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VMI 2.0: Implementing VMI in the Industry 4.0 era

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Management summary

The past years have been tough for many organisations that generally could rely on their supply chains. Many disruptions, varying from Covid-19-related lockdowns to the blocking of the Suez Canal, have caused lead times to increase extremely resulting in failing business operations. Benchmark Electronics, this study's case company, have also faced many supply chain disruptions and lead time increases. The company is currently investigating how the concept of Vendor Managed Inventory (VMI) can be implemented in order to decrease lead times. VMI is an inventory management concept where upstream organisations, such as suppliers, manage and control the downstream customers' inventory (Zhao, 2019, p. 1000). However, this study does not only focus on the implementation of VMI but also combine the concept with new insights from the Industry 4.0 era. Adding these together, a conceptual VMI 2.0 implementation framework is created.

Purpose – to design a framework that describes how VMI 2.0 should be implemented to minimise lead times. This thesis defines the concept of VMI 2.0 whilst elaborating on how Industry 4.0 can change and improve the concept of VMI. Finally, this paper establishes a comprehendible VMI 2.0 implementation framework that consists of a preparation-, an implementation-, and an optional evaluation stage.

Method – to follow the Design Science Research Process (DSRP) principles introduced by Pfeffers et al. (2006, p. 93). Within these DSRP steps, diverse types of analyses are conducted. A Delphi study is performed for the primary research results, including both qualitative and quantitative aspects. For this Delphi study, a sample of eight experts is used, containing four academic and four industry specialists.

Results – a VMI 2.0 implementation framework is successfully designed based on the Delphi experts' input. The framework consists of three stages: a preparation stage, an implementation stage, and an optional documentation stage. The stages are further divided into steps.

The preparation stage consists of the steps: 1) analysing MBBA's, which generally presents motivators, benefits, barriers, and alternatives for VMI 2.0, 2) assessing VMI 2.0 readiness, which, based on quantitative analysis, indicates that having a forecasted demand and closely monitored stock levels is the most important condition for VMI 2.0 implementation, 3) selecting suppliers,

whereof having Industry 4.0-ready information systems is the most important applicability condition.

The implementation stage consists of the steps: 1) implementing a standardised VMI process, including different Industry 4.0 technologies that are recommended by the Delphi experts, 2) determining the exchanged information between the buyer and supplier, whereof the real-time exchange is added by this research, including recommended applicable Industry 4.0 technologies, and 3) designing the information exchange, based on a small survey that comes with Industry 4.0 technology suggestions for the survey answers. An example from the survey results is that when there is a desire to exchange information monthly, weekly, or daily, Predictive Analytics is a particularly valuable tool. However, when it is desirable to exchange information every hour, minute, or even every second, using sensors is recommended.

Recommendations – after VMI 2.0 is defined, a VMI 2.0 implementation framework is presented. Both, having defined the concepts and having presented a ready-to-use framework can bring awareness to and understanding of the topic and even motivate managers to implement VMI 2.0 or transition from VMI to VMI 2.0. Also, with this VMI 2.0 concept and framework, lead times and supply risk can be reduced, and successful supply chain collaboration is improved. Making use of this VMI 2.0 implementation framework is therefore the main managerial recommendation of this research. Furthermore, within the different framework stages and steps, other recommendations are made. These recommendations vary from what the most important supplier selection criteria is, based on weights, to which Industry 4.0 technology should be implemented in order to facilitate a specific need within the VMI 2.0 information exchange.

Originality – literature is exposed to a new concept: VMI 2.0. Prior research has, until now, solely focused on VMI in its traditional form. This traditional VMI concept is established in the Industry 3.0 era, which was characterised by an human-machine interface. However, VMI has yet never been brought in connection with Industry 4.0 (technologies), which is/are characterised by the machine-to-machine interface (Schiele & Torn, 2020, pp. 512-513). This research is relevant for literature because different works of literature were improved by adding a 2.0 perspective to the traditional concept of VMI. This is done by introducing other Industry 4.0 technologies that are applicable to VMI 2.0 and linking these technologies to a VMI process framework and a VMI information exchange.

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1. Company profile: researching a global, stock listed electronics manufacturer

This research was conducted at Benchmark Electronics, a global electronics manufacturer. It produces and delivers parts and subassemblies to OEMs all over the world. The company originates from Texas in the United States of America. It was founded in 1979, and now, as of July 2022, it employs over 13.000 employees divided over 22 worldwide locations. The company is listed on the New York Stock Exchange and has a market capitalisation of over 800 million US dollars as of July 2022.

This study was performed at the Dutch location in Almelo. This location employs about 500 employees and distinguishes itself by its robust New Product Introduction (NPI) and development teams. It even hosts the Benchmark European Design Centre of Innovation. The main market sectors that this Benchmark location is serving are commercial aerospace, complex industrial, medical, defence, and semiconductor capital equipment. It serves about 15 customers, including large companies such as ASML, Airbus, and Thales. Benchmark's services and products to its customers are very customer-oriented, and its operations, therefore, need to be managed separately. Also, Benchmark’s clients are liable for all the parts purchased on their behalf. This means that Benchmark owns much stock that is not actually theirs. To illustrate, parts purchased by Benchmark for a specific ASML project will be ASML’s possession, although they may be stored in Benchmark’s warehouse for months.

2. Introduction: developing a VMI 2.0 model to reduce lead time based on a design science approach

2.1 Research context: Benchmark’s supply chain suffers from too many disruptions and irregularities due to e.g., Covid-19

2.1.1 Benchmark’s business environment is changing rapidly

The case company, Benchmark, is currently struggling with the issue that its lead times have increased massively due to supply chain disruptions. Therefore, this research will look at Benchmark from a vendor’s point of view. The disrupted supply chain has multiple causes. To understand these causes, semi-structured interviews were held within the case company. A total of eight interviews were held with reputable employees from different organisational and hierarchical levels of the company. The following external and internal causes were explained by different interviewees and are summarised and illustrated in Figure 1:

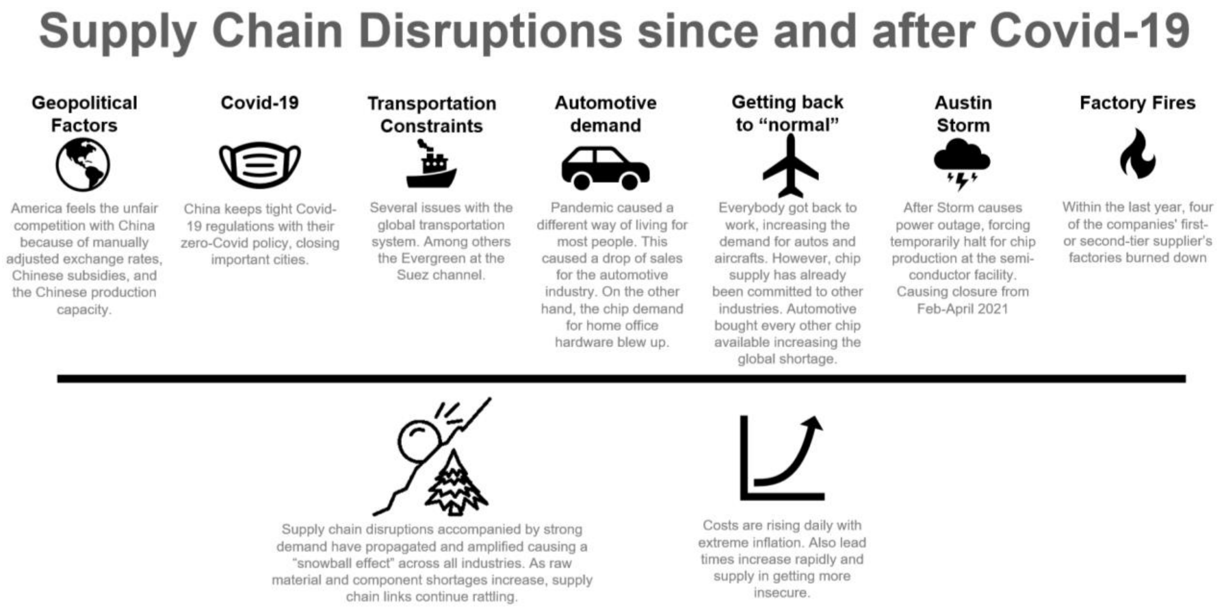

Figure 1 - An illustration of the supply chain disruptions since and after Covid-19

The following list elaborates on the external factors:

1) Benchmark, as an American organisation, feels the unfair competition with China (Interviewee 1), which is the first external cause. Chinese manufacturers are able to produce and sell for at least 20% cheaper than American manufacturers. This is due to the ability of the Chinese banking system to adjust the price of the Chinese Renminbi manually, and also, China offers large subsidies to Chinese manufacturers so that multinationals choose to produce in China instead of in the western world. Also, China is able to add production capacity a lot quicker than Western countries do. In China, it is possible to build substantial production facilities in weeks, whereas this might take months or even years for Western countries.

2) Staying in China, the country is rigorous when it comes down to Covid-19 measures (Interviewees 1 & 7). Since the pandemic has started in China, it has become one of the strictest countries in terms of measures. They have a zero-Covid policy. For example, when in some Chinese regions a Covid-19-case is found, the whole city will be put into a lock-

down. This has happened multiple times in large industrial areas, which caused all of the located manufacturers to be closed. Also, more recently, the third-largest harbour in the world, the Ningbo-Zhoushan harbour, was closed for a couple of days[1]. This also caused enormous delays for companies globally.

3) The effects of the Suez Canal obstruction are still sensible as of January 2022 (Interviewees 1 & 7). This obstruction took place on the 23rd of March 2021 and took six days[2]. A 400-meter-long vessel wedged across the Suez Canal, one of the most critical canals for global freight transport. It caused a queue of at least 369 ships, which sometimes caused delays of months. All of this sea freight trouble made the container capacity become very scarce. Prices for containers, therefore, increased by at least 600%[3].

4) Coming back to the Covid-19 pandemic, this pandemic caused a completely unusual way of living for millions of people (Interviewees 1 & 7). Instead of going to the office, people needed to work from home. Instead of travelling worldwide, people needed to stay at home. This caused the automotive industry and aircraft industry to lose 100s of billions of dollars in turnover. However, in the meanwhile, everyone needed new computers, televisions, or gaming consoles because they were stuck at home for such a long time. This caused the demand for chips to plummet in the automotive and aircraft industry. This meant that all of the chip manufacturers had surpluses of one type of chip and massive shortages for the other, now necessary, chips. The start of the pandemic was over two years ago, and as of now, January 2021, the global chip shortages are still ongoing.

5) The recovery of the world from the pandemic (Interviewees 1 & 7). Traffic has increased a lot again for both cars and aircraft, causing the need for chip manufacturers to produce many of these chips again. Meanwhile, few has changed in terms of demand for the now popular electronic devices. This means that the demand for chips has now increased enormously. However, the chip manufacturers’ production capacity has stayed the same, meaning they have difficulty satisfying the need. This has caused chips to be scarce, resulting in higher prices and lead times for Benchmark.

[1] https://theloadstar.com/port-of-ningbo-open-but-logistics-services-stutter-as-covid-restrictions-bite/
[2] https://www.bbc.com/news/business-56559073
[3] https://www.trouw.nl/economie/de-prijzen-voor-containers-gaan-door-het-dak-en-ze-waren-al-zo-hoog~b52c992f/

The following two causes are internal and more specific causes of the disrupted supply chain for the case company.

6) Interviewee 7 added that in 2021, chip production facilities in Austin, Texas, were shut down for a couple of months. This shutdown cost, e.g., Samsung, about $270 million in losses[4]. However, Samsung was not the only company affected by this shutdown. This ever-growing chip shortage was felt on a much larger scale.

7) Lastly, another case-company-specific cause for the disrupted supply chain was the relatively high number of factory fires last year (Interviewees 2, 7 & 8). Firstly, a Japanese factory fire cut off PCBs' material. Secondly, there was a fire in a sensor factory. Thirdly, a chip factory for the automotive sector burnt down. And lastly, the fourth fire was at the globally most significant memory (DRAM) chips factory.

After holding the interviews and gathering the information for determining the research context, in February 2022 the war between Ukraine and Russia started. This also caused scarcities and increased costs of certain parts. However, after discussing with a number of interviewees, the choice was made to mention but exclude this war from the main causes that increased lead times and costs within the case company's supply chain because of its relatively minimal impact considering the other factors.

2.1.2 Increasing supply chain collaboration as the proposed solution to decrease lead times again

The results of these disruptions are global material scarcities accompanied by increases in lead times for Benchmark as the vendor in this case. For decreasing these lead times again, a possible solution is the concept of supply chain collaboration. This concept has recently received a high amount of attention from from academic researchers (see Figure 2) as well as from business practitioners. This is because its practical effect is frequently observed in real businesses. What supply chain collaboration does is to share information so that the supplier can anticipate on possible supply chain disruptions. Several large multinationals have achieved remarkable results by including supply chain collaboration programs in their operations (Bookbinder et al., 2010; Niranjan et al., 2012). Probably, the best-known collaboration initiative is Vendor Managed

[4] https://en.yna.co.kr/view/AEN20210429007100320

Inventory. This is because it is the most widely used across industries. It is an inventory management concept where upstream organisations, such as suppliers, manage and control the downstream customers' inventory by analysing the downstream customers' production, operations, and inventory information (Zhao, 2019, p. 1000). E.g., Wal-Mart and Campbell's Soup have achieved tremendous successes with VMI.

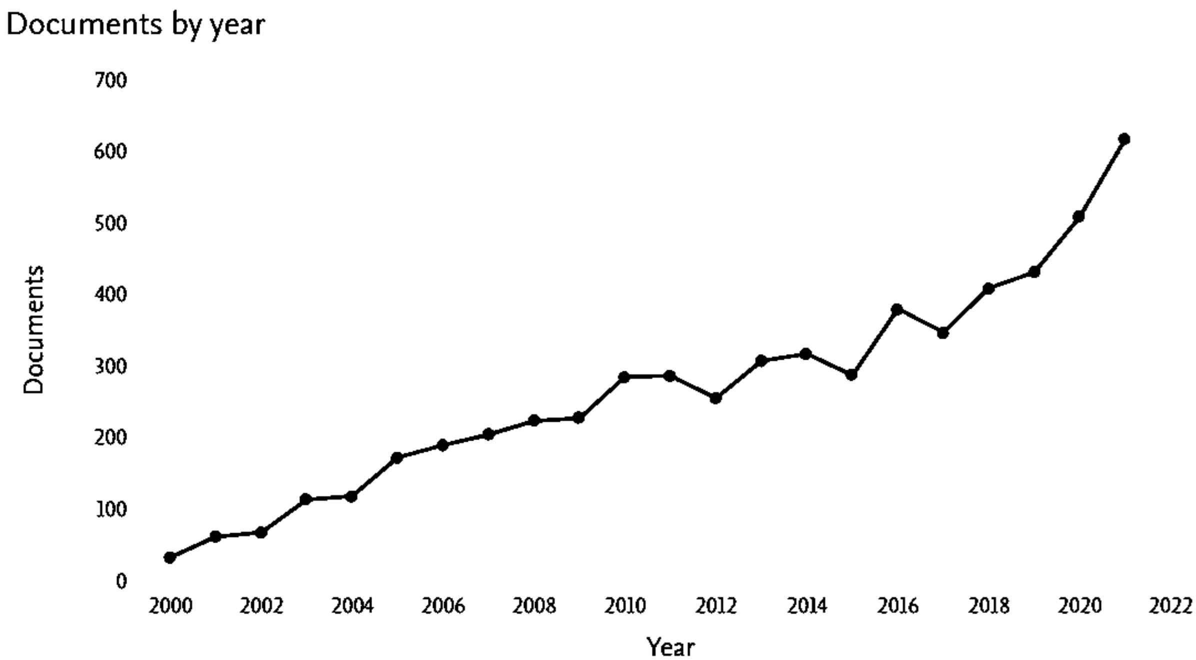

Figure 2 - Graphical representation of the number of publications in Scopus, including "supply chain collaboration" in their title, abstract, or keywords since 2000. Retrieved in February 2022.

Next to VMI, there are also other collaboration initiatives such as Quick Response (QR), Efficient Consumer Response (ECR), Continuous Replenishment Program (CRP), and Collaborative Planning, Forecasting, and Replenishment (CPFR). However, "a VMI system is one of the most effective partnership styles" (Tyan & Wee, 2003, p. 17).

Industry 4.0 refers to the fourth industrial revolution, characterised by cyber-physical systems with autonomous machine-to-machine communication (Schiele & Torn, 2020, p. 512). The increasing number of digital solutions within the supply chain, resulting from digitalisation or Industry 4.0, allows to increase supply chain collaboration based on advanced technologies. In the case of VMI, including these Industry 4.0 technologies could help solve current VMI challenges and transform the concept of VMI to VMI 2.0.

2.2 Research motivation: increase operative performance based on reduced lead times

All of these different problems contribute to Benchmark's real problem: its lead times are too long. At the moment, Benchmark, as the vendor, has a norm that their supplier's lead time is not allowed to be any longer than four weeks. This is because of the irregular demand for their products and their need to anticipate quickly on the market. However, this norm of 4 weeks maximum for their lead times is not achieved. This is a crucial problem because it will cause Benchmark to delay or even fail the delivery to their customers. This ultimately results in a significant loss of money and reputation.

Benchmark supplier's lead time is described as the time between placing a purchase order for a component needed by Benchmark until delivery of the purchased piece to Benchmark's production warehouse. The supplier's lead time differs from Benchmark's as it adds Benchmark's processing time. It is the time between placing the purchase order and delivering the finished good to Benchmark's customer. Figure 3 illustrates this. Benchmark's customers generally set the norm that they want their items to be delivered within nine weeks from their ordering point. On average, Benchmark needs five weeks to manufacture and process the items before being able to deliver them to their customers. This leaves four weeks for Benchmark's suppliers to provide the products. This is where their four-week norm comes from. However, some suppliers have 5, 8, or even 160 weeks lead times. This will mean that the nine-week delivery time is impossible. On the other hand, not to forget, Benchmark's suppliers also have to cope with longer lead times. Therefore, supplier collaboration initiatives can benefit the entire supply chain. The collaboration initiative that this research will focus on is VMI. This is because "a VMI system is one of the most effective partnership styles" (Tyan & Wee, 2003, p. 17) and because the case company already has experience with VMI (implementation).

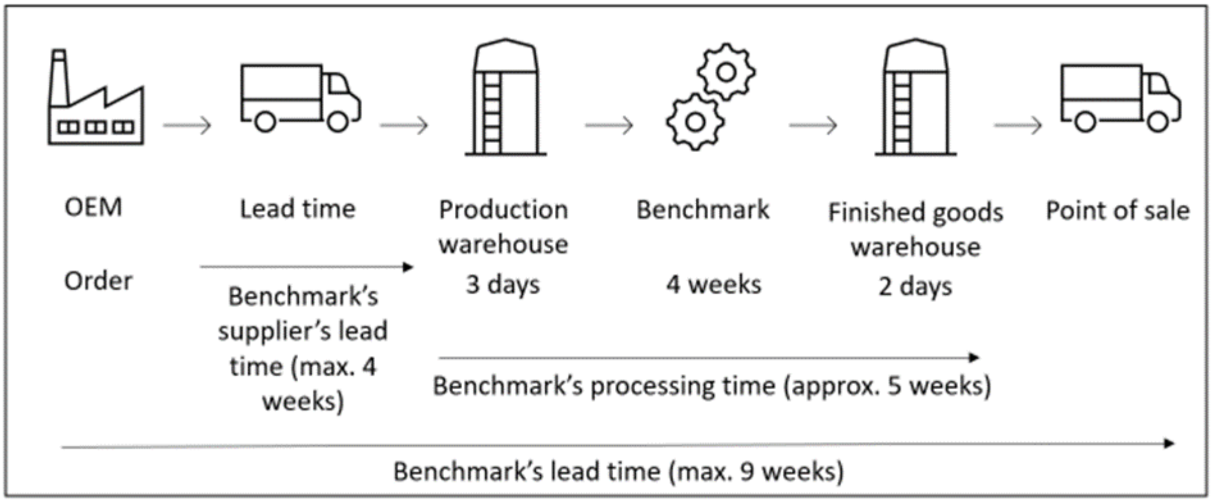

Figure 3 - An illustration of Benchmark's lead time

The second theme of this research is Industry 4.0. This is because VMI brings particular challenges with it, such as information sharing. Industry 4.0 could solve this challenge by, for example, end-to-end encrypted messaging with the use of blockchain. Including such Industry 4.0 technologies into VMI will result in a new concept: VMI 2.0.

In summary, this research's motivation is to reduce Benchmark's suppliers' lead time. This topic, reducing the lead times, has already been identified as one of the top priorities of Benchmark's supply chain manager. This means that Benchmark already acknowledges the problem and that this research is of significant importance. Additionally, Benchmark is already exploring solutions for this problem and is, in some cases, already using VMI. However, there is no transparent process or structure available for VMI implementation and monitoring.

2.3 Research objective and research questions: designing a VMI 2.0 framework to reduce supplier lead times

This research aims to design a framework that describes how VMI 2.0 should be implemented to minimise lead times. The following questions are formulated based on the template for design science research questions by Thuan et al. (2019, p. 20). Figure 4 presents this template.

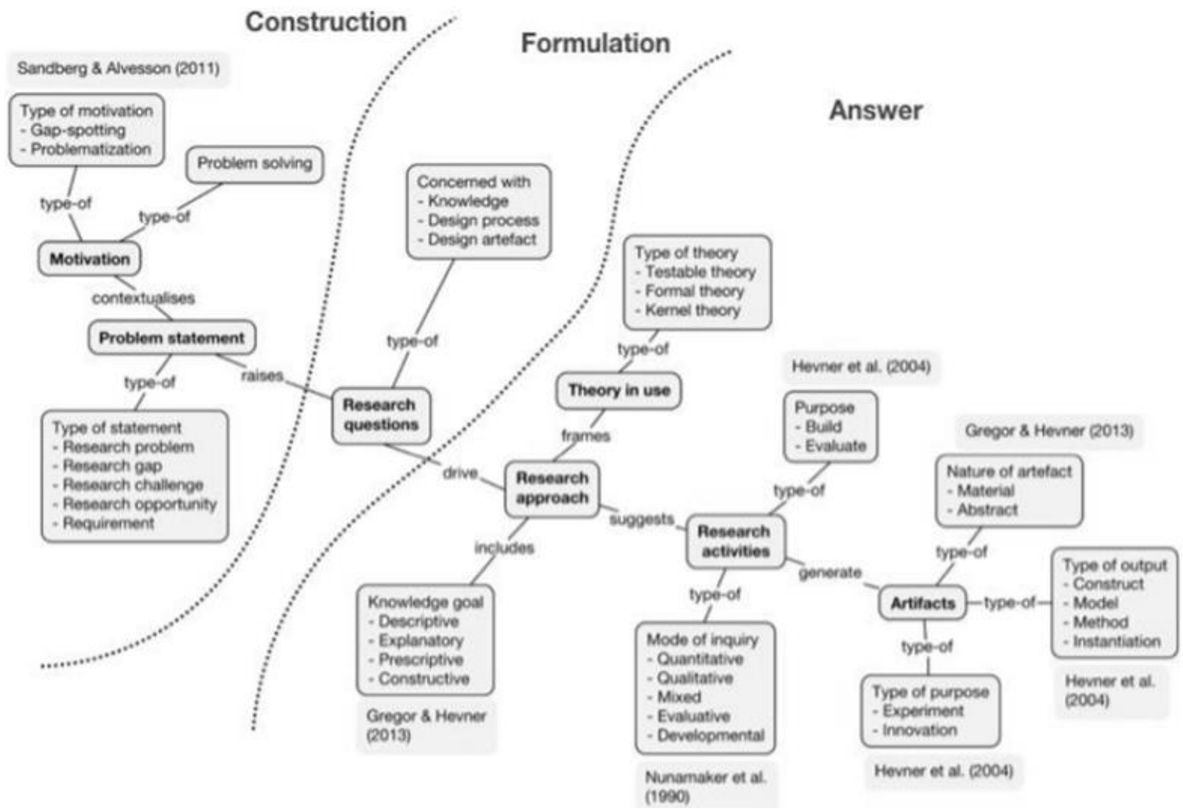

Figure 4 - Template for design science research questions by Thuan et al. (2019, p. 20)

The main research question that fits best with the described problem is:

How to implement Vendor Managed Inventory 2.0 to reduce supplier lead times?

The following sub-questions are established in order to answer this research question.

1) *What is the current situation of Benchmark regarding its spending and lead times?*
2) *Which concepts does the literature suggest to decrease lead times concerning collaborative initiatives in supply chains?*
3) *How should Vendor Managed Inventory be implemented and monitored?*

The following sub-questions are designed to include the Industry 4.0 aspect in the research so that VMI 2.0 can be described.

4) *What Industry 4.0 technologies shape VMI 2.0?*
5) *What are the implications of VMI 2.0?*

2.4 Research approach: following the DSRP model by Pfeffers et al. (2006)

The research objective is to design a framework that describes how VMI 2.0 should be implemented in order to minimise lead times. Because the purpose is to design something, the outline of this research is based on a framework for design science research activities. The design science research process (DSRP) model (Figure 5) by Pfeffers et al. (2006, p. 93) will be used because of its good fit with the case and the planned research activities.

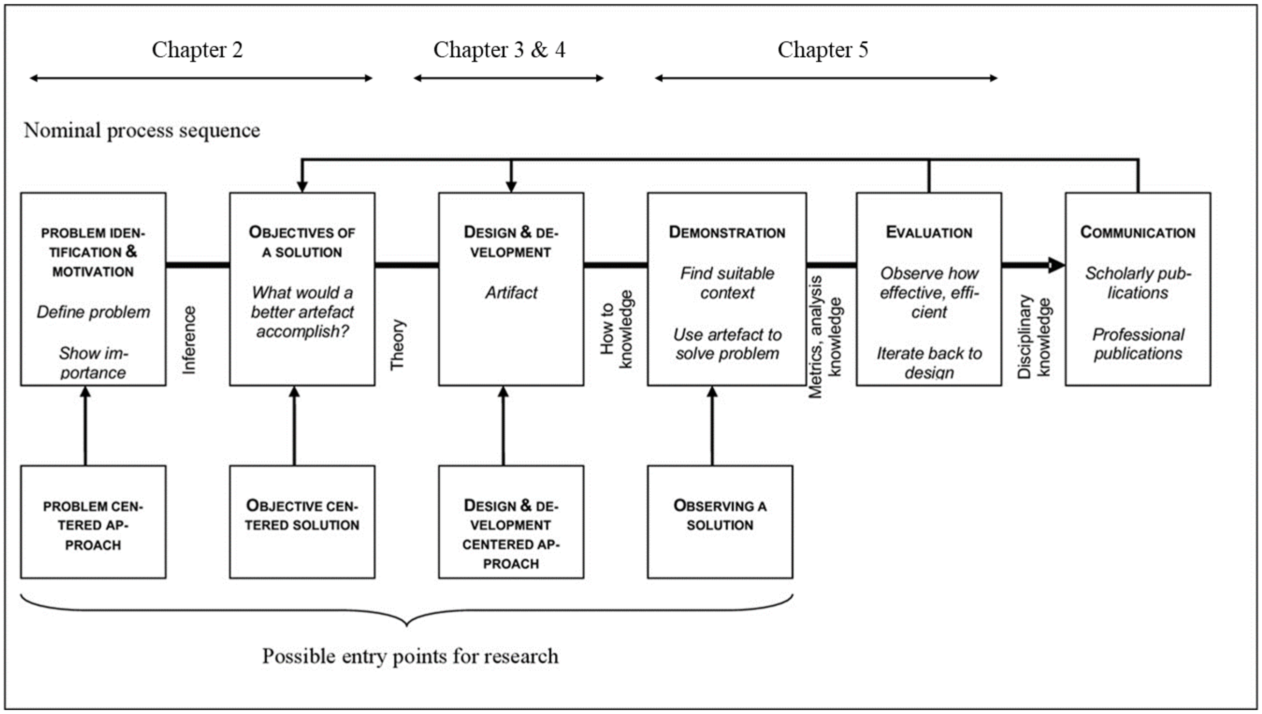

Figure 5 - Research structure based on Pfeffers et al. (2006, p. 93)

First, Chapter 1 was used to introduce the company to get familiar with the company before starting the research. Secondly, Chapter 2 has elaborated on the problem identification and the research motivation and design. Among others, the research problem and research questions are described. This chapter represented step 1 and 2 of the DSRP. Thereafter, in Chapter 3, the theoretical framework will be presented. This chapter will include literature on VMI (2.0), alternatives for VMI, lead times, and Industry 4.0. This chapter will be able to help answer sub-questions 2, 4 and 5: “Which concepts does the literature suggest to decrease lead times concerning collaborative initiatives in supply chains?”, “What Industry 4.0 technologies shape VMI 2.0?”, and “What are the implications of VMI 2.0?” Then, in Chapter 4, the research methodology used for this research will be presented. It will be based on design science research. Also in Chapter 4, the current situation of Benchmark Electronics, in relation to inventory management policy, will be briefly analysed and described. A look will be given into the different variables that are necessary to be able to comprehend the current inventory management policy. After this chapter, sub-question 1: “How can the current situation of Benchmark be described regarding its spending and lead times?” can be answered. Together, Chapters 3, and 4 represent step 3, design and development, of the DSRP. After that, in Chapter 5, the validated framework for implementation will be presented, representing step 4 of the DSRP, which is demonstration of the artefact. This validation was done by holding a Delphi study. After designing and validating the framework, sub-question 3: “How should Vendor Managed Inventory be implemented and monitored?” can be answered. Ultimately, after answering the three sub-questions and validating the framework, the central question of this research, “How to implement Vendor Managed Inventory 2.0 to reduce supplier lead times?” can be answered. This will be done in the last chapters, Chapters 6 and 7, which present the discussion and the limitations of the results.

Chapter	**Step in DSRP**	**Research-question(s) answered**
1	-	-
2	Problem identification & motivation, and Objectives of a solution	-
3	Design & Development	Sub-questions 2, 4 and 5
4	Design & Development	Sub-question 1
5	Demonstration	Sub-question 3 and main RQ
6	-	-
7	-	-

Table 1 - Research outline

3. Literature review: benefiting from supply chain collaboration and Industry 4.0 technologies to reduce lead time

3.1 Lead time is the time between placing an order and satisfying the customer’s demand

Lead time is a fundamental concept within the economic and financial evaluation of production, and it is a critical measure of the performance of the supply chain (Mohamed & Coutry, 2015, p. 2065). It can be defined as “the length of time between the time when an order for an item is placed and when it is actually available for satisfying customer demands” (Liao & Shyu, 1991, p. 72), and it includes “planning, procurement, inspection, manufacturing, handling, picking, packing and delivery” (Bianchini et al., 2019, p. 1205). Lead-time can be divided into three stages: order entry, order fulfilment, and order delivery to the customer (Mohamed & Coutry, 2015, p. 2065). Being aware of your lead time is essential because manufacturers have to control the product lead time and customers want to know when they will receive their ordered products (Kristoffersen, 2015; Sievers et al., 2017).

Having a relatively short lead-time has some benefits described by Bianchini et al. (2019, p. 1205). Firstly, it enhances greater competitiveness in the market. Also, the internal operations of production and distribution systems are improved by having shorter lead times. Furthermore, generally speaking, a higher lead time means lower customer satisfaction. When lead times are increased, increasing safety stock can help guarantee the required service levels (De Treville et al., 2014; Lin, 2016; Ponte et al., 2018).

The business strategy of the case company targets a lead time of, on average, four weeks. This means that the most prominent lead times have to be decreased by at least 90%. Bianchini et al. (2019, p. 1206) mention several strategies for lead time reduction: 1) sharing business forecasts with the involved suppliers, 2) maintaining updated and reliable business forecasts and sharing them with the involved suppliers, 3) double sourcing, 4) investments for supplier growth, 5) incorporating activities. Four out of five of these strategies indicate a form of supply chain collaboration. Ponte et al. (2018, p. 180) also found that traditional collaborative supply chains have shorter lead times and are more robust to variations in lead times. Based on this argumentation, a form of supply chain collaboration seems to be the right choice for the case company.

3.2 The supply chain collaboration techniques QR, ECR, CRP, VMI, and CPFR are frequently discussed in the academic field

The collaborative approach is identified to be the dominant approach in the buyer-supplier relationship in North America (Perdue et al., 1986, p. 175). This section will look into different collaboration techniques and initiatives to find alternatives to VMI for reducing lead times.

J.S et al. (2019) describe three different collaboration techniques that can be used within the supply chain: information sharing, collaborative planning, forecasting and replenishment, and Vendor Managed Inventory. Emphasised is that for successful implementation of any of these collaborative techniques focus should be on “SC relationship, trust, quality of IS and technological involvement” (J.S et al., 2019, p. 537).

De Freitas et al. (2018, p. 3) analyse a number of supply chain collaborative initiatives that are stated to be the most popular in the academic field (Gomes & Kliemann Neto, 2015). Based on this argumentation, this research will focus on Quick Response (QR), Efficient Consumer Response (ECR), Continuous Replenishment Program (CRP), Vendor Managed Inventory (VMI), and Collaborative Planning, Forecasting and Replenishment (CPFR). However, since section 3.1 already described VMI, it will not be mentioned again in this section.

Figure 6 - Evolutionary process of collaborative initiatives by De Freitas et al. (2018, p. 9)Figure 6, elaborated by De Freitas et al. (2018, p. 9), gives a brief overview of the different initiatives and their characteristics in a chronological scale of development.

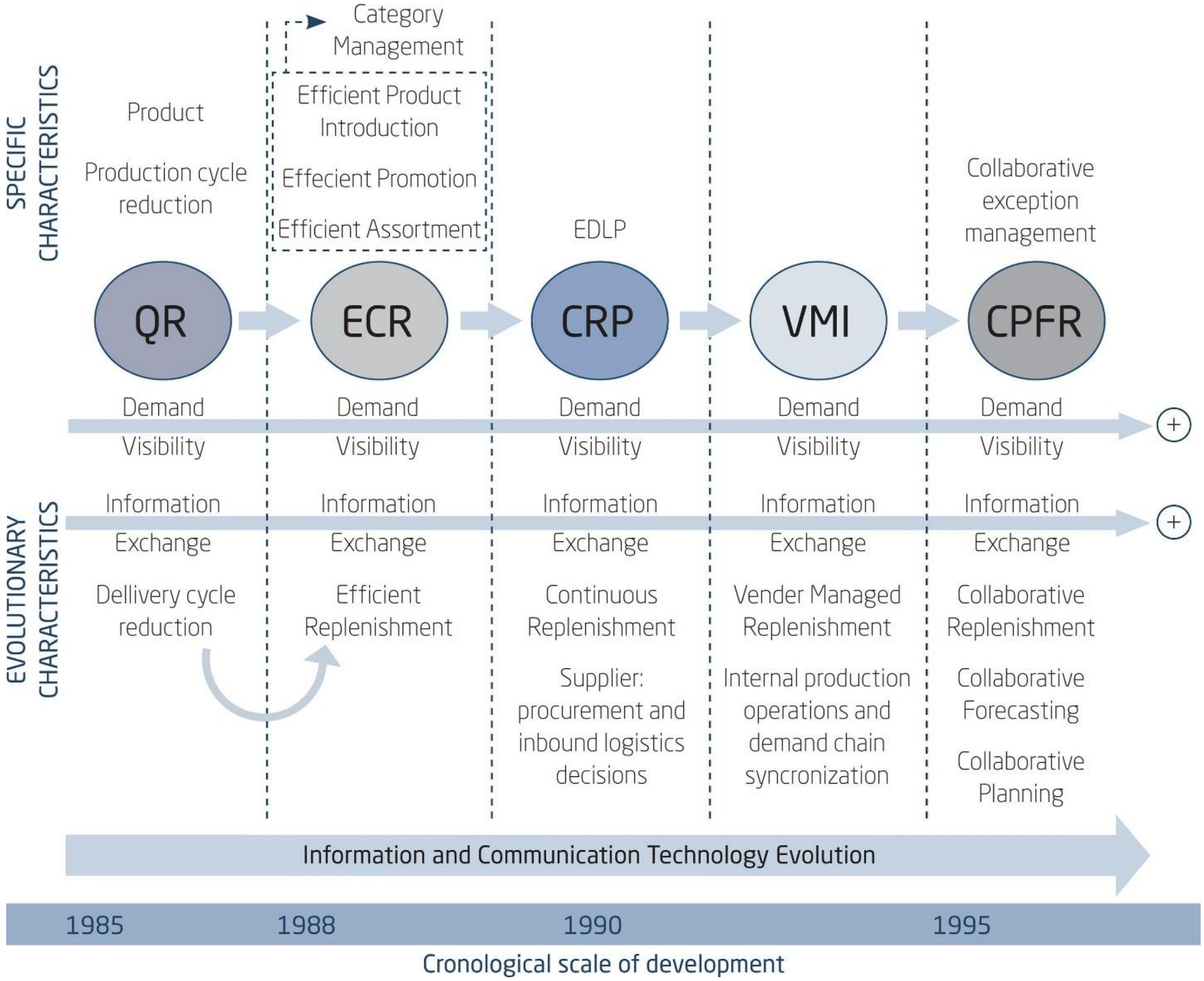

Figure 6 - Evolutionary process of collaborative initiatives by De Freitas et al. (2018, p. 9)

3.2.1 Quick Response (QR) determines inventory based on the JIT principles

QR was first used between buyers and suppliers in the fashion industry in the 1980s (Birtwistle et al., 2006). The strategy is based on the just-in-time (JIT) principles (Ellram et al., 1989; Fiorito et al., 1995; Harris et al., 1999), which involves the delivery of raw materials to production at the exact time and in the correct quantity (Harris et al., 1999, p. 35). This strategy reduces the inventory of the whole supply chain.

3.2.2 Efficient Consumer Response (ECR) used POS to transform the supply chain into a pull system

ECR was developed a couple of years later, in the early 1990s, in the grocery and consumer packaged goods industries. "ECR encouraged a philosophical shift from holding information internally to sharing strategic information, developing trusting relationships, and searching for efficiency improvements that would deliver enhanced customer value" (Kurt Salmon Associates Inc., 1993, as cited in Whipple & Russell, 2007, p. 175). ECR transforms the supply chain from a push to a pull system based on point-of-sale (POS) data (Harris et al., 1999, p. 35). ECR can be seen as an extension of QR (Derrouiche et al., 2008; Hoffman & Mehra, 2000; Soret, 2008).

3.2.3 Continuous Replenishment Program (CRP) needs inventory sharing and outsourcing of the retailer's inventory management

CPR has been developed from ECR by sophisticating its pull system (Tyan & Wee, 2003, p. 12). CPR uses two innovations described by Raghunathan and Yeh (2001, p. 406): the retailer's inventory levels need to be shared with its supplier, and the manufacturers determine the retailer's inventory management. The producer sends full loads to the distribution centre, whose composition varies based on sales and prearranged agreements (Derrouiche et al., 2008, p. 429).

3.2.4 Collaborative Planning, Forecasting and Replenishment (CPFR) integrates the supply and demand sides to respond quickly to market changes

CPFR is defined by Derrouiche et al. (2008, p. 429) as "is a set of business processes that are established and empowered by a formal agreement to cooperate on strategy, tactics, and execution by resolution of exceptions." CPFR enables "the collective creation of an effective environment to meet consumer demands" (Chang et al., 2007, p. 200) by integrating the supply and demand sides which ultimately improves the ability of the retailer to respond quickly to market changes (De Freitas et al., 2018, p. 7). Derrouiche et al. (2008, p. 429) state that the first CPFR initiative was developed and the first CPRF guidelines were published, in the late 1990s. The CPFR process consists of nine steps illustrated in Table 2.

Process step	Definition	Data consumed	Data produced
1	Develop front-end agreement	None (manual)	None (manual)
2	Create a joint business plan	Buyer's corporate strategy Seller's corporate strategy	Joint business plan
3	Create sales forecast	Joint business plan Point of sale (POS) data Events Sales forecast revisions	Sales forecast
4	Identify sale forecast exceptions	Sales forecast Exception criteria Metrics Events	Identified exception items
5	Collaborate on sales forecast exceptions	Buyer's secondary data for exception items Identified exception items Seller's secondary data for exception items	Sales forecast item revisions
6	Create order forecast	Order forecast revisions POS data Current inventory on hand Inventory strategy seasonal info Sales forecast Events Product historical demand and shipments Product availability data Item management profile data	Order forecast
7	Identify order forecast exceptions	Order forecast Exception criteria and values Events	Identified order exception items
8	Collaborate on order forecast exceptions	Buyer's secondary data for exception items Identified exception items Seller's secondary data for exception items	Order forecast revisions
9	Generate order	Order forecast Item management profile	Order

Table 2 - Original CPFR data flow summary based on VICS (1999)

3.3 Vendor Managed Inventory is a concept that lets upstream organisations manage downstream organisation's inventory

3.3.1 VMI can be defined as an inventory management concept where upstream organisations, such as suppliers, manage and control the downstream customers' inventory

Zhao (2019, p. 1000) defines VMI as an inventory management concept where upstream organisations, such as suppliers, manage and control the downstream customers' inventory by analysing the downstream customers' production, operations, and inventory information. He also states that "due to centralised decision-making and information sharing, VMI's revenue is much higher than that in traditional supply chains" (Zhao, 2019, p. 1000). After the success story of VMI implementation at Procter & Gamble and Wal-Mart in the 1980s (Tyan & Wee, 2003, p. 13), many other companies followed, such as Shell Chemical and Campbell Soup Company (Bookbinder et al., 2010; Cachon & Fisher, 1997).

3.3.2 VMI has several benefits, such as the reduction of supply chain shortages or the reduction of transportation costs

The main benefits of VMI are reduced costs of ordering, inventory and transportation, and improving production planning, service levels, customer benefits, and forecast accuracy (Zhao, 2019, p. 1000). Weißhuhn and Hoberg (2021, p. 962) state that VMI's selling points and perceived benefits are the convenience aspects of reduced lead times and automatic replenishment service. Other benefits are mentioned by Salem and Elomri (2017, p. 89) and by Beheshti (2020, pp. 842-844). These benefits are summarised in Table 3.

Benefit for supplier	**Benefit for both**	**Benefit for buyer**
Balanced production	Reduction of supply chain average inventory	Improving customer service levels
Better utilisation of resources	Reduction of supply chain costs	Improved procurement and payment processes
Reduction of bullwhip effect/demand uncertainty	Reduction of shortages and overstocks	Decreased inventory-related costs
Flexible replenishment strategy	More accurate forecasting	Decreased ordering costs
Long-term benefits (competitive advantage) to the supplier	More sustainable buyer-supplier relationship	Shorter lead times
Reduction of transportation costs	Smoothening of demand variations through the supply chain	Less working capital needed to run the business
Reduction of carrying costs	-	A consolidated supply base
Reduction of safety stock	-	Elimination of repetitive purchasing tasks

Supplier in control of inventory and scheduling	-	More detailed reporting capabilities
Savings on promotion costs of new products	-	-
Improved customer service and customer retention	-	-
Improved revenues	-	-

Table 3 - Benefits of VMI for vendors, retailers, and both based on Salem and Elomri (2017, p. 89) and Beheshti (2020, pp. 842-844)

3.3.3 Success factors such as sharing information are important for successful VMI implementation

Several factors are crucial for the successful implementation of VMI. Firstly, sharing information is vital. By sharing information, timely and accurate data can be gathered which will ultimately result in better demand forecast accuracy and in more timely and cost-effective supply (Kim, 2005, as cited in Salem & Elomri, 2017, p. 88). Sharing information, next to sharing data, also includes sharing goals. Namely, Micheau (2005, p. 17) emphasises that representing every interest or stakeholder by each firm is also a critical success factor. What also should be considered is that efficiency can be improved by the adaptation of EDI systems and automated data transfer (Vigtil, 2007, p. 144).

Additionally, Salem and Elomri (2017, p. 88) state that those who are going to implement VMI should understand their business conditions very well before the actual implementation. Also, an adversarial relationship between supplier and retailer may lead to the failure to adopt VMI (Dong et al., 2007, p. 365). Contrarily, a high degree of cooperation between supplier and retailer contributes to the success of VMI. This means that cooperation is also a success factor.

Niranjan et al. (2012, p. 941) designed a survey for VMI readiness. The company can fill this survey that considers VMI implementation for either the whole company or per commodity. The final VMI readiness score indicates whether the company should implement, consider, or not implement VMI.

Lastly, the supplier applicability conditions of VMI are described by De Toni and Zamolo (2005, p. 77): 1) high exchange levels, 2) short supplier-customer distances, 3) reliability and forecast of demand, 4) high informatisation, 5) low flexibility and reply time to market, 6) high criticality of code.

3.3.4 Multiple VMI implementation challenges need to be overcome such as high demand uncertainty

For attaining the benefits of VMI, several challenges have to be completed. Firstly, Sari (2007, p. 531) states that VMI's improvement will be reduced if there is a high demand uncertainty. This demand uncertainty can be reduced by sharing information across the supply chain (Salem & Elomri, 2017, p. 87). However, the retailer often may not be motivated to share information because the benefits of sharing information are primarily for the supplier (Lee et al., 2000; Sari, 2007; Yu et al., 2001; Zhao et al., 2002). Furthermore, the implementation of VMI can be hindered by the investments required for achieving supply chain integration (Salem & Elomri, 2017, p. 87). Another obstacle can be a long physical distance between the supplier and the retailer (De Toni & Zamolo, 2005, p. 46). Also, it might be difficult for the supplier to manage a large number of independent retailers (Blatherwick, 1998, p. 11). And lastly, it might be challenging to manage benefits among participants (Dong & Leung, 2009, p. 1189).

Concluding, Sari (2007, p. 530) states that the failure of VMI is caused by either 1) sharing outdated or inaccurate sales and inventory data, the absence of functioning IT systems, or a lack of trust among the participants in the supply chain. Or 2) the generation of inaccurate customer demand forecasts due to the exclusion of retailers from the demand forecasting process.

3.4 Industry 4.0 and its technologies radically change the way supply chains are utilised and provide lots of opportunities, also for VMI

3.4.1 Defining Industry 4.0 as the "fourth industrial revolution or the introduction of internet technology in the manufacturing industry […]"

Firstly, "the term Industry 4.0 […] refers to the "fourth industrial revolution or the introduction of internet technology in the manufacturing industry […] and integrates customers more closely into the product definition stage as well as business partners into the value and logistic chains" (Stork, 2015, p. 21). The concept of Industry 4.0 was first introduced during an event called the Hannover Fair in 2011 (Ghobakhloo, 2018, p. 910), after which it immediately was acknowledged and included by the German government in their industrial growth strategy (Ghobakhloo, 2018, p. 910). Based on a comprehensive content analysis of Industry 4.0 technologies within manufacturing by Oztemel and Gursev (2020, p. 10) it can be stated that CPS, Cloud systems, machine-to-machine (M2M) communication, Smart factories, Big Data, Internet of things, simulation tools, Artificial

Intelligence, and the processing of real-life data are the core technologies of Industry 4.0. Its improvement relative to Industry 3.0 is that the human-machine interface, digitalisation, and automation that characterise Industry 3.0 are replaced by Cyber-Physical Systems (CPSs), autonomous self-optimising systems within the entire supply chain, and M2M communication (Schiele & Torn, 2020, pp. 512-513).

3.4.2 Explaining the Industry 4.0 systems that are most applicable to purchasing and supply chain management

The variety of Industry 4.0 systems has recently gained massive attention from scholars. Literature is available about which and how Industry 4.0 systems will affect e.g. relational performance (Brookbanks & Parry, 2022; Swierczek, 2022), or sustainable manufacturing (Ojo et al., 2020). However, most important, sufficient literature is available about which and how Industry 4.0 systems will affect operations- and supply chain management (Aryal et al., 2020; Choi et al., 2022; Hallikas et al., 2021; Holmström et al., 2019; Talwar et al., 2021; Yang et al., 2021), and purchasing (Chandrasekara et al., 2020; Gottge et al., 2020; Schiele & Torn, 2020; Seyedghorban et al., 2020; Viale & Zouari, 2020). The Industry 4.0 systems that are most applicable for purchasing and supply chain management, and are mentioned most often are Artificial Intelligence, (Big data) predictive analytics, sensors, cyber tracking, Blockchain, and cloud computing.

Another research, provided by Deloitte (2017, p. 5), provides a clear overview of concrete Industry 4.0 technologies used in purchasing. They distinguish three groups: core technologies, maturing technologies, and emerging technologies, based on the degree to which the capabilities are currently being utilised in procurement. These technologies are presented in Table 4.

Technology group	**Technology**	**Definition**	**References**
Core technology	Spend analytics	Provides procurement with insights into a firm's entire set of purchases.	(Monczka et al., 2016, p. 201)
	eSourcing	"The process of identifying new suppliers for a specific category of purchasing requirements using Internet technology".	(De Boer, Harink, & Heijboer, 2002, p. 26)
	Electronic catalogues	Low-dollar purchase systems that enable online ordering, and can also be used to identify suppliers.	(Monczka et al., 2016, p. 81)
	Contract management	"A process associated with defining the contract, defining roles and responsibilities of both parties, and advising when to modify and ensure appropriate escalation".	(Monczka et al., 2016, p. 48)

	Supplier Information Management	Provides management and governance over the massive volume of supplier data coming from different sources.	(Flynn, 2017)
	eProcurement	"The panel of functionalities and electronic tools adaptable to automate the supply process, which includes the transactional activities after the contract subscription, starting from order placement and including the whole order-to-pay cycle".	Caniato, Longoni, & Moretto, 2012, pp. 935-936)
	eInvoicing	Includes the utilisation of electronic means for the sending and receiving of invoices.	(Sandberg, Wahlberg, & Pan, 2009, p. 289)
	eAuctions	An electronic competitive bidding tool where potential qualified suppliers go online and bid against each other to get the business.	(Monczka et al., 2016, p. 65)
Maturing technology	Cognitive Computing and Artificial Intelligence *	Provide new insights and opportunities by leveraging pattern recognition software and iterative machine learning algorithms that can quickly categorise unstructured spending, cost, contract, and supplier data.	(Deloitte, 2017, p. 5)
	Intelligent Content Extraction	Uses Optical Character Recognition (OCR) and learning algorithms to read unstructured documents and quickly extracts critical pieces of data that would have taken days or weeks to assemble manually.	(Deloitte, 2017, p. 5)
	Predictive and Advanced Analytics *	Enables proactive decision-making by predicting the most likely scenarios based on combining modeling, statistics, machine learning, and Artificial Intelligence with multiple third-party data sources.	(Deloitte, 2017, p. 5)
	Visualisation	Simplifies decision-making by transforming data into user-friendly formats.	(Deloitte, 2017, p. 5)
	Collaboration Networks	Platforms that deliver insights into opportunities and risks by providing buyers and suppliers with visibility into all elements of their joint value chains.	(Deloitte, 2017, p. 5)
	Crowdsourcing	Gives an organisation insights into trends and events impacting supply chains and supplier performance through capturing large and diverse inputs.	(Deloitte, 2017, p. 5)
	3D Printing	Can quickly make a physical object based on a digital model. It can be used for rapid prototyping.	(Deloitte, 2017, p. 5)
	Robotic Process Automation	Software recognises and learns patterns to perform rule-based tasks. It can be used to replace repetitive manual tasks.	(Deloitte, 2017, p. 5)
Emerging technology	Blockchain *	A cryptologic data structure that uses a peer-to-peer network to create digital transaction ledgers. It can be used to trigger automated payment.	(Deloitte, 2017, p. 5)
	Sensors and Wearables *	Devices that detect, capture and record physical data. With this data, the devices can observe the movement of goods and inventory levels, improving reordering and enabling audit tracking during site visits.	(Deloitte, 2017, p. 5)
	Cyber Tracking *	Uses real-time tracking of online or physical activity. It can deliver trends and predictions on supply chain risks and can therefore be used to monitor supplier behaviour and performance proactively.	(Deloitte, 2017, p. 5)
	Virtual Reality and Spatial Analytics	Allow procurement professionals to quickly gain data by detecting events or changes of status using video, location data, or pattern analysis and conducting supplier visits or audits.	(Deloitte, 2017, p. 5)

Table 4 - Industry 4.0 technologies based on Deloitte (2017, p. 5) and Emmerich (2021, p. 3)

* most applicable technologies within this research

3.4.3 Industry 4.0 offers multiple opportunities for VMI and ultimately creates the VMI 2.0 concept

Before looking specifically at how Industry 4.0 influences VMI, first, briefly the term Supply chain 4.0 will be introduced to emphasise the relations between Industry 4.0, and the supply chain as a whole (Frederico et al., 2019, p. 263). Supply chain 4.0 is defined as a "… transformational and holistic approach for supply chain management that utilises Industry 4.0 disruptive technologies to streamline supply chain processes, activities and relationships to generate significant strategic benefits for all supply chain stakeholders" (Frederico et al., 2019, p. 275). Strategic outcomes of Supply chain 4.0 are improved customer and supplier focus, cost reduction and improved profitability, and improvements in strategic impacts (Frederico et al., 2019, p. 275).

Now that the concept of Supply chain 4.0 and its strategic implications are clear, elaborated will be on VMI and its Industry 4.0 implications. Firstly, it must be understood that the buyer-supplier information exchange is essential to VMI. This is because all the data that contribute to determining the supply level, sales orders, forecasts, et cetera need to be transmitted and shared with the suppliers for VMI to work. Within the VMI process, the information exchanges can be divided based on their temporal horizon between long-term, mid-term, and short-term. Figure 7 illustrates the three different information exchanges.

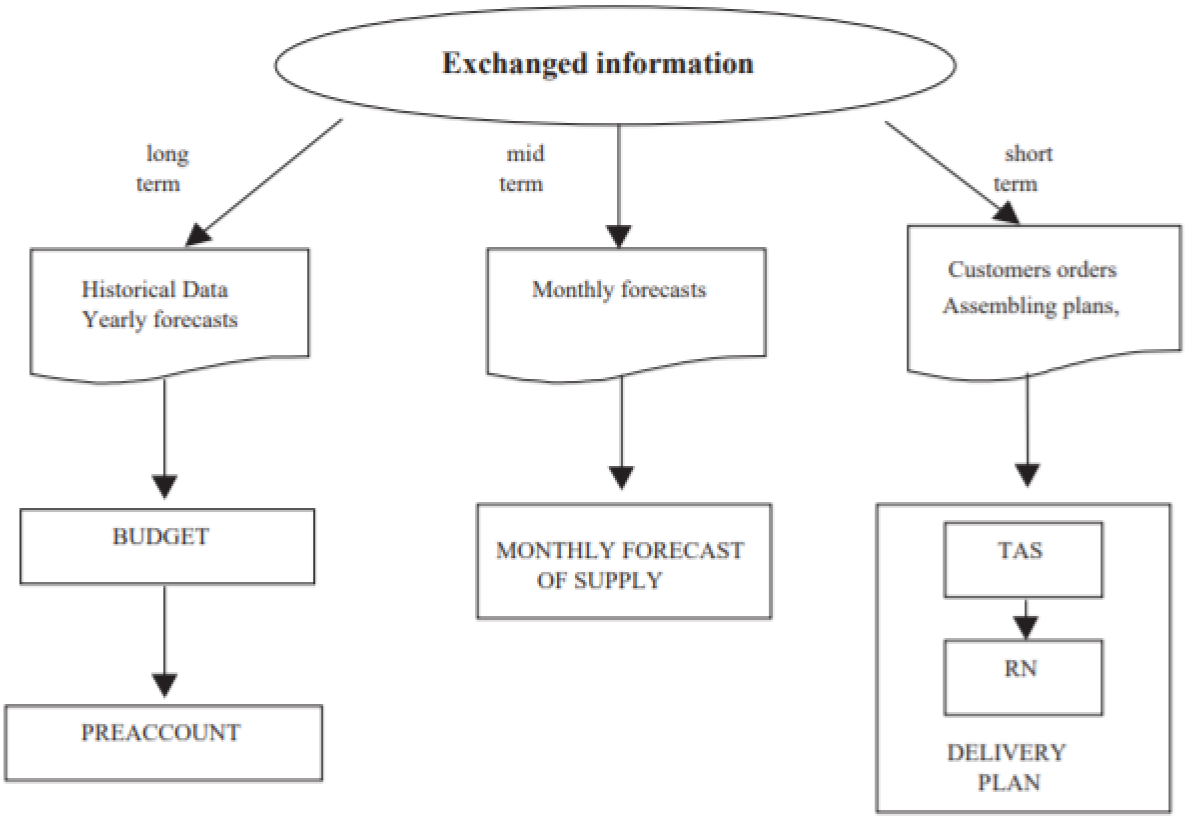

Figure 7 - The information exchange within VMI by De Toni and Zamolo (2005, p. 71)

Based on the definitions in Table 4, several Industry 4.0 technologies are found to be interesting technologies for VMI 2.0. These technologies are split up between analytical technologies, tracking technologies, and communication technologies. Firstly, for analytical technologies, Artificial Intelligence can help develop data and information (Tian et al., 2017, p. 58). The same goes for predictive analytics (PA) (Jeble et al., 2018, p. 6). Sensors are a tracking technology that can be used for, e.g. inventory tracking and are therefore also helpful for information generation (Wu et al., 2016, p. 400). The same goes for Cyber tracking, which can be used as a means to generate information about e.g., supply chain risks and supplier performance. Blockchain does not seem particularly beneficial for VMI 2.0 when looking solely at its definition in Table 4. However, based on other definitions, the technology can be helpful as a communication technology for safely exchanging information with stakeholders (Omar et al., 2020, p. 182704). Also, Cloud computing could, as a communication technology benefit VMI 2.0 by providing solutions to problems such as inefficient data exchange and sharing, low productivity, and non-optimal utilisation of manufacturing resources (Xu, 2018, p. 2947).

Analytical technologies	Tracking technologies	Communication technologies
Artificial Intelligence	Sensors	Blockchain
Predictive analytics	Cyber tracking	Cloud computing

Table 5 - Categories of VMI 2.0 Industry 4.0 technologies

Analytical technologies

Artificial Intelligence (AI) is one Industry 4.0 technology worth considering for VMI. It works just like human intelligence, including a person's visual, auditory, taste, and other sensory systems. AI typically begins with sensor data, which it processes and synthesises, often with prior knowledge and models (Tian et al., 2017, pp. 58-59). With this processed and synthesised data, information can be extracted, such as geometric features, attributes, location, and velocity, that can solve the task of the AI system (Tian et al., 2017, p. 58).

De Giovanni (2021, p. 515) states that "in supply chain management, the AI system will create a knowledge-driven collaborative assurance and supply/marketing/service platform to collect production, procurement, logistics, supply chains and warehouse and marketing data." He also summarises the benefits wherein AI will help with "intelligent scheduling and planning, process parameter optimisation, intelligent quality analysis, improvement and control, preventive maintenance, production costs analysis, estimation and control, intelligent control of energy consumption and emissions, and monitoring of production process and procedures" (De Giovanni, 2021, pp. 515-516).

Predictive analytics (PA) is "the application of skills, expertise and algorithms on collected data to estimate the likelihood an event will take place in the future" (Ardolino et al., 2018, p. 2117). PA is an upgraded form of business intelligence combined with data mining and statistical techniques (Jeble et al., 2018, p. 7). Its application allows companies to become more productive and profitable than competitors (McAfee et al., 2012, p. 6). It uses both quantitative and qualitative methods, such as pattern recognition, statistics, machine learning, Artificial Intelligence, and data mining (Abbott, 2014, p. 3), to improve supply chain design and competitiveness (Waller & Fawcett, 2013, p. 80). Also, it "enables proactive decision-making by predicting the most likely scenarios based on combining modelling, statistics, machine learning, and Artificial Intelligence with multiple third-party data sources" (Deloitte, 2017, p. 5).

PA's most significant benefits are "seen in the form of informed decision-making capabilities, ability to improve supply chain efficiencies, enhanced demand planning capabilities, improvement in supply chain costs, and increased visibility" (Schoenherr & Speier-Pero, 2015, p. 123). Significantly this second benefit, the increased demand planning capabilities, can improve the VMI 2.0 process by making the forecasts more accurate.

Tracking technologies

Cyber tracking uses "real-time tracking of online or physical activity. It can deliver trends and predictions on supply chain risks and can therefore be used to monitor supplier behaviour and performance proactively." (Deloitte, 2017, p. 5). Therefore, it is a means to develop information about supply chain risks and supplier performance. This broadens the perspective of Industry 4.0 technologies in a way that it not only provides information about current stock levels but also about risks and performance. It is therefore used for more strategic purposes instead of operational ends. Summarising, cyber tracking could help VMI 2.0 by assessing risk more accurately and assessing and selecting suppliers for VMI 2.0 implementation.

Sensors are "devices that detect, capture and record physical data. With this data, the devices can observe the movement of goods and inventory levels which can improve reordering and enable audit tracking during site visits" (Deloitte, 2017, p. 5). This means that it is another means to develop information. Sensors replace human observance at specific points in the supply chain. They can send signals to suppliers whenever replenishment is necessary or even keep suppliers updated on the stock levels in real-time. An example of a VMI system equipped with sensors is the Smartbin. This is a container that contains screws attached to a scale. Sensors track the weight of the container, and the supplier gets this information in real-time. When the tray's weight falls below a predetermined amount, a signal is sent to the supplier that asks for replenishment.

The benefits of sensors are that they can help reduce inventory shrinkage, prevent stockouts, avoid excess stocks, and improve data accuracy (Wu et al., 2016, p. 404). Also, other Industry 4.0 technologies, such as Internet of Things, cloud computing, and data analytics, depend on the quality of the data that is gathered by sensors (van Staden & Boute, 2021, p. 586). These technologies can, together, reduce maintenance costs by enabling condition-based maintenance policies (van Staden & Boute, 2021, p. 586).

Communication technologies

The Industry 4.0 technology to improve the exchange of information is *Blockchain*. Omar et al. (2020, p. 182704) state that "VMI operations face critical challenges related to data integrity, transparency, traceability, and single point of failure due to its centralised architecture." He defines Blockchain technology as "a distributed ledger that ensures a transparent, safe, and secure exchange of data among supply chain stakeholders" (Omar et al., 2020, p. 182704). It is thus a, "secure, efficient, fair, and trustworthy data-sharing mechanism" (Wang, 2021, p. 1965). What Blockchain does is that it creates a decentralised platform by offering transparency and trackability to enhance trust among supply chain members (Guggenberger, 2020, p. 1074).

It is stated that Blockchain can replace traditional CPFR practices within the supply chain and establish supply chain provenance (Cui et al., 2019, p. 157115). Decentralised control, security, traceability, and auditable time-stamped transactions are mentioned as advantages of implementing Blockchain in VMI operations within the supply chain (Omar et al., 2020, p. 182704).

A process description of a Blockchain-based VMI process is described by Dasaklis (2019, pp. 51-52) and summarised in Table 6.

Step	**Description**
1	The retailer keeps an updated track of its inventory. There are two options: sending its inventory status periodically to the Blockchain or storing the inventory status in a local database.
2	The vendor checks the retailer's inventory via Blockchain or directly via the local retailer's database.
3	The vendor detects the series of needs of the retailer and then deploys a smart contract with a new order to refill the retailer's needs. This smart contract includes specific conditions, periods and additional information. Also, other participants that must be mentioned in the smart contract such as delivery companies are able to update and change the status of products.
4	The retailer checks the content of the smart contract and accepts or denies it, confirming or denying the transaction.
5	The vendor delivers the retailer's new products. The products' status, such as location or delivery times, can be updated throughout all of the supply chain.

Table 6 - Process description of a Blockchain-based VMI process by Dasaklis (2019, pp. 51-52)

This Industry 4.0 technology has not been used in the paper of Deloitte (2017). However, citing Shou (2020, p. 873), "*Cloud computing* is a major enabling technology for Industry 4.0 and the Big Data era." This, together with its high number of mentions and dedicated contributions in academic literature, and its perceived relevance by several interviewees of the case company, it will be added to the VMI 2.0 framework.

Cloud computing is described as a computing technology that offers high performance at low costs (Mitra et al., 2017; Zheng et al., 2014). It provides solutions to problems such as inefficient data exchange and sharing, low productivity, and non-optimal utilisation of manufacturing resources (Xu, 2018, p. 2947). These problems often occur because manufacturers use different computing resources, such as multiple servers for databases and decision-making units (Xu, 2018, p. 2947). What cloud computing then provides to support these complex decision-making tasks, is that "all data can be stored in private or public cloud servers" (Xu, 2018, p. 2947). By offering the opportunity to upload "a large volume of data … to a cloud computing centre for storage and computation, which facilitates manufacturing and production" (Xu, 2018, p. 2947), it enables, among others, improved resource sharing, dynamic allocation, and flexible extensions (Xu, 2018, p. 2947). For VMI 2.0, cloud computing can thus help with storing and sharing large volumes of data, e.g., forecasts, with internal as well as external stakeholders such as suppliers.

3.4.4 VMI 2.0 is a more sophisticated form of VMI, that is designed in the Industry 4.0 era

In summarising, VMI 2.0 can be described as the more sophisticated form of VMI, that is designed in the Industry 4.0 era, and that includes multiple Industry 4.0 technologies: 1) Artificial Intelligence could help VMI 2.0 by, amongst others, developing data and making advanced forecasts, 2) Predictive analytics could help VMI 2.0 by making accurate forecasts, 3) Cyber Tracking could help VMI 2.0 by assessing risk more accurately and assessing and selecting suppliers for VMI 2.0 implementation, 4) Sensors could enable Predictive analytics and other types of analytics together with real-time data exchange, 5) Blockchain technology enables fast, traceable and secured data exchange, and 6) Cloud computing helps with storing and sharing large volumes of data.

4. Methodology: conducting semi-structured interviews and a Delphi study within the DSRP approach

4.1 Introducing the Design Science Research Process

This research aims to develop a framework that describes how VMI 2.0 should be implemented. This research objective can be placed in the Design Science Research field because of its explorative and designing character. Dresch et al. (2015, p. 1124) state that this field of research might be appropriate for researchers who seek more relevant studies for the solution of problems of organisations and that "Design Science Research proved adequate because it contributed directly to reducing the gap between theory and practice, since this method addresses problems both on the interest of professionals in organisations and academic interests" (Hughes et al., 2011, as cited in Dresch et al., 2015, p. 1124).

Figure 8 describes the steps within the Design Science Research Process (DSRP) model by Pfeffers et al. (2006, p. 93). This methodology chapter is part of step 3, the design & development stage.

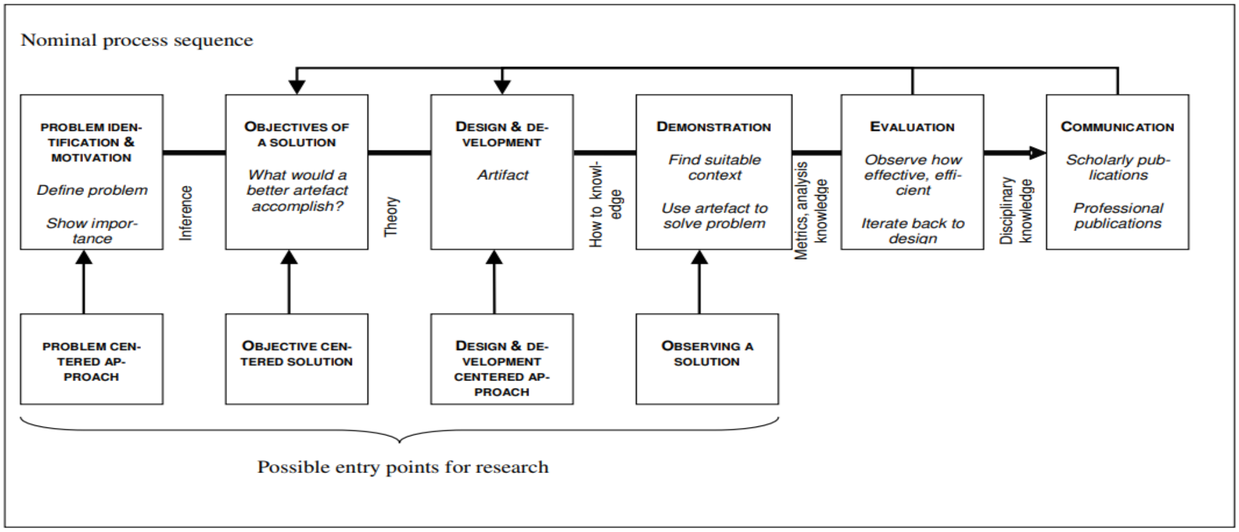

Figure 8 - The DSRP model by Pfeffers et al. (2006, p. 93)

4.2 DSRP step 1: Identifying the problem based on semi-structured interviews

4.2.1 Holding a single case study to align the case company's and academic interests

For the identification of the problem and the definition of objectives, a single case study was held. The research method of case studies is a complex one. While the name itself provides immediate insight into its scope of application, its unravelling can take many forms. The core of this research method lays in theory building, and because of this, traditional research phases can be changed. Eisenhardt (1989, pp. 546-547) mentions the following strengths of building theory from cases: 1) the likelihood is high that by building theory from cases, a novel theory is generated. 2) it is likely that the emergent theory is testable with constructs that can be readily measured because they have already been measured within the theory-building process and with hypotheses that can be proven false. And 3) the likelihood that the resultant theory is empirically valid is high because the theory process is related closely to evidence. This makes it highly likely that the resultant theory and the empirical observation will be consistent.

Also, Yin (2009, p. 18) defined the case study as an empirical study that "investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident." For organisational scholars, in particular, this can prove to be advantageous, as complex organisational scenarios can be brought to greater clarity by conducting research in the context of where the scenario usually occurs.

According to Stake (1995, p. 2), there are three types of case studies. These types are based on their use. Intrinsic case studies are used to describe the uniqueness of the phenomenon. Instead, it is possible to gain a broader understanding of general issues through instrumental case studies. In collective case studies, multiple cases are selected and compared in order to use the findings to generalise a theory or directly evaluate an existing theory.

4.2.2 Using semi-structured interviews for context understanding

Semi-structured interviews were held with multiple employees of Benchmark. This was the last research method for the problem identification and objective definition stage. A qualitative interview is called the primary method in qualitative research (Oltmann, 2016, p. 1). It is also called the most direct, research-focused interaction between research and participant (Kazmer & Xie, 2008, p. 258). Therefore, it is an important research method for this research. The semi-structured interviews were held using the interview guide that can be found in Appendix 1.

The purpose of the interviews with the Benchmark employees was to analyse the research context and determine the importance of the research for Benchmark, both presented in Chapter 2 of this research. Also, the interviews complement the spend analysis with qualitative information and context. Questions were asked about the motivators, benefits, and barriers of VMI, as these were the elements used in the VMI framework by Freitas et al. (2019, p. 11). Additionally, alternatives to VMI were identified as a fourth element. Table 7 presents the sample of interviewees used for this round of interviews.

Respondent number	**Function**	**Company (case company or supplier)**	**Modality (face-to-face or video call)**
1	Supply chain manager	Case company	Face-to-face
2	Tactical buyer	Case company	Video call
3	Tactical buyer	Case company	Video call
4	Project leader	Case company	Video call
5	Program manager	Case company	Video call
6	Tactical buyer	Case company	Video call
7	Supply chain architect	Case company	Video call

8	Program manager	Case company	Video call

Table 7 – The sample of interviewees

Coding

The interviews were transcribed and then uploaded into Atlas.ti in order to be coded and analysed. Atlas.ti is an analysis software used for manually coding any text document to retrieve and analyse qualitative data. Additionally, the code-occurrence explorer can be used to find potential relationships between codes. The benefits of using Atlas.ti are summarised by Hwang (2008, p. 521): 1) It enhances the credibility of the research as it makes the research processes more transparent and replicable. And 2) in project management, and especially in a teamwork context, using Atlas.ti can be timesaving and more efficient.

The coding strategy used was the inductive content analytic coding strategy, outlined by Gioia et al. (2013).

4.3 DSRP step 2: setting objectives based on a spend- and lead time analysis

4.3.1 Executing a spend analysis to understand the case company's situation

A spend analysis was held to get a clear picture of the current situation of Benchmark regarding its current spending and additionally its current lead times. This spend analysis helped with prioritising suppliers in terms of lead time reduction and savings opportunities. Robert M. Monczka et al. (2016, p. 201) define the spend analysis as an analysis used to identify savings by reviewing a firm's entire set of purchases. Moreover, they state that the spend analysis provides insights and clarity into the questions: 1) "What did the business spend its money on over the past year?", 2) "Did the business receive the right amount of products and services, given what it paid for them?", 3) "What suppliers are awarded the majority of our business volume, and did they charge an accurate price across all the divisions in comparison to the requirements in the POs, contracts, and statements of work?", 4) "Which divisions of the business spent their money on products and services that were correctly budgeted for?", and 5) "Are there opportunities to combine volumes of spending from different businesses, and standardise product requirements, reduce the number of suppliers providing these products, or exploit market conditions to receive better pricing?".

A reasonably accurate spend database is necessary for a spend analysis (Robert M. Monczka et al., 2016, p. 202). This condition was fulfilled, so the spend analysis was conducted following the steps of Robert M. Monczka et al. (2016, pp. 202-205). Table 8 gives an overview of the seven steps.

Step Number	Description
1	Sort the data in the spend database based on the spend category.
2	Find the total spend by spend category.
3	Make a chart of the top 10 commodities by descending euro spend. To get the total value of spend that occurs within each category, a Pareto chart can be used.
4	Find the number of suppliers for each spend category, performing a descending sort of number of suppliers by spend category.
5	Make a chart of the top ten commodities by descending the number of suppliers.
6	Find the average spend per supplier by spend category by performing an ascending sort of average spend per supplier.
7	Apply a Pareto analysis to the chart of the top 10 commodities and look for saving opportunities.

Table 8 - Steps of a spend analysis (Monczka et al., 2016, pp. 202-205)

After the spend analysis, the supply chain manager of the case company also wanted some insights into how the lead times of VMI items differ from non-VMI items. For this purpose, another database was used that provided the information necessary for comparing the two means by the use of a T-test.

Holding a spend analysis gave several interesting insights into the case company's sourcing base. This spend analysis was conducted following the steps of Robert M. Monczka et al. (2016, pp. 202-205) as described in Table 8.

Performing steps 1-3 gave the results shown in Figure 9:

CENSORED

Figure 9- Results of steps 1-3 of the spend analysis

The commodities with the highest spending are CENSORED and CENSORED. The commodities with the lowest spending are CENSORED and CENSORED. Now the results of steps 4-5 are shown in Figure 10.

CENSORED

Figure 10 - Results of steps 4-5 of the spend analysis

Notable is the high number of suppliers for the commodity CENSORED. This amount is more than twice as high as the second-largest number on the list. Also, the relatively small number of suppliers for CENSORED is notable. This is because it seems odd relative to the high sum of spend. Figure 11 better illustrates this, representing steps 6-7 of the spend analysis.

CENSORED

Figure 11 – Results of steps 6-7 of the spend analysis

Drawing up a simplified conclusion, the higher the spend, the higher the savings opportunities by e.g., implementing VMI 2.0. And also, in terms of implementation costs and effort, it is more efficient to implement VMI 2.0 with a few suppliers with a high spend, than with lots of low-spend suppliers.

4.3.2 The case company’s supplier’s lead times are shorter when VMI is implemented

For the lead times, first, the average supplier lead time and standard deviation were calculated. A distinction was made between VMI and non-VMI items to test the significance of VMI purely on lead time.

CENSORED

Figure 12 - Group statistics of the case company's lead times

Summarising Figure 12, the average lead time of the case company’s suppliers *without* VMI implementation is CENSORED with a standard deviation of CENSORED. The average lead time of the case company’s suppliers *with* VMI implementation is CENSORED with a standard deviation of CENSORED.

To compare the means, a T-Test was held with the help of SPSS. The following output was retrieved from SPSS:

CENSORED

Figure 13 - SPSS output of the T-Test

The output, presented in Figure 13, shows that the difference between the group means is CENSORED. Based on this data, it can be stated that CENSORED

4.3.3 Summary and conclusion: realising savings is possible by implementing several sourcing levers and implementing VMI

Based on the results of the spend analysis, a couple of suggestions can be made to realise savings. In terms of VMI 2.0 implementation effort and costs, it is more efficient to implement VMI 2.0 in commodities where there is a high amount of average spend per supplier.

Another, non-VMI-related suggestion for the case company could be supplier portfolio diversification in case the amount of average spend per supplier is high. Instead, when there is a low amount of average spend per supplier, supplier reduction might be an interesting option when pursuing savings. Both of these options are a form of supply base optimisation that will result in "real improvements in cost, quality, delivery, and information sharing between buyer and supplier" (Robert M Monczka et al., 2016, p. 332). Also, "suppliers in an optimised supply base often develop longer-term relationships with buyers, which can lead to collaboration in further joint improvement efforts" (Robert M Monczka et al., 2016, p. 333). Both suggestions are also related to different sourcing levers, as described by Hesping & Schiele (2016, pp. 479-481). Supplier portfolio diversification is related to "extension of the supply base" and supplier reduction is related to "volume bundling". These levers are seen as tricks, used by purchasers, to achieve cost savings Schiele (2019, p. 66).

For the lead times, CENSORED

4.4 DSRP step 3: Designing the framework based on a systematic literature review

4.4.1 A systematic literature review to include all the relevant information in the framework

For the design step of the DSRP, a systematic literature review was held. First, the most reputable and recent supply chain and operations management journals were read via Scopus for the systematic literature review. Subsequently, a keyword search was done via Scopus to find relevant papers that were published in other journals.

The decision on which journals to review is based on the journal ranking made by the Academic Journal Guide 2021. This ranking was read, and the journals related to supply chain management and/or operations management and ranked within at least category "4" were found appropriate for this research. These journals are Journal of Operations Management, Management Science, Operations Research, European Journal of Operational Research, International Journal of

Operations & Production Management, Journal of Supply Chain Management, and Production & Operations Management. Later, some other well-known Supply Chain- and Operations Management journals were added to the literature review to ensure no important literature was missed. A time span of three years was chosen for the Journal review so that most of the up-to-date and relevant articles would be included in the review, and ultimately in the research. Unfortunately, few articles were found that matched the subject. A possible cause is the specificity of this subject and study. Table 9 summarises the journal review:

Journal	**Papers in period 2020-2022 (retrieved 4/3/2022)**	**Papers relevant according to abstract**	**Articles used for this research**
Journal of Operations Management	98	0	-
Management Science	722	5	0
Operations Research	239	0	-
European Journal of Operational Research	1858	15	3
International Journal of Operations & Production Management	177	10	0
Journal of Supply Chain Management	54	0	-
Production & Operations Management	510	6	0
Supply Chain Management: An International Journal	168	11	3
International Journal of Procurement Management	93	1	1
International Journal of Integrated Supply Management	44	5	1
International Journal of Physical Distribution and Logistics Management	109	7	0
Total	4072	63	8

Table 9 - The journal review

Furthermore, a keyword search was held. This research's subject, and that of the keyword search, is VMI 2.0. Because this is a still undefined concept, other terms have to be looked into in order to cover all of the literature related to the subject. Different time spans have been chosen according to the newness of the keyword(s). A maximum time span of five years is determined to ensure the assessed papers are all still relevant. This is longer than the time span chosen for the Journal review because much fewer papers were initially found. Table 10 summarises the literature review based on the keyword search:

Keyword(s)	**Papers in period 2018-2022**	**Papers relevant**	**Articles used for**	**Search key**

	(retrieved 4/3/2022)	**according to abstract**	**this research**	
Digitalisation supply chain	298	21	7	TITLE-ABS-KEY (digitalisation AND supply AND chain) AND (LIMIT-TO (PUBYEAR , 2022) OR LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018)) AND (LIMIT-TO (SUBJAREA , "BUSI"))
Digitalisation purchasing	34 (including duplicates)	3 (excluding duplicates)	1	TITLE-ABS-KEY (digitalisation AND purchasing) AND (LIMIT-TO (PUBYEAR , 2022) OR LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018)) AND (LIMIT-TO (SUBJAREA , "BUSI"))
Industry 4.0 supply chain	462	27	1	TITLE-ABS-KEY ("industry 4.0" supply AND chain) AND (LIMIT-TO (PUBYEAR , 2022) OR LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018)) AND (LIMIT-TO (SUBJAREA , "BUSI"))
Industry 4.0 procurement	31 (including duplicates)	2 (excluding duplicates)	2	TITLE-ABS-KEY ("industry 4.0" procurement) AND (LIMIT-TO (SUBJAREA , "BUSI")) AND (LIMIT-TO (PUBYEAR , 2022) OR LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018))
Industry 4.0 purchasing	20 (including duplicates)	2 (excluding duplicates)	1	TITLE-ABS-KEY ("industry 4.0" purchasing) AND (LIMIT-TO (SUBJAREA , "BUSI")) AND (LIMIT-TO (PUBYEAR , 2022) OR LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018))
Lead time reduction	149	12	2	TITLE-ABS-KEY ("lead time" reduction) AND (LIMIT-TO (SUBJAREA , "BUSI")) AND (LIMIT-TO (PUBYEAR , 2022) OR

				LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018))
VMI	82	11	4	TITLE-ABS-KEY (VMI) AND (LIMIT-TO (PUBYEAR , 2022) OR LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018)) AND (LIMIT-TO (SUBJAREA , "BUSI"))
Vendor managed inventory	104 (including duplicates)	2 (excluding duplicates)	2	TITLE-ABS-KEY (vendor managed inventory) AND (LIMIT-TO (PUBYEAR , 2022) OR LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018)) AND (LIMIT-TO (SUBJAREA , "BUSI"))
Total	1180	80	21	-

Table 10 - The keyword search

Lastly, articles in a less structured way by snowballing. The articles found during the journal review, the keyword search and via snowballing, and that were determined applicable for this research **and of critical use for the ultimately presented framework** are presented in Table 11:

Article title	**Author(s)**	**Year**	**Journal**	**Relevance for framework**	**Article found via**
The role of digital technologies for the service transformation of industrial companies.	Ardolino et al.	2018	International Journal of Production Research	Provide understanding of PA application for VMI.	Snowballing
Collaborative initiatives: Motivators, barriers and benefits	De Freitas, D.C., De Oliveira, L.G., Alcântara, R.L.C.	2018	Revista de Administracao Mackenzie	Provide different collaboration initiatives and a framework for motivators, barriers, and benefits.	Keyword search

From a traditional replenishment system to vendor-managed inventory: A case study from the household electrical appliances sector.	De Toni, A. F., & Zamolo, E.	2005	International Journal of Production Economics	Provide basics of standardised VMI process, VMI information exchange, and VMI applicability conditions.	Snowballing
Digital Procurement New Capabilities from Disruptive Technologies.	Deloitte	2017	-	Provide concrete Industry 4.0 technologies and definitions.	Snowballing
A theoretical framework to adopt collaborative initiatives in supply chains.	Freitas, D. C. D., Oliveira, L. G. D., & Alcântara, R. L. C.	2019	Gestão & Produção	Provide framework for implementing collaboration initiatives.	Keyword search
Improving Interorganizational Information Sharing for Vendor Managed Inventory: Toward a Decentralized Information Hub Using Blockchain Technology.	Guggenbegger	2020	IEEE Transactions on Engineering Management	Provide understanding of Blockchain technology application for VMI.	Keyword search
Prerequisites to vendor-managed inventory.	Niranjan, T. T., Wagner, S. M., & Nguyen, S. M.	2012	International Journal of Production Research	Provides survey for VMI readiness.	Snowballing
Cyber-physical systems with autonomous machine-to-machine communication: Industry 4.0 and its particular potential for purchasing and supply management.	Schiele, H., & Torn, R. J.	2020	International Journal of Procurement Management	Provide Industry 4.0 context.	Keyword search
Supplier selection for vendor-managed inventory in healthcare using fuzzy multi-criteria decision-making approach.	Sumrit, D.	2020	Decision Science Letters	Provide supplier selection criteria.	Snowballing
Towards human-like and transhuman perception in AI 2.0: a review.	Tian et al.	2017	Frontiers of Information Technology & Electronic Engineering	Provide understanding of AI application for VMI.	Snowballing
Industry 4.0: State of the art and future trends.	Xu et al.	2018	International Journal of Production Research	Provide understanding of cloud computing application for VMI.	Keyword search

Table 11 - Key literature found and used for final framework

4.4.2 Presenting the first framework

After concluding the systematic literature review, a first concept VMI 2.0 implementation framework was established. This framework was also sent out to the Delphi experts, on which section 4.5 will elaborate. Figure 14 presents the first overall framework. The rest of the framework is shown in Appendix 2.

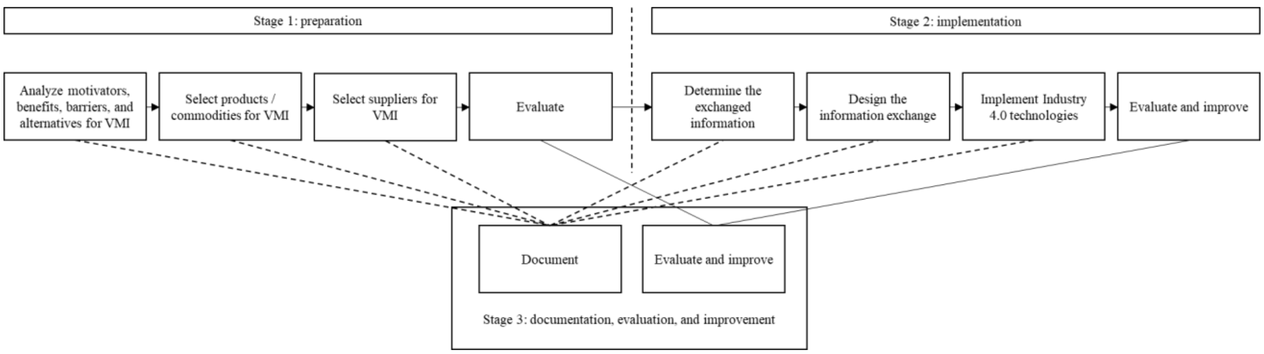

Figure 14 - Concept VMI 2.0 implementation framework

4.5 DSRP step 4: Demonstrating and evaluating the framework

4.5.1 A Delphi study to demonstrate and evaluate the framework

A real-time Delphi study was chosen as the research method for evaluating the proposed framework. The framework was developed based on the systematic literature review, as presented in section 4.2.1. The Delphi study is "… a well-established approach to answering a research question through the identification of a consensus view across subject experts" (Barrett & Heale, 2020, p. 69). The Delphi study was organised in the steps shown in Figure 15, based on the steps used by Schulze and Bals (2020, p. 3) and Persist (2021, p. 15).

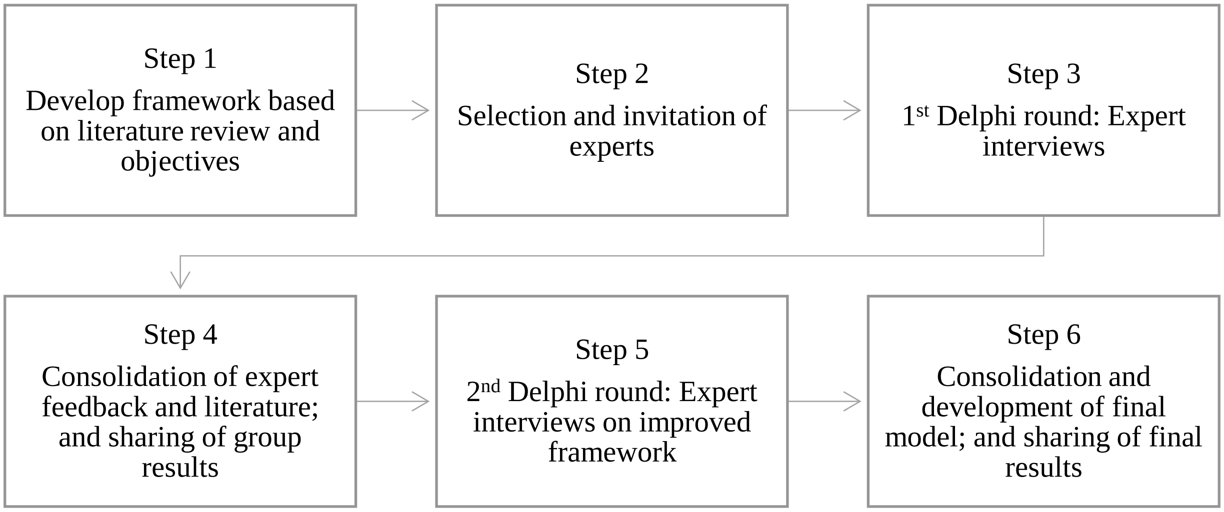

Figure 15 - Steps for Delphi Method based on Schulze and Bals (2020, p. 3) and Persist (2021, p. 15)

First, the framework was developed based on the literature review and in accordance with the research objectives. Next, a sample of experts was selected and invited for the Delphi study. These experts were asked to read the framework and the accompanying context and answer a set of predetermined questions. This set of questions was closely related to the findings in the literature review. The questions were provided to the experts in the form of an interview guide that can be found in Appendix 3. After this first Delphi round, expert feedback and literature findings were consolidated and an improved framework was developed. This improved framework was then sent out for a second Delphi round in which, again, the experts were asked to read the framework and answer the interview questions in the interview guide (Appendix 4). However, before sending out the framework and interview guide, the experts also received feedback about the group opinions which gave them the possibility to re-evaluate some of their initial answers. Now that the experts gave input on the second Delphi round, in which they included their thoughts on the group opinion also, the framework was again improved in order to compromise the thoughts of the experts and the literature findings. Several more Delphi rounds can be added in case harmonising the results is difficult. In this case, after the second Delphi round, the final framework was developed based on the consolidated findings. This framework will be presented in Chapter 6.

Introducing the traditional paper-pencil Delphi method:

This Delphi study was held using the traditional paper-pencil version of the Delphi method. This type of Delphi is, together with the internet-based real-time Delphi method, the most used type of

Delphi (Gnatzy et al., 2011, p. 1681; Persist, 2021, p. 15). The paper-pencil method was chosen because of its good fit with evaluating complete frameworks.

The paper-pencil and the real-time Delphi methods, together with the other types of Delphi methods, have four characteristics described by Rowe et al. (1991, p. 237) and Geist (2010, p. 148): 1) anonymity, which removes the experts from pressures that would have been present if the topic had been evaluated face-to-face, 2) iteration, which enables multiple rounds of discussions and revisions, 3) controlled feedback, which allows the expert to read and comment on the systematic and organised feedback between the iterations, and 4) statistical group response, which consists of quantitative information and feedback after the final iteration.

Delphi expert selection

For the expert selection, a group of twelve experts was invited to join the Delphi study whereof eight ultimately participated. This selection process was not random, as is done with e.g., a survey. However, the experts are selected because of each expert's specific perspective on the research topic and because the individual's professional expertise is expected to impact the outcome of the study (Häder, 2014, p. 106). In the case of a Delphi study, the quality and uniqueness of the participants are more important than the quantity of the experts (Schulze & Bals, 2020, p. 5). For this research, only experts knowledgeable about VMI were invited to ensure the high reliability of the results. Three experts were selected from the case company, the supply chain architect, a strategic buyer, and a project buyer. These experts are somehow knowledgeable about VMI and its implementation. Furthermore, the supply chain consultant of a supplier was invited. This supplier has a role model status as it utilises Smartbins, a prominent VMI 2.0 example. However, they were selected based on the condition that they had an affiliation with VMI. Also, multiple academics were invited to join the Delphi study. 8 responded out of 12. These academics were all experts in the supply chain management field. The demographics of the Delphi experts are presented in Table 12:

Delphi expert	**Practitioner or Academic**	**Job Title / Area of Focus**	**Company of practitioner (case company or supplier)**
Expert A	Practitioner	Strategic buyer	Case company
Expert B	Practitioner	Project buyer & system implementer	Case company
Expert C	Practitioner	Supply chain architect	Case company
Expert D	Practitioner	Supply chain consultant	Supplier

Expert E	Academic	Public, Health & Industrial Procurement	-
Expert F	Academic	Enterprise Systems Engineering	-
Expert G	Academic	Supply Management	-
Expert H	Academic	Engineering & Materials Science	-

Table 12 - The sample of Delphi experts

5. Results: presenting the validated VMI 2.0 implementation framework

5.1 The framework consists of preparation, implementation, and documentation stages

First, the overall VMI 2.0 implementation framework will be shown in Figure 16:

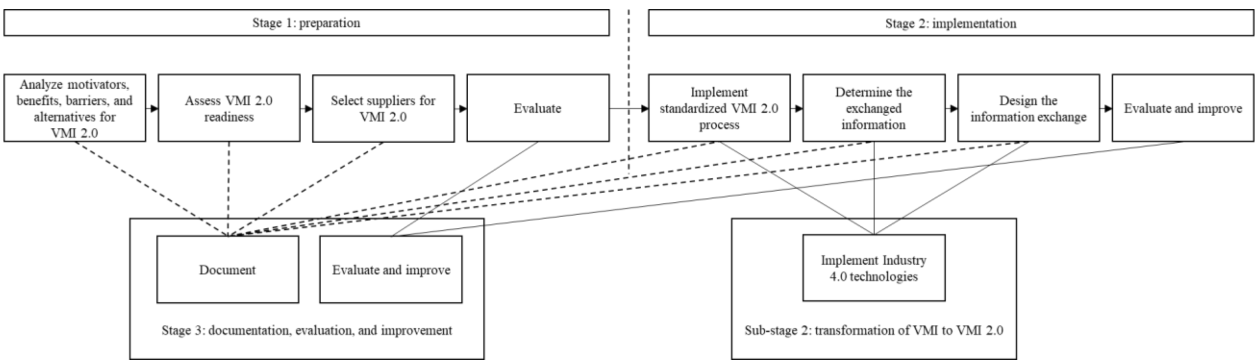

Figure 16 - VMI 2.0 implementation framework

This framework was improved and validated by the Delphi experts. It consists of three stages: 1) preparation, 2) implementation, and 3) documentation, evaluation, and improvement. These stages consist of different steps, illustrated in the framework. The last stage, documentation, evaluation, and improvement, flows through the entire process. This is because every step needs to be documented in order to be evaluated and improved. Ultimately, by correctly performing this step, the entire VMI 2.0 implementation process can be improved. Also, emphasis was put on utilising Industry 4.0 technologies as a sub-stage within the implementation stage of the framework as this improves the VMI process and upgrades the process to a VMI 2.0 one.

5.2 Preparation as stage 1 of the framework that consists of 4 steps: analysing MBBA's, assessing readiness, selecting suppliers, and optionally evaluating

The preparation stage of the VMI 2.0 implementation process consists of several steps. First, the different motivators, benefits, barriers, and alternatives (MBBA's) of VMI 2.0 are analysed. Thereafter, the VMI 2.0 readiness is assessed by the organisation. Next, suppliers for VMI 2.0

implementation are selected based on different applicability conditions. And finally, the preparation stage will include an optional *evaluation* step.

5.2.1 Analysing the different MBBA's of VMI 2.0 for understanding what VMI 2.0 will bring but also what challenges need to be overcome

These MBBA's of VMI 2.0 are based on an MBBA framework by De Freitas (2019) and further expanded by the results of semi-structured interviews and the Delphi experts to include the VMI 2.0 perspective. Also, the interviewees added alternatives to VMI 2.0 to reduce lead times to the framework of De Freitas (2019).

Type of VMI 2.0 motivator	VMI 2.0 motivator
Economic or Market	More intense competition
"	Demand/product/market characteristics
"	Economic globalisation
"	Market reaction
"	Decreased supplier reliability
"	Material scarcity
Organisational	Supply chain problems
"	Previous experiences
"	Pressure from a commercial partner
"	Increased lead times

Table 13 - VMI 2.0 motivators

Type of VMI 2.0 benefit	VMI 2.0 benefit
Economic or Market	Cost reduction
"	Better level of customer service
"	Increase in sales
"	Profit increase
"	Improvement of competitiveness
"	Improved financial performance
"	Greater customer responsiveness
Organisational	Better asset management
"	Better inventory management
"	Better demand predictability
"	Improved replenishment process
"	Better product availability
"	Better production cycle
"	Reduced cycle time
"	Improved relationship
"	Improved supply chain management
"	Improved product assortment
"	Improved product launch efficiency
"	Improvement of promotional activities
"	Better planning
"	General benefits for SC
"	Shorter lead time
"	SC stability

Table 14 - VMI 2.0 benefits

Type of VMI 2.0 barrier	VMI 2.0 barrier
Economic or Market	Insufficient financial investments
"	Other insufficient investments
"	Product barriers
"	Volume barriers
Organisational	Lack of training for new mentalities and skills
"	Divergent goals and targets
"	Lack of a relationship orientation
"	Lack of ability to share risks and rewards
"	Difficulties in the integration of key processes
"	Inflexible organisational processes and systems
"	Inconsistent / inadequate performance measures
"	Lack of support from top management
"	Lack of cross-functional coordination
"	Incompatible organisational culture
"	Lack of formalisation of processes and documents
"	Lack of joint planning
"	Lack of focus on meeting customer needs
"	Individual problem-solving and decision making
"	Lack of trust
"	Inability or unwillingness to share information
"	Problems in the flow of information and communication
"	Resistance to change
"	Lack of commitment
"	Buyer-supplier barriers
"	Insufficient information technology / information systems / telecom investment

Table 15 - VMI 2.0 barriers

Type of VMI 2.0 alternative	VMI 2.0 alternative for reducing lead times
Economic or Market	Changing materials
"	Changing order types
"	Changing suppliers
Organisational	Lead time checks
"	Increasing safety stock
"	Improving buyer-supplier communication
"	Early supplier involvement
"	Sharing forecasts
"	Quick Response (The strategy is based on the just-in-time principles, which involves the delivery of raw materials to production at the exact time and in the correct quantity.)
"	Efficient Customer Response (encourages a shift from holding information internally to sharing strategic information, developing trusting relationships, and searching for efficiency improvements that would deliver enhanced customer value.)
"	Continuous Replenishment Program (the retailer's inventory levels need to be shared with its supplier, and the manufacturers determine the retailer's inventory management. The producer sends full loads to the distribution centre, whose composition varies based on sales and prearranged agreements (Derrouiche et al., 2008, p. 429).)
"	Collaborative Planning, Forecasting and Replenishment (is a set of business processes that are established and empowered by a formal agreement to cooperate on strategy, tactics, and execution by resolution of exceptions.)

Table 16 - VMI 2.0 alternatives for reducing lead times

No certain conclusions can be drawn from these MBBA's other than that all four of the domains are important and worthy of consideration when determining the feasibility of utilising VMI 2.0.

5.2.2 Assessing VMI 2.0 readiness based on a survey that indicates that having a forecasted demand and closely monitored stock levels is the most important condition for VMI 2.0 implementation

This survey for VMI 2.0 readiness is partly based on a survey described by Niranjan et al. (2012, p. 941). The other part of the survey will be used for the next step: selecting suppliers. Table 17 presents the VMI 2.0 readiness survey that resulted from the Delphi study. Also, in order to prioritise these features, weights were assigned by the Delphi experts. These weights were assigned based on how Niranjan et al. (2012) assigned their weights to the survey questions so that theirs's and this research's weights are easily comparable.

Survey feature	**Weight (1-10)**
Demand is forecasted and stock levels are closely monitored	8.25
The company has no problem sharing inventory/forecast information with the suppliers	8
Traditional transaction costs for purchasing are higher than transaction costs after implementing VMI 2.0	8
Products are repetitive i.e., infrequent changes in product specification by customer	7.875
Information and communication systems are up-to-date and designed for Industry 4.0 system implementation	7.375
Products are standardised, i.e., customisation is minimal	6.875
Products have a standard product identification throughout the supply chain	6.375
Demand variance is low	5.875
Purchasing and supply chain management are core competencies of our organisation	5
Our company revenues have been stable over the years i.e., neither grown rapidly nor fallen	3.625

Table 17 - Survey for VMI 2.0 readiness

For ease purposes, the conditions are presented in the table based on their assigned average weight. The conclusions that can be drawn from this survey are that a forecasted demand and closely monitored stock levels are perceived as being the most important VMI 2.0 condition that the organisation must fulfil. The least important VMI 2.0 condition is that the organisation's revenues have been stable over the years.

5.2.3 Selecting suppliers based on different applicability conditions whereof having Industry 4.0-ready information systems is the most important

These applicability conditions of VMI 2.0 are based on the applicability conditions of De Toni and Zamolo (2005, p. 77), the survey described by Niranjan et al. (2012) about the supplier relationship, and supplier selection criteria for VMI implementation by Sumrit (2020). These applicability conditions were improved by the Delphi experts and validated for the VMI 2.0 preparation process. The resulting applicability conditions are shown in Table 18. Also, in order to prioritise conditions, weights were assigned by the experts. These weights were assigned based on the method Niranjan et al. (2012) assigned their weights to the survey questions so that their and this research's weights are easily comparable.

Applicability condition type	**Applicability condition**	**Weight (1-10)**
Product	High exchange levels (sales volume)	6.25
"	High criticality of supply and product shipments	6.25
"	Key suppliers constitute a high percentage of purchase orders	7.25
Geographical	Short supplier-customer distances	3.25
IT	High informatisation of communication (advanced IT)	7.375
"	The company's information and communication systems are up-to-date and designed for Industry 4.0 system implementation	7.5
"	The company's information systems are integrated with the suppliers	7.125
Co-operation	High levels of trust and long-term relationships with the suppliers exist	7.25
"	Good past delivery performance of supplier	6
"	Suppliers are willing to cooperate/invest with/in a VMI 2.0 collaboration initiative	7.125
Risk/reward-sharing	VMI 2.0 benefits are evident to both our company and our suppliers	7
"	VMI 2.0 risks are evident to both our company and our suppliers	6
Flexibility/reliability	Low flexibility and reply time to market of our company (better predictability and production planning)	5.429
"	High supplier flexibility	5.75
"	High reliability of forecast of demand	6.714

Table 18 - Applicability conditions of VMI 2.0

The conditions are sorted based on their condition type to generalise and to further understand the findings. The conclusions that can be drawn from this survey are that "the company's information and communication systems are up-to-date and designed for Industry 4.0 system implementation" is perceived as being the most important VMI 2.0 supplier selection condition. The other two of the IT conditions were also perceived as being important. What scored low and was thus perceived as being not important is the geographical condition of "short supplier-customer distances".

5.3 Implementation VMI 2.0 after preparation is finished by implementing a standardised VMI 2.0 process, determining the frequency of exchanging information and designing the information exchange

First, a standardised VMI 2.0 process needs to be implemented, based on the VMI process by De Toni and Zamolo (2005, p. 66) that is improved by Industry 4.0 technology allocations by the Delphi experts. Also, with the following steps, the Delphi experts were asked to allocate Industry

4.0 technologies to several stages of the information exchange within the VMI 2.0 process. Including these Industry 4.0 technologies in the VMI implementation process will upgrade VMI to VMI 2.0. The last step of the implementation stage consists of the optional but recommended *evaluation and improvement* step.

5.3.1 Implementing a standardised VMI process including different Industry 4.0 technologies

Firstly, for the implementation of VMI 2.0. One must understand what a VMI process should look like and consist of. The following framework expands on a VMI process scheme made by De Toni and Zamolo (2005, p. 66) Added on are different Industry 4.0 technologies that were assigned by the Delphi experts.

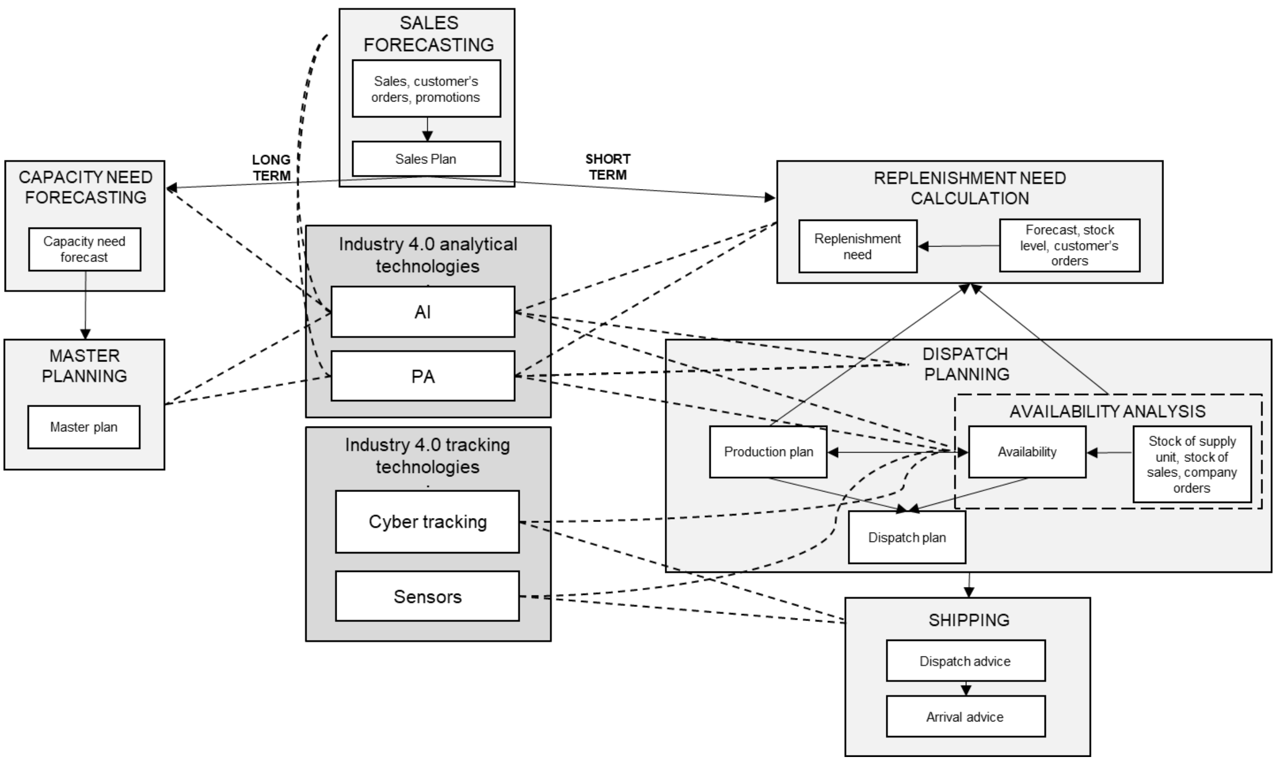

Figure 17 - VMI 2.0 process description

The analytical technologies, AI and PA, seem to be important in every stage except for shipping. Contrarily, the tracking technologies seem to be only usable in the later stages of the process, the availability analysis and shipping stages.

5.3.2 Determining the exchanged information whereof the real-time exchange is the most recently added possibility

De Toni and Zamolo described this information exchange for VMI in 2005. It is expanded by allocating different Industry 4.0 technology options, by the Delphi experts, to the real-time information exchange typical for the VMI 2.0 process.

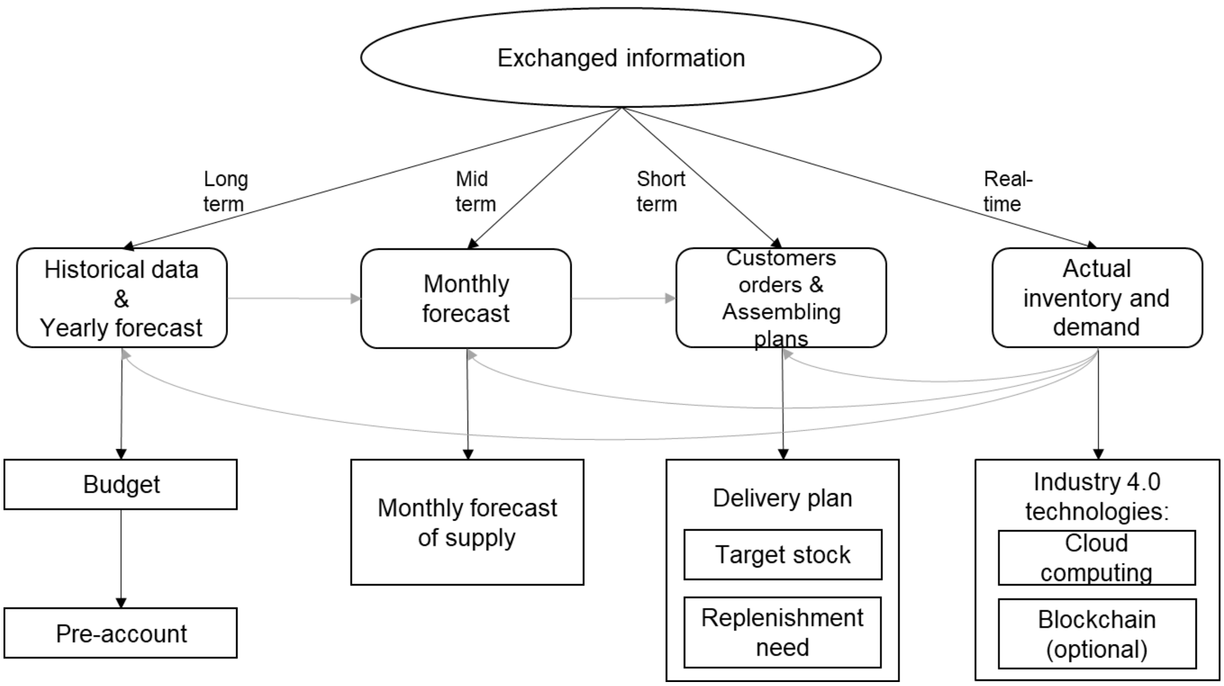

Figure 18 - VMI 2.0 information exchange

The Delphi experts emphasised that cloud computing is necessary for exchanging real-time information. Blockchain, however, was mentioned as being optional. Common arguments are that it is too expensive to implement and excessive for a VMI 2.0 process.

5.3.3 Designing the information exchange based on a survey that comes with Industry 4.0 suggestions for possible answers

This small survey is found to ask the appropriate questions for the purpose of designing the information exchange of VMI 2.0. This survey was validated and improved by the Delphi experts. Also, the Delphi experts were asked to allocate an Industry 4.0 technology that could be implemented to upgrade the VMI to a VMI 2.0 process for each answering possibility to each survey question so that a list of Industry 4.0 technology recommendations could be made. The survey including these suggestions is presented in Table 19.

Survey question	**Possible answer**	**Industry 4.0 technology suggestion**
How often would you like to exchange information?	Every month	PA
“	Every week	PA
“	Every day	PA
“	Every hour	Sensors
“	Every minute	Sensors
“	Every second	Sensors
Which forecasts do you desire to share with your supplier?	Solely own forecast	AI
“	Solely the customer’s forecast	AI/PA
“	Both	AI
Via which means do you desire to share information?	Non-integrated systems like Excel	PA
“	Integrated systems like EDI	Cloud computing
Which information would you like to share?	Yearly forecasts	PA/Cloud computing
“	Monthly forecasts	PA/Cloud computing
“	Assembling plans	PA
“	Actual inventory and demand	Sensors
Do you desire to optimally secure and speed up the information exchange?	Yes	Blockchain
“	No	PA

Table 19 - Survey for designing the VMI 2.0 information exchange including Industry 4.0 technology suggestions

Some conclusions can be drawn from the list of Industry 4.0 technology suggestions:

Firstly, PA is a particularly valuable tool when exchanging information monthly, weekly, or daily. However, when it is necessary or desirable to exchange information every hour, minute, or even every second, sensors are recommended.

Another finding, based on the results of the Delphi, is that when sharing forecasts AI is always of good help. In addition, when only sharing the customer’s forecast with your supplier, using PA is recommended.

Furthermore, when sharing information via integrated systems, cloud computing is recommended, whilst when sharing information via non-integrated systems, using PA is sufficient.

Then, when choosing which information to share, recommended is to use PA, and optionally cloud computing, when sharing yearly or monthly forecasts, and assembling plans. However, when sharing actual inventory and demand sensors are strongly recommended.

Lastly, when there is a desire to speed up and secure the information exchange, using blockchain is recommended. When this desire is not present, using PA is recommended by the Delphi experts.

5.4 Documentation, evaluation, and improvement as the third and optional stage of the framework

This stage was found optional and beyond the scope of this research. However, it was still found helpful to include. For that purpose, the two steps *evaluate* and *evaluate and improve* were added at the end of the preparation and the implementation stage, respectively. Because of this, the Delphi experts were asked to give suggestions and/or best-case recommendations. Disappointingly, only few Delphi experts responded to this question in either round 1 or round 2 of the study. Therefore, everything that was mentioned by the experts will be shown in Table 20.

Recommendation number	**Description of recommendation**
1	Documentation and evaluation are only helpful when the other party in the VMI contract does the same.
2	Make learning points from barriers found in previous VMI implementation attempts.
3	The documented data coming from that step can also be used to feed AI and PA when several trajectories have been completed and enough data exists (pro-active data collection for future analyses).
4	Cloud computing and blockchain are relevant Industry 4.0 technologies for this step.

Table 20 - Delphi experts' recommendations for Stage 3: documentation, evaluation, and improvement

6. Discussion: evaluation and implications

6.1 Evaluation of the framework

This research's main objective was to design a framework that describes how VMI 2.0 should be implemented to minimise lead times. This was in accordance with the case company's research objective, which was to investigate how VMI 2.0 should be implemented in order to reduce its lead times to a maximum of four weeks. Although the result of this research, the VMI 2.0

implementation framework, is a conceptual model, it is proven that VMI (2.0) is a logistical concept that, amongst others, reduces lead times. Adding the Industry 4.0 technologies to VMI can help with optimising the VMI process by e.g., more accurate forecasting with the help of predictive analytics, keeping real-time track of inventory with the help of sensors, and securing the information exchange with the help of blockchain. This optimised VMI process has now been labelled as VMI 2.0. Altogether, the VMI 2.0 concept and this research's VMI 2.0 implementation framework will help with pursuing the case company's objective of reducing lead time.

6.2 Theoretical implications: this research extends and improves multiple VMI-related literature pieces

Next to generally validating and empirically improving the used literature with the help of semi-structured interviews and a Delphi study, this research has proposed a framework that sheds light on how VMI can be transformed into VMI 2.0. It is an extremely specific topic that has rarely been mentioned in literature before. However, it is essential to inform academics, as well as practitioners, about VMI 2.0 and its importance because supply chains in the Industry 4.0 era differ much from supply chains in the Industry 3.0 era and those before. The framework, unlike prior studies, includes a start-to-finish perspective on how VMI 2.0 should be implemented by presenting both preparation, implementation, and documentation and evaluation stages. Also, within these stages, different frameworks, surveys, and processes of previous researchers are checked and improved on their up-to-datedness, accuracy, and relevance by gathering qualitative and quantitative information and transforming their research into ones that fit better within the Industry 4.0 era.

The basis of the framework is provided by the literature of De Freitas (2019), Niranjan et al. (2012), Sumrit (2020), De Toni and Zamolo (2005), who published an MBBA framework, a survey for VMI readiness, supplier selection criteria, and applicability conditions together with a concept VMI process framework and an illustrated VMI information exchange, respectively. Together, these pieces of literature helped with completing this research's research objective and, with that, answering the research question that was described as:

How to implement Vendor Managed Inventory 2.0 to reduce supplier lead times?

By answering this research question, the above-mentioned literature was complemented by adding a 2.0 perspective to the concept of VMI. This was done by introducing different Industry 4.0

technologies that are applicable to VMI 2.0 and linking these technologies to the VMI process framework and the illustrated information exchange descriptions found in the work of De Toni and Zamolo (2005, pp. 66-71). E.g., the main additions to the standardised VMI 2.0 process relative to the VMI process are the analytical and tracking Industry 4.0 technologies that could be implemented in the different forecasting, calculating, and planning stages. What was found was that the tracking technologies are perceived as most important in the later stages of the VMI 2.0 process while the analytical technologies were found important in the former stages of the process.

Whilst researching the actual communication of the information, it was found that for the newly introduced real-time VMI 2.0 information exchange, cloud computing is a crucial communication Industry 4.0 technology to implement and that Blockchain can be an optional addition.

For the lead time part that is stated in the research question, next to presenting the VMI 2.0 framework that is supposed to decrease lead times, also alternatives to VMI 2.0 that could decrease lead times were added to the framework of De Freitas (2019). The presented alternatives are changing materials, changing order types, changing suppliers, lead time checks, increasing safety stock, improving buyer-supplier communication, early supplier involvement, sharing forecasts, Quick Response, Efficient Customer Response, Continuous Replenishment Program, Collaborative Planning, Forecasting and Replenishment.

Next to qualitatively complementing the literature mentioned above, this research also presents weights for specific steps in the framework based on the expert's perceived importance. When assessing VMI 2.0 readiness, based on the assigned weights, forecasted demand and closely monitored stock levels is the most important VMI 2.0 condition that the organisation must fulfil. The least important VMI 2.0 condition is that the organisation's revenues have been stable over the years. For supplier selection, "the company's information and communication systems are up-to-date and designed for Industry 4.0 system implementation" is the most important VMI 2.0 supplier selection condition based on the assigned weights. What scored low and was thus perceived as being not important is the geographical condition of "short supplier-customer distances".

Noteworthy is that the weights assigned by the Delphi experts for assessing VMI 2.0 readiness are pretty much in accordance with the weights for the product-related and company-related features of the survey for VMI readiness by Niranjan et al. (2012, p. 941) as shown in Table 21. This research's highest three weights are the same as their research's highest three weights, and the same goes for the condition with the lowest weight. And other than the conditions "The company has no problem sharing inventory/forecast information with the suppliers" and "Purchasing and supply chain management are core competencies of our organisation", which have pretty large weight differences of 1.97 and 2.07 respectively, the weights do not differ more than one point.

Survey feature	**Weight (1-10)**	**Weight by Niranjan et al. (2012)**
Demand is forecasted and stock levels are closely monitored	8.25	7.4
The company has no problem sharing inventory/forecast information with the suppliers	8	9.97
Traditional transaction costs for purchasing are higher than transaction costs after implementing VMI 2.0	8	N/A
Products are repetitive i.e., infrequent changes in product specification by customer	7.875	8.04
Information and communication systems are up-to-date and designed for Industry 4.0 system implementation	7.375	N/A
Products are standardised, i.e., customisation is minimal	6.875	7.07
Products have a standard product identification throughout the supply chain	6.375	6.75
Demand variance is low	5.875	4.82
Purchasing and supply chain management are core competencies of our organisation	5	7.07
Our company revenues have been stable over the years i.e., neither grown rapidly nor fallen	3.625	3.86

Table 21 - VMI 2.0 readiness weights compared to weights determined by Niranjan et al. (2012)

The supplier-related features, used in the VMI readiness check by Niranjan et al. (2012, p. 941), were used in this research's supplier selection step. Only the common applicability conditions are shown in Table 22 to compare both the research's weights.

Applicability condition	**Weight (1-10)**	**Weight by Niranjan et al. (2012)**
Key suppliers constitute a high percentage of purchase orders	7.25	5.14
The company's information systems are integrated with the suppliers	7.125	4.50
High levels of trust and long-term relationships with the suppliers exist	7.25	7.72
Suppliers are willing to cooperate/invest with/in a VMI 2.0 collaboration initiative	7.125	8.68
VMI (2.0) benefits are evident to both our company and our suppliers	7	7.07

Table 22 - VMI 2.0 supplier selection weights compared to weights determined by Niranjan et al. (2012)

Here, two out of the five weights differ over two points, which indicates a relatively large difference in perceived importance. The largest difference is in the weights of the applicability condition of "The company's information systems are integrated with the suppliers", with a 2.625 difference. A possible argument for this gap is that this research is about the VMI 2.0 concept, whereas

Niranjan's was about VMI. This difference perfectly illustrates the evolution of stand-alone Industry 3.0 systems to integrated Industry 4.0 systems that include machine-to-machine communication, and the perceived importance of these integrated systems.

The other three applicability conditions' importance seems to be perceived similar to the research of Niranjan et al. (2012, p. 941).

6.3 Practical and managerial applications: this research informs, brings awareness, motivates, and guides managers toward implementing VMI 2.0

Within this research, VMI 2.0 was defined as *the more sophisticated form of VMI, that is designed in the Industry 4.0 era* and presented together with an implementation framework. Both, having defined the concepts and having presented a ready-to-use framework can bring awareness to and understanding of the topic and even motivate managers to implement VMI 2.0 or transition from VMI to VMI 2.0.

For the successful implementation of VMI 2.0, various stages of the process have to be completed, including several optional but recommended steps. These steps and overarching stages are "analyse the MBBA's", "select products", "select suppliers", and optionally "evaluate" for "stage 1: preparation". The first step will help managers carefully consider and assess the opportunities and challenges that VMI 2.0 brings. The second step helps to determine which products or commodities are suitable and beneficial for VMI 2.0 implementation. Lastly, the third non-optional step will guide managers in deciding which suppliers are capable and suitable for VMI 2.0 implementation.

For "stage 2: implementation", these are "implement standardised VMI process", "determine the exchanged information", "design the information exchange", and optionally "evaluate and improve". It is recommended for managers to get familiar with a standard VMI process because this process lays the basis for the VMI 2.0 process. The presented VMI 2.0 process also suggests some recommended Industry 4.0 technologies per stage of the process. For designing the information exchange, a standard VMI information exchange is extended with a VMI 2.0 real-time information exchange option. This real-time information exchange shows managers the opportunities that VMI 2.0 can bring compared to VMI. Also, Industry 4.0 technologies have already been suggested for implementation to make this real-time information exchange successful.

In summary, cloud computing is necessary for real-time information exchange, whereas blockchain is perceived as optional because of its high implementation costs and effort.

Then “stage 3: documentation, evaluation, and improvement” was presented as the optional but recommended stage for which a few Delphi experts shared their suggestions and best-case recommendations. The recommendations that were presented in section 5.4 will again be shown in Table 23.

Recommendation number	**Description of recommendation**
1	Documentation and evaluation are only helpful when the other party in the VMI contract does the same.
2	Make learning points from barriers found in previous VMI implementation attempts.
3	The documented data coming from that step can also be used to feed AI and PA when several trajectories have been completed and enough data exists (pro-active data collection for future analyses).
4	Cloud computing and blockchain are relevant Industry 4.0 technologies for this step.

Table 23 - Delphi experts' recommendations for Stage 3: documentation, evaluation, and improvement

7. Limitations and future research

Whilst this study makes some significant academic and practical contributions, the study is limited to the applied research method. Future studies might address these limitations and improve this research. The first limitation is that the Delphi method is limited to the knowledge of the participating experts. The research is based on the non-yet-existing concept of VMI 2.0, which means that it is impossible for the experts to have a full understanding of the topic already.

The second limitation is related to the first one since the VMI 2.0 implementation framework has not been tested in practice yet. Future research could use the opportunity to implement this conceptual model and test the framework empirically.

Thirdly, the presented framework is based on a case study that included only one company and a Delphi study that included the case company, one of its suppliers, and a number of academics. Although the invited academics were all experts in the supply chain management and operations management domain and familiar with the topic of VMI, the sample of practitioner Delphi experts makes the framework, and with that the research, hard to generalise. Again, future research could implement this model and test this framework empirically to see whether it actually is generalisable.

Finally, the Delphi study as well as the semi-structured interviews, were coded and interpreted by only one person. This limits the reliability of the results. In future research, different researchers could code the information and test the intercoder reliability. Having a high intercoder reliability value is essential for statistical analysis and hypothesis testing (Burla et al., 2008, p. 115).

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Appendices

Appendix 1 Guide for the semi-structured interviews

Interview Guide Semi-structured interviews

Introduction: Introduction of interview moderator

Briefing: **Is it possible to record the interview? The recording will be deleted after finishing this research.**

Purpose of research

Purpose of interview

Explain the interview procedure

Question: **Do you have any questions before starting the interview?**

Introductory questions:

Question A: Would you be so kind to introduce yourself? This can include information on your position, what your responsibilities are, and how long you have been doing this.

Main questions:

Question 1: Hoe heeft u in de afgelopen 2 jaren de supply chain ervaren? (lead times, assembly times, supplier performance)

Question 2a (sales): Hoe ziet de vraag van uw klanten eruit? Is deze elke maand ongeveer gelijk of niet? (stock levels, order levels)

Question 2b (inkoop): Hoe ziet de vraag van Benchmark eruit? Is deze elke maand ongeveer gelijk of niet? (stock levels, order levels)

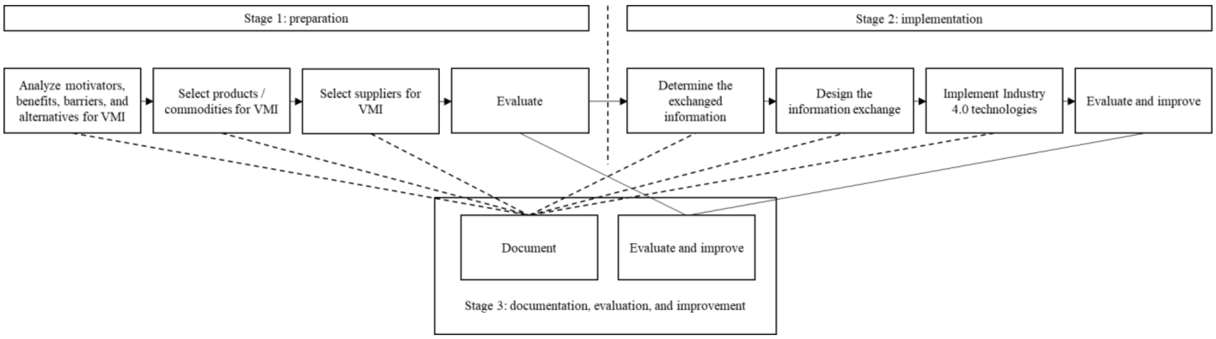
Question 3: Wat zou een mogelijkheid zijn om de supply chain weer stabiel te krijgen en lead times te verkorten?

Question 4: Bent u bekend met VMI?

Question 5: Wat zouden voordelen kunnen zijn van VMI? (Denk aan de supply chain stabieler maken / lead times te verkorten)

Appendix 2 Concept VMI 2.0 implementation framework based on the structured literature review

Appendix 2.1 The overall framework



Appendix 2.1 Stage 1: preparation

Appendix 2.1.1 Analysing the MBBA's of VMI 2.0

Motivators to use VMI

ECONOMIC OR MARKET
- More intense competition
- Demand/product/market characteristics
- Economic globalization
- Market reaction
- Decreased supplier reliability
- Material scarcity

ORGANIZATIONAL
- Supply chain problems
- Previous experiences
- Pressure from a commercial partner
- Increased lead times

Benefits of VMI

PRIMARY
- Better inventory management
- Better demand predictability
- Improved replenishment process
- Better production cycle
- Reduced cycle time
- Improved relationship
- Improved relationship
- Improved supply chain management
- Improved product assortment
- Improved product launch efficiency
- Improvement of promotional activities
- Better planning
- General benefits for SC
- Shorter lead time
- SC stability

SECONDARY
- Cost reduction
- Better level of customer service
- Increase in sales
- Profit increase
- Improvement of competitiveness
- Better asset management
- Improved financial performance
- Greater customer responsiveness

Barriers of VMI

ORGANIZATIONAL CULTURE
- Lack of training for new mentalities and skills
- Divergent goals and targets
- Lack of a relationship orientation
- Lack of ability to share risks and rewards
- Difficulties in the integration of key processes
- Inflexible organizational processes and systems
- Inconsistent / inadequate performance measures
- Lack of support from top management
- Lack of cross-functional coordination
- Incompatible organizational culture
- Lack of formalization of processes and documents
- Lack of joint planning
- Lack of focus on meeting customer needs
- Individual problem solving and decision making

BEHAVIORAL
- Lack of trust
- Inability or unwillingness to share information
- Problems in the flow of information and communication
- Resistance t change
- Lack of commitment
- Buyer-supplier barriers

PHYSICAL
- Insufficient information technology / information systems / telecom investment
- Insufficient financial investments
- Other insufficient investments
- Product barriers
- Volume barriers

Alternatives to VMI for reducing lead time

SOURCING ALTERNATIVES
- Changing materials
- Changing order types
- Changing suppliers

CONTROL INITIATIVES
- Lead time checks

INVENTORY MANAGEMENT INITIATIVES
- Increasing safety stock

COLLABORATION INITIATIVES
- Improving buyer supplier communication
- Early supplier involvement
- Sharing forecasts
- Quick Response (The strategy is based on the just-in-time principles, which involves the delivery of raw materials to production at the exact time and in the correct quantity.)
- Efficient Customer Response (encourages a shift from holding information internally to sharing strategic information, developing trusting relationships, and searching for efficiency improvements that would deliver enhanced customer value.)
- Continuous Replenishment Program (the retailer's inventory levels need to be shared with its supplier, and the manufacturers determine the retailer's inventory management. The producer sends full loads to the distribution centre, whose composition varies based on sales and prearranged agreements (Derrouiche et al., 2008, p. 429).)
- Collaborative Planning, Forecasting and Replenishment (is a set of business processes that are established and empowered by a formal agreement to cooperate on strategy, tactics, and execution by resolution of exceptions.)

Appendix 2.1.2 Selecting products and checking internal conditions based on a survey for VMI readiness

Survey for VMI readiness

Related to	Feature
Product	Products are standardized, i.e. customization is minimal
	Products are repetitive i.e. infrequent changes in product specification by customer
	Products have a standard product identification throughout the supply chain
	Demand variance is low
	Demand is forecasted and stock levels are closely monitored
Company	Our company revenues have been stable over the years i.e. neither grown rapidly nor fallen
	Transaction costs pertaining to purchasing are high
	Information and communication systems are good
	The company has no problem sharing inventory/forecast information with the suppliers
	Purchasing is a core competence of our organization

Appendix 2.1.3 Selecting suppliers based on different applicability conditions

Product conditions:

1) High exchange levels (sales volume),

2) High criticality of supply and product shipments,

3) Key suppliers constitute a high percentage of purchase orders,

Geographical conditions:

4) Short supplier-customer distances,

IT conditions:

5) High informatization of communication (advanced IT),

6) The company's information system is integrated with the suppliers,

Co-operation conditions:

7) High levels of trust and long-term relationships with the suppliers exist,

8) Good past delivery performance of supplier

9) Suppliers are willing to cooperate with a VMI initiative,

Risk/reward-sharing conditions:

10) VMI benefits are evident to both our company and our suppliers,

11) VMI risks are evident to both our company and our suppliers,

Flexibility/reliability conditions:

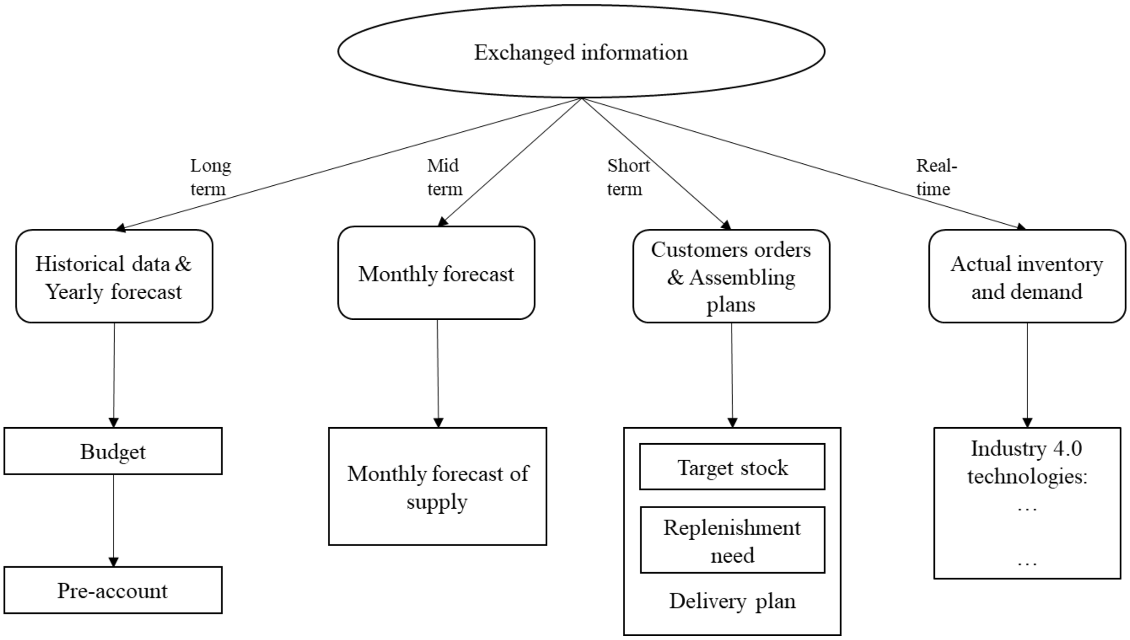
12) Low flexibility and reply time to market of our company (better predictability and production planning),

13) High supplier flexibility,

14) High reliability of forecast of demand.

Appendix 2.2 Stage 2: implementation

Appendix 2.2.1 Determining the exchanged information



Appendix 2.2.2 Designing information exchange based on a small survey

Survey for designing the information exchange

- How often would you like to exchange information? (every month / every week / every day / every hour / every minute / every second)
- Which forecasts do you desire to share with your supplier? (solely own forecast / solely the customer's forecast / both)
- Via which means do you desire to share information? (non-integrated systems like Excel / integrated systems like EDI)
- Which information would you like to share? (yearly forecasts, monthly forecasts, assembling plans, actual inventory and demand)
- Do you desire to optimally secure and speed up the information exchange? (yes / no)

Appendix 2.2.3 Implement Industry 4.0 technologies

Nothing was included in the concept framework here.

Appendix 3 Delphi-study round 1 interview guide

Interview guide Delphi Study round 1

Thom Emmerich – s2190745

University of Twente

Designing an implementation framework for VMI 2.0

See slide 1 - Introduction

Introduction: this research will be held based on these six steps. Would you be so kind as to send back to me the answers in this Word format?

See slide 2 - The research (context)

The research: a little introduction about this research is shown.

See slides 3 & 4 - VMI 2.0 and the Industry 4.0 technologies

VMI 2.0: On these slides, VMI 2.0 and different Industry 4.0 technologies are explained. Later on, questions will be asked about these concepts; however, you may move back and forth to the slides whenever you would like.

See slide 5 - A framework for implementing VMI 2.0

The framework: the overall framework is presented. Questions about the framework as a whole will be asked at the end of the questionnaire.

See slide 6 - Analysing the different MBBAs of VMI

1. **Question 1 -** Preparation: Analysing the different MBBAs of VMI. These MBBAs of VMI are described by De Freitas et al. (2019) and further expanded by the results of semi-structured interviews. Also, alternatives to VMI to reduce lead times are added to the framework of De Freitas (2019).
    a. Are these MBBAs complete when preparing for implementing VMI 2.0?

- Yes
- No, this is missing:
- No, this is obsolete:

    b. Is the allocation of these MBBAs correct?

- Yes
- No, explain: (e.g., lack of trust is in the wrong category)

See slide 7 - Selecting products and checking internal conditions based on a survey for VMI readiness

2. **Question 2 -** Preparation: Selecting products and checking internal motivation. This survey for VMI readiness is a part of a survey described by Niranjan et al. (2011). The other part of the survey will be used for the next slide: selecting suppliers.
    a. Is this survey complete when preparing for implementing VMI 2.0?

- Yes
- No, this is missing:
- No, this is obsolete:

See slide 8 - Selecting suppliers based on different applicability conditions

3. **Question 3 -** Preparation: Selecting Suppliers based on different applicability conditions. These applicability conditions of VMI are based on applicability conditions of De Toni and Zamolo in 2005, the survey described by Niranjan et al. (2011) about the supplier relationship, and supplier selection criteria for VMI implementation by Sumrit (2020).
    a. Are these conditions up-to-date when preparing for implementing VMI 2.0?

- Yes
- No, this is missing:
- No, this is obsolete:

    b. Are these conditions complete when preparing for implementing VMI 2.0?

- Yes
- No, this is missing:

- No, this is obsolete:

See slide 9 - Illustrating a standardised VMI process

4. **Question 4 -** Implementation: Illustrating a standardised VMI process. This standardised VMI process is described by De Toni and Zamolo in 2005.
    a. Take a look at the Industry 4.0 technologies on both the left and the right sides. Where would you suggest implementing which Industry 4.0 technology/technologies? Also, multiple or no technologies can be chosen.

- sales forecasting - …
- capacity need forecasting - …
- replenishment need calculation - …
- dispatch planning - …
- availability analysis - …
- shipping - …

(Possible answer):

- sales forecasting - none
- capacity need forecasting – AI
- replenishment need calculation - PA & Blockchain
- dispatch planning – none
- availability analysis – PA & AI & Cyber tracking
- shipping - Sensors

b. After implementing these Industry 4.0 technologies, is this process description up-to-date when implementing VMI 2.0?

- Yes
- No, this is missing:
- No, this is obsolete:

c. After implementing these Industry 4.0 technologies, is this process description complete when implementing VMI 2.0?

- Yes
- No, this is missing:
- No, this is obsolete:

See slide 10 - Determining the exchanged information

5. **Question 5 -** Implementation: Determining the frequency of exchanging information. This information exchange for VMI was described by De Toni and Zamolo in 2005. It is also expanded by adding different Industry 4.0 technology options to the real-time information exchange.

a. At the right bottom of the figure, space is left for implementing Communicative Industry 4.0 technologies. Which Communicative Industry 4.0 technologies would you implement?

- Blockchain
- Cloud computing
- Both
- None

b. After deciding whether to implement the Communicative Industry 4.0 technology/technologies, is this process description complete when implementing VMI 2.0?

- Yes
- No, this is missing:
- No, this is obsolete:

See slide 11 - Designing information exchange based on a small survey

6. **Question 6 -** Implementation: Designing information exchange based on a small survey. This small survey is found to ask appropriate questions for the purpose of designing the information exchange.
    a. After reading the survey, please select **for each answering possibility to each survey question** an Industry 4.0 technology that could be implemented to improve the process. *Also, multiple options can be chosen*. Choose between: none, AI, PA, Cyber tracking, Sensors, Blockchain, Cloud computing.

(e.g. every month – none / every week - AI / every day – PA / every hour – Cyber tracking/ every minute – Sensors / every second – Blockchain & Cloud computing)

- How often would you like to exchange information? (every month - … / every week - … / every day - … / every hour - …/ every minute - … / every second - …)
- Which forecasts do you desire to share with your supplier? (solely own forecast - … / solely the customer's forecast - … / both - …)
- Via which means do you desire to share information? (non-integrated systems like Excel - … / integrated systems like EDI - …)
- Which information would you like to share? (yearly forecasts - … / monthly forecasts - … / assembling plans - … / actual inventory and demand - …)
- Do you desire to optimally secure and speed up the information exchange? (yes - … / no - …)

    b. Is this survey complete when implementing VMI 2.0?

- Yes
- No, this is missing:
- No, this is obsolete:

See slide 12 - Optional and beyond the scope of research

7. **Question 7 -** Documentation and evaluation: optional and beyond the scope of research.
    a. Do you have any suggestions or best-case recommendations?

See slide 13 - The overall framework

8. **Question 8 -** Overall framework
    a. Do you think that the overall framework is complete?

- Yes

- No, this is missing:
- No, this is obsolete:

See slide 14 - Thank you for your participation

Thank you very much for answering the questions. As a reminder: would you be so kind as to send me the answers in this Word format back to this e-mail address: t.l.emmerich@student.utwente.nl

Also, in case you have any further questions: do not hesitate to contact me on the above-stated e-mail.

Appendix 4 Delphi-study round 2 interview guide

Interview guide Delphi Study round 2

Thom Emmerich – s2190745

University of Twente

Designing an implementation framework for VMI 2.0

See slide 1 – Introduction (Reminder from round 1)

Introduction: this research will be held based on these six steps. Would you be so kind as to send back to me the answers in this Word format?

See slide 2 - The research (context) (Reminder from round 1)

The research: a little introduction about this research is shown.

See slides 3, 4 & 5 - VMI 2.0 and the Industry 4.0 technologies (Reminder from round 1)

VMI 2.0: On these slides, VMI 2.0 and different Industry 4.0 technologies are explained. Later on, questions will be asked about these concepts; however, you may move back and forth to the slides whenever you would like.

See slide 6 - A framework for implementing VMI 2.0 (Reminder from round 1)

The framework: the overall framework is presented.

See slide 10 - Selecting products and checking internal conditions based on a survey for VMI readiness

1. **Question 1 -** Preparation: Selecting products and checking internal motivation. This survey for VMI readiness is a part of a survey described by Niranjan et al. (2011). The other part of the survey will be used for the next slide: selecting suppliers. This survey has been altered into a newer version based on the expert feedback of round 1. Now for the quantitative assessment, you are asked to weigh the survey conditions on a scale of 1 to 10 where 1 is the least important for measuring VMI 2.0 readiness and 10 is crucial for measuring VMI 2.0 readiness.

Survey condition	**Weight (1-10)**
Products are standardised, i.e. customisation is minimal	…
Products are repetitive i.e. infrequent changes in product specification by customer	
Products have a standard product identification throughout the supply chain	
Demand variance is low	
Demand is forecasted and stock levels are closely monitored	
Our company revenues have been stable over the years i.e. neither grown rapidly nor fallen	
Traditional transaction costs for purchasing are higher than transaction costs after implementing VMI 2.0	
Information and communication systems are up-to-date and designed for Industry 4.0 system implementation	
The company has no problem sharing inventory/forecast information with the suppliers	
Purchasing and supply chain management are core competencies of our organisation	

See slide 11 - Selecting suppliers based on different applicability conditions

2. **Question 2 -** Preparation: Selecting Suppliers based on different applicability conditions. These applicability conditions of VMI are based on applicability conditions of De Toni and Zamolo in 2005, the survey described by Niranjan et al. (2011) about the supplier relationship, and supplier selection criteria for VMI implementation by Sumrit (2020). These applicability conditions have been altered into a newer version based on the expert feedback of round 1. Now for the quantitative assessment, you are asked to weigh the applicability conditions on a scale of 1 to 10 where 1 is the least important for selecting suppliers for VMI 2.0 collaboration and 10 is crucial for selecting suppliers.

Applicability condition	**Weight (1-10)**
High exchange levels (sales volume),	…
High criticality of supply and product shipments,	
Key suppliers constitute a high percentage of purchase orders,	
Short supplier-customer distances,	
High informatisation of communication (advanced IT),	
The company’s information and communication systems are up-to-date and designed for Industry 4.0 system implementation,	
The company’s information systems are integrated with the suppliers,	

High levels of trust and long-term relationships with the suppliers exist,	
Good past delivery performance of supplier	
Suppliers are willing to cooperate/invest with/in a VMI 2.0 collaboration initiative,	
VMI 2.0 benefits are evident to both our company and our suppliers,	
VMI 2.0 risks are evident to both our company and our suppliers,	
Low flexibility and reply time to market of our company (better predictability and production planning),	
High supplier flexibility,	
High reliability of forecast of demand.	

See slide 12 - Illustrating a standardised VMI process

3. **Question 3 -** Implementation: Illustrating a standardised VMI process. This standardised VMI process is described by De Toni and Zamolo in 2005. In round 1, the experts were asked to assign technologies to the different VMI 2.0 process stages. The assigned technologies are now included in the illustrated process. Now for the quantitative assessment, the following question is asked.

Take a look at the Industry 4.0 technologies assigned to each process stage and indicate your top 4, when applicable, between these assigned technologies based on its perceived importance for VMI 2.0 in the following table. Since "Master planning" was not included in the prior framework, all options are still possible.VMI 2.0 process stage	First choice	Second choice	Third choice	Fourth choice
Sales forecasting	Kies een item.	Kies een item.	N/A	N/A
Capacity need forecasting	N/A	N/A	N/A	N/A
Master planning	Kies een item.	Kies een item.	Kies een item.	Kies een item.
Replenishment need calculation	Kies een item.	Kies een item.	N/A	N/A
Dispatch planning	Kies een item.	Kies een item.	N/A	N/A
Availability analysis	Kies een item.	Kies een item.	Kies een item.	Kies een item.
Shipping	Kies een item.	Kies een item.	N/A	N/A

See slide 14 - Designing information exchange based on a small survey

4. **Question 4 -** Implementation: Designing information exchange based on a small survey. This small survey is found to ask appropriate questions for the purpose of designing the VMI 2.0 information exchange. However, the questions about this survey in round 1 were perceived as difficult. Therefore, now the questions are split up and made to answer in a quantitative way.
    a. Each survey question has multiple possible answers. The questions and answering options are shown in the following table. Also, for each answering possibility you are asked to fill in a top 3 of Industry 4.0 technologies that will facilitate this option. An example: question 1, "How often would you like to exchange information?" has the possible answers every month / every week / every day / every hour / every minute / every second. Please indicate for each possible answer which will be the most important Industry 4.0 technologies to facilitate this. E.g. in case I want to exchange information *every month*, PA is crucial, AI is also important, and Cyber tracking is nice to have. And in case I want to exchange information *every second*, Sensors are crucial, Cyber tracking is also important, and AI is also nice to have. In case these are your answers (the other answering options are kept N/A for this example), please fill in the table as follows:

Question	Answering option	First choice	Second choice	Third choice
How often would you like to exchange information?	Every month	PA	AI	Cyber tracking
"	Every week	N/A	N/A	N/A
"	Every day	N/A	N/A	N/A
"	Every hour	N/A	N/A	N/A
"	Every minute	N/A	N/A	N/A
"	Every second	Sensors	Cyber tracking	AI

Now please select one of the following technologies …:

Question	Answering option	First choice	Second choice	Third choice
How often would you like to exchange information?	Every month	Kies een item.	Kies een item.	Kies een item.
"	Every week	Kies een item.	Kies een item.	Kies een item.

"	Every day	Kies een item.	Kies een item.	Kies een item.
"	Every hour	Kies een item.	Kies een item.	Kies een item.
"	Every minute	Kies een item.	Kies een item.	Kies een item.
"	Every second	Kies een item.	Kies een item.	Kies een item.
Which forecasts do you desire to share with your supplier?	Solely own forecast	Kies een item.	Kies een item.	Kies een item.
"	Solely the customer's forecast	Kies een item.	Kies een item.	Kies een item.
"	Both	Kies een item.	Kies een item.	Kies een item.
Via which means do you desire to share information?	Non-integrated systems like Excel	Kies een item.	Kies een item.	Kies een item.
"	Integrated systems like EDI	Kies een item.	Kies een item.	Kies een item.
Which information would you like to share?	Yearly forecasts	Kies een item.	Kies een item.	Kies een item.
"	Monthly forecasts	Kies een item.	Kies een item.	Kies een item.
"	Assembling plans	Kies een item.	Kies een item.	Kies een item.
"	Actual inventory and demand	Kies een item.	Kies een item.	Kies een item.
Do you desire to optimally secure and speed up the information exchange?	Yes	Kies een item.	Kies een item.	Kies een item.
"	No	Kies een item.	Kies een item.	Kies een item.

See slide 15 - Documentation and evaluation

5. **Question 7 -** Documentation and evaluation: optional and beyond the scope of research. Only one answer came in in round 1, if someone has some suggestions or recommendations please answer this time. It will be appreciated.
    a. Do you have any suggestions or best-case recommendations?

See slide 16 - Thank you for your participation

Thank you very much for answering the questions. As a reminder: would you be so kind as to send me the answers in this Word format back to this e-mail address: t.l.emmerich@student.utwente.nl

Also, in case you have any further questions: do not hesitate to contact me on the above-stated e-mail.