simple A-orders and the supply chain of the larger B and C-orders will share the capacity of the laser-cutter. For example: 30% of the capacity will be used for A-orders and 70% will be used for B and C-orders. This way, the planning of the A-orders can also be separated from the B and C-orders. Also, the A-orders do not have to wait for all the other handlings of the B and C-orders. The A-orders can directly go to the transport department after being cut and pressed. This offers even more speed to the A-orders. A third option could be to completely separate both supply chains. The production department would need a separate production cell with its own laser cutter and pressing bench. As it was in the first and second option, the order process within the office would also be separated for the small orders and the larger orders. When also separating the complete production process within both supply chains, the small orders could go through the whole process even quicker than in the second option, because they have much more capacity than in the second option.

5. Demonstration

This section will demonstrate a potential new situation for HVL metal & technics, when they implement a build-to-print service for their A-orders as described in section 4.2.4. In section 5.1 the new order process for A-orders, will be presented. The order process will remain the same for the B and C-orders. In section 5.2, the new tasks for the employees will be discussed.

5.1 The new order process at HVL

As mention before, the new order process for A-orders, will be presented in this section. The order process will remain the same for the B and C-orders. A visualization of the complete, new ordering process can be found in figure 7 and appendix B. In this visualization also the split between the base lean-supply chain for the B and C-orders and the high-speed bespoke supply chain for the A-orders will become clear.



5.1.1 Step 1: Customer Sends Order

The customer will have two options for placing an order. Customers can choose whether they prefer to send the order through the new online build-to-print service or via the traditional E-mail. The same information will be sent through both ways of sending the order. This information includes: customer number, preferred delivery day, delivery address, quantities, revision numbers, drawing numbers and description of the products. The customer also sends a drawing of the products they want HVL to produce in this order.

An exception to this usual situation is, when the customer is a new customer. Usually, new customers first ask for a quotation, instead of directly placing the order. This will still only be done using E-mails, because the online build-to-print service will only be available to existing customers.

5.1.2 Step 2: Sales Department

This order is received by the sales department of HVL. HVL's new software package will determine the price, planning and create all the programs for all the machines in the production. This price and planning is checked by an employee of the sales department. When there is certain information missing to calculate a correct price and determine the correct planning, the sales department employee will add this information to the order by hand. When the customer asks for an unrealistic delivery date, the sales department will correct this. After that, the production can start, instead of having more handlings within the office.

This is much quicker than before, because previously the information of each product within the order had to be filled in by hand. Also, all programs for each machine in the production had to be made by someone from the product engineering department. The planning is currently checked twice before the order confirmation will be send. It is first checked by the sales department and checked a second time by the planning department. In this new situation it will only be checked once by the sales department, before the order confirmation will be send. All of this will save a lot of time in the ordering process before the production.

There are still two exceptional situations where step 2 differs in the new situation for HVL. The first exceptional situation is when a client orders the same products on a regular basis. When this happens, the client sends an extra file (EDI-file) within their ordering E-mail. With this EDI-file, the sales department can automatically load the order within the ERP system. This way they automatically have all the information of the previous production. This includes, for example, drawings and previous production time. This way the new software package does not have to create all programs again, but the previously created programs can be used. This way the production can directly start, after a quick check by the sales department.

The second exceptional situation is when a new customer asks for a quotation, instead of directly placing the order. Previously, it would take HVL a few days to deliver a quotation, because many employees had to add their information into the ERP-system. In this new situation, this will not be the case anymore. All information will automatically be drawn out of the files send by the customer and do not have to be manually added to the ERP-system anymore. Also, in the previous situation all the programs for the machines in the production had to be created by the product engineering department. In the new situation, this will also be done by the new software package of HVL. This way the new customers will have a much quicker response. It is also usual that someone from the sales department visits the other company, before they start doing business together. When the new customer accepts the quotation, the quotation will become an order and the production will start.

5.1.3 Step 3: Business coordinator

After the production is completed and the quotation can be sent by the business coordinator, who is part of the sales department. Since the final production times are known, the ERP-system is able to determine the final production costs. A profit-margin is added on to this final production cost, to come to the price the customer has to pay. In some cases, depending on the distance and loyalty of the customer, delivery costs are also added. This price will be lower when comparing it to the previous situation, because there will be no more time spend by the production engineering department on these orders. This final price will be communicated via an invoice with the customer by the business coordinator.

5.2 New tasks for HVL's employees

A lot of time will be saved on multiple departments and therefore new tasks need to be added to the day-to-day jobs of the employees. This section will discuss what the new tasks for the different types of employees of HVL could be.

5.2.1 New tasks for the sales department

In the previous situation, the sales department had to add all the order information into the ERP-system manually. This took a lot of time, especially when an order contained many small and simple products. In the new situation, all of this information will be added automatically by a new software package. An employee of the sales department only has to check the order and add the missing information, if there is any at all. This way, the sales department is able to communicate much quicker to the customer. The old procedure will still be used for the B and C orders. The time saved for the simple A-orders, can be used for other tasks.

This quicker response is also beneficial when it comes to sending quotations to new customers. When a potential new customer receives a quotation within an hour, he is less likely to contact other companies. In the previous situation it would take, in some cases, three days to send out a quotation. In this situation, it is more likely that the customer already has contacted other companies as well. He does not feel connected to HVL yet, because he has not heard from them yet.

A large change in the day-to-day tasks for the sales department is the way of and reason for communicating with the customer. Currently, HVL only has contact with customers, when the customer places an order, or when there is a problem with an order. The sales department currently has little time to contact or visit customers for other reasons. They also have no time to attract new customers. Since the sales department will have more time available in the new situation, the sales department can start spending time to attract new customers and build a better relationship with existing customers. They have the time to physically visit existing customers to see how they are doing. Or invite potential new customers over to HVL and show everything that is possible within HVL.

This new way of communicating with the customer is consistent with the vision of HVL. They want to add extra value, by investing more time in the relationship with the existing customers, they will better understand each other, which results in better products. For example, they invite an existing customer and show them ways of cutting or pressing products, the customer did not know were possible. This way HVL is able to offer more value to its existing customers.

5.2.2 New tasks for the product engineering department

The tasks for the product engineering department for the A-orders will basically all be gone. Only when there are miscellanies problems that the sales department cannot fix. The tasks for the B and C-orders will still remain the same as before. Beforehand, it was only allowed for one product engineer to work on a C-order at the same time, because otherwise the A and B-orders would pile up too much. This could be changed, because the product engineering of the A-orders will be automated by the new software package. In the new situation, it will be possible for more product engineers to work on large C-orders.

The large change for the product engineering department, will be that they have more time to spend as a project manager instead of purely being a product engineer. Currently, they do not see the product again, after they finished engineering it. In the new situation they have the time to constantly follow and monitor projects on speed, quality, deviations and errors. They will have to make sure that the production flow becomes more consistent. They will monitor the production department through the data that comes back from the machines and the ERP-system. They will for example be able to see where a deviation is happening or where a certain material is lacking. This way they can act on this, before it is too late.

Both changes are in line with the vision of HVL that they want to add extra value to their products. HVL has a diverse set of operations that can be performed. When the product engineers have more time to focus on the B and C-orders, more complicated products will be produced that include more operations than the simple A-orders. Also, quality and speed are important values of HVL. Both will be increased through having the product

engineers also acting as project managers that constantly monitor the speed and quality of the projects in production. This way the speed and quality of HVL's products will increase.

5.3 Summary demonstration

This chapter demonstrated a potential new situation for HVL metal & technics, when they implement a build-to-print service for their A-orders. This was demonstrated by describing a new ordering process and discussing new tasks for the employees of HVL.

The new order process will only change for A-orders. The order process will remain the same for the B and C-orders. The customer will have two ways of placing an order. Customers can choose whether they prefer to send the order through the new online build-to-print service or via the traditional E-mail. These orders are both received by the sales department. HVL's new software package will determine the price, planning and create all the programs for all the machines in the production. This price and planning is only checked by an employee of the sales department, before the production is planned. This is much quicker than before, because previously the information of each product within the order had to be filled in by hand. After the production is completed and the quotation can be sent by the business coordinator.

The saved time at multiple departments can be filled in with new tasks for the employees. A change in the day-to-day tasks for the sales department is the way of and reason for communicating with the customer. The sales department will have time to attract new customers and build a better relationship with existing customers. This is beneficial to HVL, because they will get more customers of which they can make profit. A change for the product engineering department, will be that they will have more time to spend as a project manager for the B and C-orders instead of purely being a product engineer. This is beneficial to HVL, because the B and C-orders make more profit than the A-orders. All of these changes are also supported by the vision and values of HVL. HVL has a diverse set of operations that can be performed. When the product engineers have more time to focus on the B and C-orders, more complicated products will be produced that include more operations than the simple A-orders. Also, quality and speed are important values of HVL. Both will be increased through having the product engineers also acting as project managers that constantly monitor the speed and quality of the projects in production. This way the speed and quality of HVL's products will increase.

6. Evaluation

This section will consist of the final evaluation of the research. First of all, section 6.1 includes points of discussion that could come forward after reading this report. Secondly, section 6.2 presents the recommendations for further research on supply chains that supports online build-to-print services in small manufacturing companies. Finally, section 6.3 discusses the academic and practical conclusion that can be drawn from this research.

6.1 Discussion

This research shows how academic theory and literature can play a role in determining a new supply chain within a manufacturing company. This research also shows how different theories and literature on manufacturing processes can be combined, in order to fit the processes within a small manufacturing company. This combined integrative theory was applied to a small manufacturing company, HVL metal & technics. This research may already help companies working in the manufacturing industry which are facing similar problems as discussed within this research. These issues are regarding the fact that certain simple orders take too much time and effort and therefore there is too little focus on the more important orders. Companies facing similar problems may get insight and ideas on how the solve these issues through reading this report. This research may especially be useful for companies who want to automate their ordering process within the office or want to create a sub-supply chain besides their base supply chain. This research may help them to get an understanding of what theories may be used to set up their new ordering process. It may also help to get an understanding on what is possible when having two separate supply chains for the simple and complicated orders. However, this research has a few points of discission. These points of attention exist due to the short

time span of this research. This research was executed in 11 weeks. On top of that, this research was performed during the Covid-19 pandemic, which offered some difficulties with organizing meetings and conducting interviews. For example, interviews were being postponed or even canceled, because of sick employees of HVL metal & technics. This resulted in the following points of discussion.

First of all, there was little to no existing literature found about combinations of the four discussed theories within this research. Therefore, the discussed integrative theory is only based on four individual theories. No already existing combinations were used when creating the integrative theory of the four theories. Only the vision and knowledge of the researcher were used to create the integrative theory.

Secondly, within the high-speed bespoke supply chain theory, it is usual that also the production department is split into two different supply chains, not only the ordering process within the office. Within the case-study of HVL, this is only given as a third option for the future, because HVL is currently not able to set up a second production facility. Therefore, this is mostly excluded from the new supply chain.

Thirdly, the conclusions made within this research are only based on one case study. Therefore, they could be biased. It could be that the findings within this case study, do not hold up in other small manufacturing companies, because they have a different vision or different company values on how they see their company.

Fourthly, this research does not include any financial statements for HVL when implementing a build-to-print service along with a high-speed bespoke supply chain. The costs for the new build-to-print system within HVL are known. However, it is extremely difficult to determine all financial benefits within 11 weeks. A lot will change, not only with the simple orders, but also the tasks of employees. For example, the sales department will actively start seeking for new customers. Currently, they only get new customers when these customers send an E-mail to HVL. The financial benefits that come forward through all changes and new tasks should all be included within such a financial statement, when done correctly. It is extremely difficult to give an accurate estimate of this, let alone in 11 weeks. Besides the difficulty of the task, the focus and goal of this research was to find a way to create a supply chain for a build-to-print service, not to find out what financial benefits would come forward when implementing a build-to-print service. Therefore, it was decided to present only practical advantages and disadvantages of the new supply chain, instead of the financial benefits.

In order to solve these points of discussion, further research is recommended.

6.2 Recommendation

Firstly, in order to get a more general conclusion, it is recommended to search for more theories that are involved with supporting an online build-to-print service. This newly found literature may be used to create a better integrative theory in the next research about supply chains that supports an online build-to-print service in a small manufacturing company.

Secondly, it is recommended to perform more literature study on combinations of the theories that were used to create integrative theory. This solves the issue of the integrative theory only being based on four individual theories and not on already existing combinations. When already existing combinations will be included, also the opinion of other researchers on combinations of different theories can be included in the next research.

Thirdly, in order to give a more general conclusion, it is recommended to perform more case studies in the next research. Within this research, the conclusions made are only based on one case study. Therefore, they could be biased. When performing multiple case studies, the conclusion becomes more general. This means that the chance increases that the findings are valid in other small manufacturing companies, because multiple different vision and different values on how such a supply chain should operate are included within the next research.

Fourthly, this research does not include financial benefits of a second supply chain supporting a build-to-print service. This research only focuses on practical advantages and disadvantages of the supply chain. It is recommended that the next research does look into the financial aspects of the new supply chain. This way, you have a more complete overview of the new situation, so not only practically but also financially.

7. Conclusion

This section consists of the conclusion of this study. The conclusion is split into two different sections. The first section will discuss the academically relevant conclusion and the second section will discuss the practically relevant conclusion.

7.1 Academically relevant conclusion

Theories and pre-defined processes usually do not hold in small manufacturing companies. These are often only partly, if at all, integrated. Small manufacturing companies work mostly out of their own knowledge and insights. When trying to get a complete and theory-based overview of the processes within a small manufacturing company, it is difficult to base this on only one existing theory. Therefore, it helps to look into multiple theories that could collectively describe the processes within a small manufacturing company. This way of exploring and expanding the existing literature is called an integrative literature study.

In case of HVL metal & technics, this research has shown that their ordering process consists of four different theories. These are the following: lean manufacturing, computer integrated manufacturing, build-to-print service and high-speed bespoke supply chain. A combination of these four theories within HVL could be seen as followed. HVL is currently using lean manufacturing as their base supply chain and they want to continue with eliminating waste. They saw constrains within their ordering process for the simple orders. The goal is to eliminate the waste of spending so much time on the simple orders and therefore making less profit on these simple products, because they are more expensive to produce. HVL wants to do this by improving on their computer integrated manufacturing within the customer order process. This creates a better integration between the business and IT. To do this, they are planning on setting up an online build-to-print service. This online build-to-print service should allow customers to upload the drawing to an online website, instead of sending them via an E-mail. However, since their current lean supply chain is not ideal for an online custom ordering platform. HVL needs to extend their current supply chain with second supply chain. This second supply chain will be a high-speed bespoke supply chain. This type of supply chain focuses on small quantities and custom orders delivered at high speed through an online website available to its customers.

This research has shown that processes and business structures within small manufacturing companies do not fit into one theory. They consist of combinations of multiple theories, because these companies work out of their own insights and visions. Therefore, it is needed to look into different theories to get a complete and theory-based overview of the ordering process within a small manufacturing company. When setting up a new supply chain within small manufacturing companies, it is also needed to look into different theories and create a combination of multiple theories. Most scientific theories about business structures and business processes are based on large manufacturing companies. That is why all these theories do not perfectly fit within small manufacturing companies. These small manufacturing companies will have to make deviations from excising theories and create combinations of theories to create a theoretical foundation for their new supply chain.

7.2 Practically relevant conclusion

Besides this conclusion about the usefulness of combining different theories, also some conclusion could be drawn and generalized from the case study at HVL metal & technics.

For manufacturing companies, it is important to keep the focus within their ordering process, on what their manufacturing unit is built for. In order to maximize profit within a manufacturing company, all manufacturing machines should produce as many hours as possible. When a manufacturing company offers a wide variety of operations, it is key to keep their main focus on orders that include as many of these operations as possible. This way, the profit is maximized, because the machines make the profit and therefore should produce instead of standing still. Also, in this way the added value of the company towards the customer is maximized, because they are able to produce more complicated products. This conclusion was drawn from the fact that HVL wants

to spend less time on simple orders, in order to have more time that can be spend on the complicated orders that include a wider variety of operations.

An option of keeping this focus at the orders that are worth the time and effort, is to automate the orders that do not deserve the time and effort. A way of doing this is setting up an online build-to-print. When partly automating the ordering process within a manufacturing company, it is important to have a clear split between the processes that deserve the extra time and effort and the orders that are not worth as much time and effort. When everything goes through the same ordering process, you will spend too much focus and time on the orders you do not want to spend it on. To be able to keep your focus on the orders that offer the much value to the company as well as the customer, a second supply chain should be set up. While keeping the base supply chain in place. This conclusion can be drawn from the fact that HVL wants to split the tasks within the office for their A-orders from the B and C-orders. They want to keep their main focus on the B and C-orders. The calculation, preparation and planning tasks for the A-orders will be automated and only be checked once, instead of doing everything by hand and checking it twice. This way HVL can keep their focus on the B and C-orders that offer the most value to the customer and HVL itself, because these orders include more operations than the A-orders. Their B and C-orders will continue to go through their base lean supply chain and their A-orders will go through a high-speed bespoke supply chain.

There are three options for a variation of the high-speed bespoke within HVL. The first option is to create a second supply chain for the simple custom orders, only in the office. In the production department the supply chain of the simple A-orders and the supply chain of the larger B and C-orders would merge again. This means that the planning and capacity of the laser-cutter and press-machines are shared between the A, B and C-orders. The calculation, preparation and planning of the simple orders could completely be automated by the new software package HVL is planning to use. This way the employees within the office have more time to focus on the larger orders, since these orders deserve the time and effort. As mentioned before, the high-speed supply chain and the base-supply chain would merge again during the production phase. Therefore, the orders are planned into the same planning.

The second option is to create a second supply chain for the simple custom orders, in the office and partly in the production. In the production department the supply chain of the simple A-orders and the supply chain of the larger B and C-orders will each have its own part of the capacity of the laser-cutter. The calculation, preparation and planning of the simple orders could completely be automated by the new software package HVL is planning to use. This way the employees within the office have more time to focus on the larger orders, since these orders deserve the time and effort. As mentioned before, in this option the high-speed supply chain and the base-supply chain will have separated capacity of the laser-cutter. The laser-cutter will spend a set percentage of its time on A orders each day and the rest of the time on B and C orders. For example: 30% of the capacity will be used for A-orders and 70% will be used for B and C-orders. This way, the planning of the A-orders can also be separated from the B and C-orders. Also, the A-orders do not have to wait for all the other handlings of the B and C-orders. The A-orders can directly go to the transport department after being cut and pressed. This offers even more speed to the A-orders.

A third option could be to completely separate both supply chains. The production department would need a separate production cell with its own laser cutter and pressing bench. As it was in the first and second option, the order process within the office would also be separated for the small orders and the larger orders. When also separating the complete production process within both supply chains, the small orders could go through the whole process even quicker than in the second option, because they have much more capacity than in the second option.

7.3 Acknowledgements

I would like to express my appreciation towards my first supervisor dr.ir. A.A.M. Spil for all the guidance and advice throughout this research. Next, I would like to thank my second supervisor dr. P.C. Schuur for reviewing and examining this research. I am also thankful towards all HVL employees that helped me with the interviews during my HVL metal & technics internal research. I would especially like to thank my supervisor E. van Helvoort within HVL metal & technics, that provided me with helpful information, knowledge and guidance during my internship at HVL metal & technics.

References

Alavudeen, A., & Venkateshwaran, N. (2010). *computer integrated manufacturing.* New Delhi: PHI Learning Private Limited.

Doyle, A. (2020, 6 27). *What Is a Semi-Structured Interview?* Retrieved from The Balance Careers: https://www.thebalancecareers.com/what-is-a-semi-structured-interview-2061632#:~:text=A%20semi%2Dstructured%20interview%20is,straightforward%20question%20and%20answer%20format.

Elitesoh. (2014, 6 6). *Build to Print vs. Build to Specification*. Retrieved from Elitetech: http://www.elitetecheng.com/blog/build-to-print-vs-build-to-specification/#:~:text=On%20the%20other%20hand%2C%20build,of%20the%20component%27s%20functional%20requirements.

Elvin, R., & Ward, J. (1999). *A new framework for managing IT-enabled business change.* Wadern: DBLP. Retrieved from https://www.researchgate.net/publication/220356460_A_new_framework_for_managing_IT-enabled_business_change

Goldratt, E. (1990). *What is this thing called THEORY OF CONSTRAINS and how should it be implemented?* Goldratt. Retrieved from http://brharnetc.edu.in/br/wp-content/uploads/2018/11/5.pdf

Hobbs, D. (2004). *Lean Manufacturing Implementation.* Boca Raton: J. Ross publishing.

HVL metaal & Techniek. (2021, 1 26). *About HVL*. Retrieved from HVL metaal & techniek: https://www.hvlmetaal.nl/en/about-hvl

Jiao, R., Wang, Y., & Tseng, M. (2017). *Mass Customization.* Berlin: CIRP Encyclopedia of Production Engineering.

MKG. (2021, 4 26). *ERP software voor de metaal*. Retrieved from MKG: https://www.mkg.eu/

Nejati, M. (2010). *Global Business and Management Research: An International Journal.* Boca Raton, Florida USA: Uiversal-Publishers.

Peffers, K., Tuunanen, T., Gengler, C., Rossi, M., Wendy, H., Virtanen, V., & Bragge, J. (2006). *THE DESIGN SCIENCE RESEARCH PROCESS: A MODEL FOR PRODUCING AND PRESENTING INFORMATION SYSTEMS RESEARCH.* Claremont, CA: Desrist.

Roser, C. (2018, 8 17). *Lean and Industry 4.0*. Retrieved from allaboutlean: https://www.allaboutlean.com/lean-and-industry-4-0/

Scheer, A.-W. (2012). *CIM Computer Integrated Manufacturing: Towards the Factory of the Future.* Berlin: Springer-Verlag Berlin.

Snyder, H. (2019). *Literature review as a research methodology: An overview and guidelines.* Oslo: BI-Norwegian School of Business.

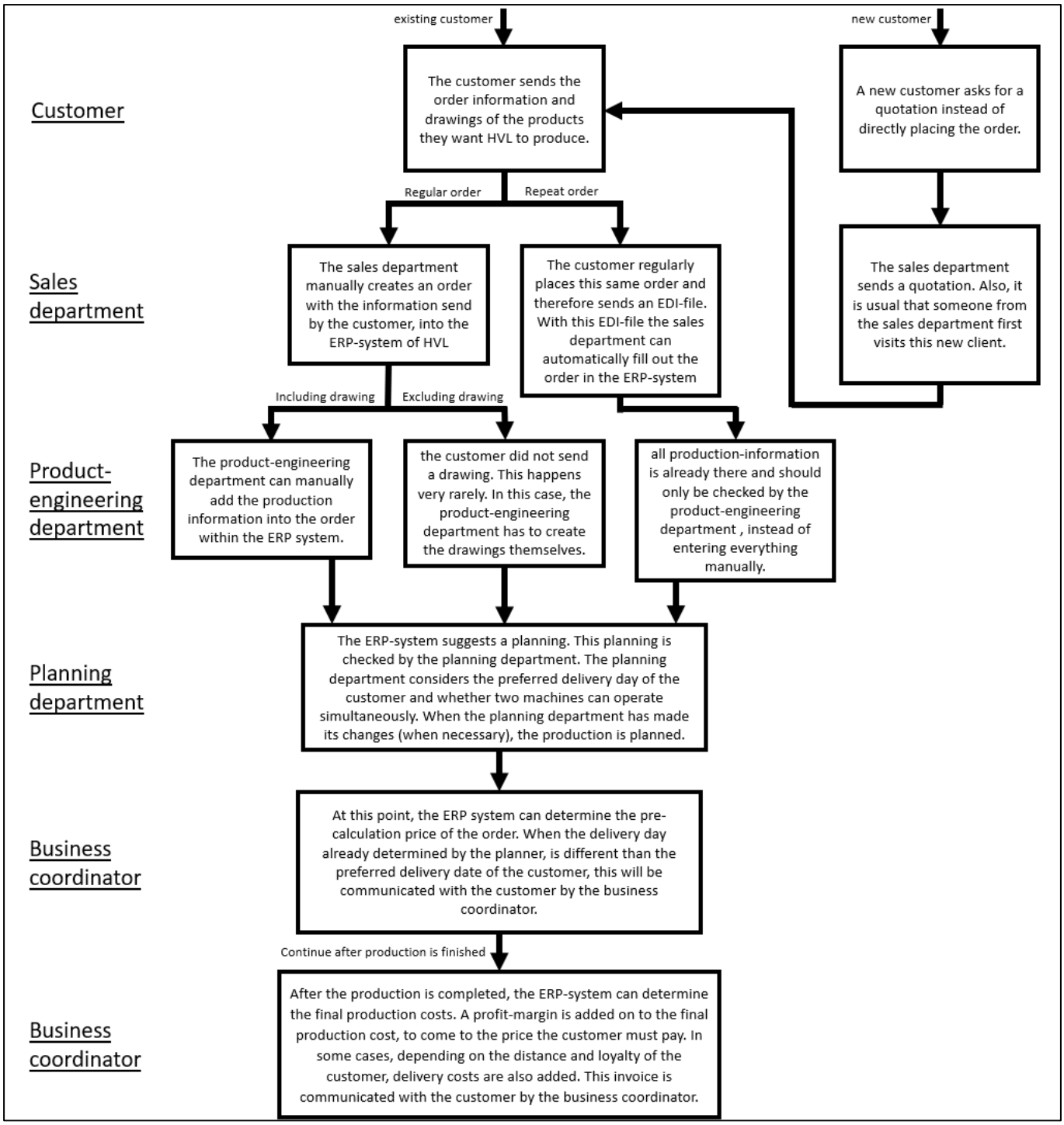
Sodhi, M., & Tang, C. (2017). *Supply Chains Built for Speed and Customization.* Londen: University of London.

Torraco, R. (2005). *Writing Integrative Literature Reviews: Guidelines and Examples*. Thousand Oaks, Californië, Verenigde Staten: Acedamy of human resource development.

Womack, J., & Jones, D. (1996). *Lean Thinking: Banish Waste and Create Wealth in Your Corporation.* Oregon: J Randers.

Appendix

A. Current Ordering Process at HVL



B. New ordering process at HVL