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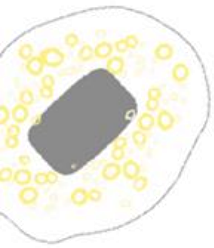

"Shaping the Factory of the Future"

Analyzing the impact of make or buy supply chain strategies on waste reduction in manufacturing organizations

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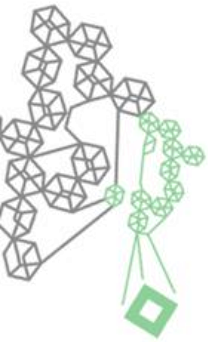

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"Rowing harder doesn't help if the boat is headed in the wrong direction." -
Kenichi Ohmae

Abstract

The world around manufacturing organizations is changing rapidly. Because of this, manufacturers need to keep improving their own supply chain in order to stay competitive in this ever changing world around us. Improving the supply chain is not an easy task, which is why supply chain strategies can give manufacturing organizations guidance in navigating through this complex supply chain. An indicator of how well a supply chain strategy is performing, is the identification of the total waste in the chain per strategy. This can be done by analyzing underlying supply chain KPIs of the supply chain strategies. For this research, the following supply chain strategies and KPIs are considered:

Supply chain strategies

- Local sourcing (buy)
- EU sourcing (buy)
- Outside EU sourcing (buy)
- Vertical integration (make)

Supply chain KPI's

- Inventory turnover
- Supplier not on time delivery (SNOTD)
- Transportation costs per unit (TCPU)
- Purchasing costs
- Purchasing process time
- Supplier quality performance (SQP)

This research aims to explore to which extent the supply chain strategies influence waste reduction from the lean perspective. To determine the connection between the supply chain strategies and waste reduction, a mixed-method analysis is conducted. For the qualitative part, six manufacturers were interviewed to gain information about their experiences and perceptions of different supply chain strategies, the underlying KPIs and external factors that are influencing the supply chain. The qualitative analysis showed that respondents consider mostly the "waiting", "defect" and "inventory" waste as crucial for the total waste in the chain. Flexibility and having a good relationship with the supplier, are essential for controlling these wastes according to the respondents. Also, external factors, like CO2 reduction in the near future is weighted as important for the near future for choosing a strategy.

For the quantitative part, a data analysis is conducted.The data analysis measured the waste among the strategies based on the KPIs that are mentioned before. The data analysis showed that the "SNOTD" and "purchasing costs" KPI are highly influential for the total waste for every strategy because of the average weight factors of respectively 0.45 for both KPIs. A limitation of this available data is the skewed purchasing prices among the strategies. Even though the data is statistically significant, this is a big disadvantage. The practical example showed that the SNOTD and purchasing price are again highly influential for choosing the "best" supplier based on costs. For the future, with the CO2 reduction priority, advisable for companies is to pre-sort on this and chose a supplier based on external factors,

SNOTD and purchasing costs. This is mainly because vertical integration controls both SNOTD and purchasing costs. Win-win situations can be generated due to making products easier, which will lead to less complex products that are simpler to produce which will also drain the purchasing price. According to the respondents, this can only be done by having an intensive relationship with the supplier.

The general theoretical implication of this research is the interdisciplinary nature of this paper where strategic management, logistics and procurement are incorporating contribute to a holistic understanding of the supply chain in general, which can lead to new theories about how supply chain KPIs in different strategies interact with the help of the mixed-method results from this paper.

The practical implication of this research is mainly the insight of the weights of the supply chain KPIs. The strategy which controls these KPIs, especially the SNOTD and the purchasing costs the best, should be chosen in order to reduce the most waste in the supply chain.

This thesis is a public format without confidential data from the organization where this research is held. Due to the sensitivity of this data, this cannot be shared.

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List of abbreviations

Table 0.1. List of abbreviations.

Abbreviation	***Meaning***
VUCA	Volatile, Uncertainty, Complexity Ambiguity
SNOTD	Supplier Not On Time Delivery
PPT	Purchasing Process Time
TCPU	Transportation Costs Per Unit
SQP	Supplier Quality Performance
FTE	Full-Time Equivalent

1. Introduction

Today's world is a dynamic landscape where technology developments and market necessities are changing rapidly. Because of this, manufacturing organizations must adapt their supply chain portfolios to respond to this rapidly changing world around us in order to stay competitive (Seifert & Langenberg, 2011). An example of why change is needed is the COVID-19 pandemic, where the vulnerabilities in the global supply chains were exposed. Manufacturers must enhance the resilience of their supply chains to reduce the impact of potential disruptions like pandemics or for instance political regulations (Jomthanachai et al., 2022). Besides important adaptation to the VUCA world, the result of an optimized supply chain for an organization is for instance the reduction of excess inventory, elimination of transportation inefficiencies and minimization of waiting times. This can be seen as waste reduction. This automatically makes effective management of the supply chain a critical factor and a key strategic element for organizational success (Wilding, 2003). With this in mind, anyone can understand that the ability to measure the supply chain performance is vital because it will lead to greater understanding of today's supply chain in general and it provides feedback to optimize the supply chain process in a company (Gamme & Johansson, 2015a).

At this point in time, the complexity of the supply chain is still increasing due to new technological advancements and automation. This makes it hard for manufacturers to navigate to the "Factory of the Future". This Factory of the Future signifies a paradigm shift from conventional manufacturing practices to intelligent and highly connected production environments. This is characterized by the integration of advanced technologies and data-driven decision-making, redefining how goods are produced, distributed, and consumed (Mubarok & Arriaga, 2020).

Because of the upcoming paradigm shift to the Factory of the Future and the need for organizations to stay competitive in order to survive in the ever-changing world around them, it is more than ever essential to observe the flow of goods and services from raw materials into final products. If organizations fail to do so, they will face the struggle of for instance, increased costs, reduced competitiveness, poor customer satisfaction and environmental concerns (Patil, 2015). The problem lies in the fact that an organization can have excessive inventory, long lead times, poor customer services and wasted resources like materials and time. In summary, organizations with unoptimized supply chains have multifaced problems. From financial implications and operational inefficiencies to customer dissatisfaction and misalignment with the external world. The consequences of neglecting the supply chain optimization can significantly impact a company's long-term success (Anderson & Delattre, 2002).

One way to improve the supply chain of an organization is by reducing waste in the chain. This is a principle that finds its origin in lean management. lean focuses on waste-free processes, value for the

customer and "flow" in processes with the end goal to shorten delivery times, create good quality products and to minimize the costs for the company in general. Resource efficiency is a key element in this management theory, which refers to the targeted use of resources, such as time, material and space (Bertagnolli, 2018). lean encourages organizations to be flexible and responsive to changes in the market, to embrace technological advancements and automation (Harrison, 1997) and customer preferences while pursuing resilience and innovation in processes, like for instance the supply chain (Ahmed & Rashdi, 2021).

Waste can be found everywhere in the chain, from the supplier to the inventory stage. To reduce this waste to the minimum, organizations need to find their "optimal supply chain strategy" that will collect all the materials and information in the most efficient matter to create their product or service. The key problem for organizations is to define which decisions should be made and which supply chain road should be taken. Departments from organizations do usually have goals that are contradictory which does not help in finding this "optimal supply chain strategy". For example, organizations tend to have little stock in order to achieve a high cashflow to invest, but also prefer the lowest possible purchase price that can often only be achieved if products are bought in bulk (Nauta & Sanders, 2001).

This leads immediately to the problem why this research is executed; organizations don't know which supply chain strategy they have to follow which has the least waste. Currently, there is no existing literature that helps them to determine this optimal strategy, even though there is enough literature about the importance of waste reduction (Aucasime-Gonzales et al., 2020; Valverde-Curi et al., 2019) and efficient supply chains for getting all the needed materials and information (Gamme & Johansson, 2015b). If organizations don't focus on reducing the waste along the chain, the consequence will be that it will lead to customer dissatisfaction and higher costs which is fatal for the competitive advantage of a manufacturer and essential for survival.

Because the supply chain is big and complex, this research' focal point lies on strategies that are focused on gaining all the materials and information to create the end product or service (purchasing), which has a significant role in the supply chain (Chen et al., 2004). These supply chain strategies are also known as the "make or buy" strategies. In this research, the following strategies will be analyzed for the manufacturing industry:

- Local sourcing (buy)
- EU sourcing (buy)
- Outside EU sourcing (buy)
- Vertical integration (make)

To measure the performance of these different strategies, Key Performance Indicators (KPIs) can be used. These indicators are financial and non-financial measures used to assess the degree of achievement regarding strategic and operational objectives in a company (Midor et al., 2020). With the

use of KPIs, it is easier to measure the complex supply chain behind organizations' processes (Kumari & Kumar, 2013). In this research, six KPIs will be used that are stated below. These KPIs will measure each supply chain strategy and are chosen because they align well with lean management principle of waste reduction and with the supply chain strategies that are focused on purchasing. Also, by focusing on a specific set of KPIs, the results will become more actionable for organizations.

- Inventory turnover
- Supplier not on time delivery (SNOTD)
- Transportation costs per unit (TCPU)
- Purchasing costs
- Purchasing process time (PPT)
- Supplier quality performance (SQP)

The goal of this research is on one hand to explore the relationship between the different supply chain strategies and their effects on waste reduction. On the other hand, the goal is to produce a simulation model to quantitatively analyze the of impact supply chain strategies on waste reduction in the supply chain, which can help organizations to choose a corporate strategy. With the help of the KPIs that are stated above, this research should provide insights into how different supply chain strategies would impact waste reduction in the manufacturing area.

With this information in mind, the research question of this study reads:

To what extent do "make or buy" supply chain strategies impact waste reduction in the manufacturing sector?

To find an answer to this research question, a mixed method approach will be used. This is because leveraging qualitative data can enrich the outcomes of quantitative data by offering a more profound comprehension of the phenomena (Vernon, 2010). Like Albert Einstein stated, not all phenomena could be counted or measured in terms of quantities. It is important to know the "whole story", to draw valid conclusions (Mayer, 2015). In this specific case it means that qualitative data from interviews with production organizations will help to interpret the simulation model that is made.

2. A literature review: Unveiling the underlying principles

This section provides a brief overview about the concept of lean management, where key lean principles like waste reduction are described. Also, the make or buy supply chain strategies that are mentioned in the introduction will be explained next to the supply chain KPIs which will help with measuring these strategies. In the end, the connection between the key variables waste reduction and supply chain strategies will be described.

2.1. Lean management

When "lean" is mentioned, most people will know that it is a reference to Toyota, where this management/production approach is invented (Womack & Jones, 2003). In the 1940's at Toyota, this approach was created because there was a desire to produce in a continuous *flow*, where long production runs where eliminated. Within these long production runs, the time that was actually spent on creating *value* for the customer was just a fraction. At this point in time, Henry Ford's approach of standardizing components and assembly techniques with these long production costs was the way to go for organizations. However, the side effect of this approach was that the costs for indirect labor were high; a lot of time was consumed with engineering, management and (production) planning. In addition, the production workers that had to do work which required no skill, find this dispiriting and boring (Poppendieck, 2011). This event effected into the "lean thinking". In Toyota, they focused on finding new ways to provide to their customer with the best product or service, with the least number of resources to reduce *waste* in the chain. This will generate competitive advantage in the market. In this theory of lean thinking, there are three essential principles (Melton, 2005a):

The identification of value

The elimination of waste

The generation of flow

2.1.1. The identification of value

In lean, the starting point is the identification of value for customers the starting point. The definition of value is based on the judgement of the usefulness or necessity of a product or service by the customer (Douglas et al., 2015). For most of the manufacturers, the challenge is to understand these values from the customer and develop a product portfolio based on these judgements (Melton, 2005a). A way to identify the value is making use of the Value Stream Mapping (VSM) tool, which helps organizations to identify the value stream in the chain. With the VSM, the current process state is

analyzed where the non-adding value steps to the customer becomes visible. Also, the desired future state is created. The "gap", which is the difference between the current-and future state must be overcome in order to eliminate all the non-adding value steps (C. Grewal, 2008). Every system in organizations, if it is an IT or financial system, contains processes that should add value to the external, but also to internal customers, indicating that every system within organizations is important in doing so (Munro et al., 2015). Sometimes it can be the case that not every process adds value, which is identified as waste (Douglas et al., 2015).

2.1.2. The elimination of waste

The most important lean variable for this research which needs to be explained is waste reduction. Waste reduction denotes to the systematic and strategic efforts that are undertaken by organizations to minimize inefficiencies and unnecessary resource consumption in their supply chains. When these factors are minimized, the goal is to streamline activities with the goal of a more sustainable use of for instance time, energy, and materials (Fricker, 2003). Everything that does not add value to the customers or business, is defined as waste. Waste can be categorized into two groups; type 1 waste which enables activities and type 2 which is pure waste. Type 1 activities are not creating direct value for the end customer but is needed for support. A few examples are administration tasks, product testing and management. The type 2 waste are activities that need to be eliminated because it is identified as pure waste. There are 7 forms of pure waste or "Muda", including over-production, over processing, inventory, waiting, motion, transportation and defects (Welo & Ringen, 2016). According to (Tanasic et al., 2022), another waste that needs to be added is the untapped human potential, which is a result from mismanagement and the inability of managers to use employees within problem-solving teams.

2.1.3. The generation of flow

The last principle of the lean thinking theory is flow. In this theory, flow refers to the way which work/information is going through the system. The goal is to create flow in continuous movements, where work/information is going smooth through the value stream without interruptions or delays (Melton, 2005a). In an ideal state, the customer's experience is moving seamlessly from one process step to the next with no barriers. One way to gain more flow in processes is with the help of standardization. Without this it is unthinkable to create a foundation where iterative cycles of improvement can be applied. When standard work is implemented, each step in the process becomes more predictable and can be better analyzed with data-driven reviews (Rutman et al., 2015). Improving the flow is thus about creating continuous movements, which will help by giving value to the customer within a fast timeline (Petersen & Wohlin, 2011).

2.1.4. The link between value, waste and flow

The key principles of lean are of course linked with each other (figure 1), but this link is not trivial. If all wastes in a process could be reduced, like overproduction or motion, the value would probably not be maximized (Wallström, 2016). However, the identification of the value stream in organizations process helps to diagnose the waste in the process. Waste can be identified as: "'everything that does not add value to the end customer", which makes the principles waste and value definitely connected (Khurum et al., 2014). For the connection between value and flow, the value stream plays again a crucial role. Focus on the value stream means that also the flow of material, information and money becomes more visible in organizations (Rosa & Machado, 2013). Besides this, a process flow that has interruptions is not creating value to the end customer due to the fact that it leads to time delay. These interruptions which create delays can be identified as waste, that can be reasoned as the last link between the principles, that makes the essence of lean management (Melton, 2005a).

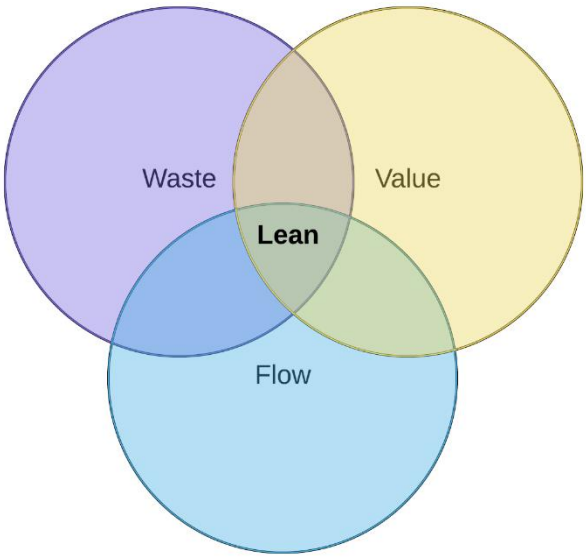

Figure 1: The key principles of lean.

For this research, the main goal is to determine what the impact is of different supply chain strategies on waste reduction. Even though this means that from the lean management theory, waste is the most important variable in this research, the variables value and flow are unquestionably connected to waste as is stated above. Where waste is reduced to the minimum, the value to the customer and flow in the (supply chain) process will be increased greatly which is essential for organization's survival.

2.2. Supply chain management

When working in the manufacturing business, the supply chain is a word which is commonly used and more frequently discussed. But what is it? In one sentence, the supply chain is the flow of material and information through a manufacturing company from the supplier to the end customer (Stevens, 1990). The metaphor "chain" is an interesting one, in a lot of languages there is an edition of the expression "a chain is only as strong as its weakest link" (Jażdżewska-Gutta & Borkowski, 2022). The "chain" encompasses various key elements which contribute to the creation of value for the customer (Kumar, 2001). These key elements are (Maheswari, n.d.):

- Purchasing
- Operations
- Distribution
- Integration of these three elements

To "manage" the supply chain, businesses need effective communication and collaboration between these elements to ensure that the materials and information is moved efficiently through the chain. Because of this, there is an urgency for a supply chain strategy. This strategy plays a big part in businesses, because they see the supply chain as a key driver of competitive advantage, to create cost efficiency, customer satisfaction and risk reduction (Ambe, 2009). While cost efficiency and customer satisfaction are logic factors, the reduce of risks in the supply chain is on the rise for the last years (Sreedevi & Saranga, 2017). Effective supply chain management involves taking proactive steps to detect and navigate risks, to avoid unexpected hurdles and to guarantee seamless operations.

Thus, the supply chain is a very broad connection of different elements which connection is constantly changing due to the ever-changing world around us. To determine effective waste reducing "supply chain management", this research looks at different supply chain strategies for the purchasing element. Because supply chain strategies cannot be measured easily due to the fact that it is not numerically quantifiable, supply chain KPIs will help to compute the supply chain strategy (Chae, 2009). This is visualized below in figure 2.

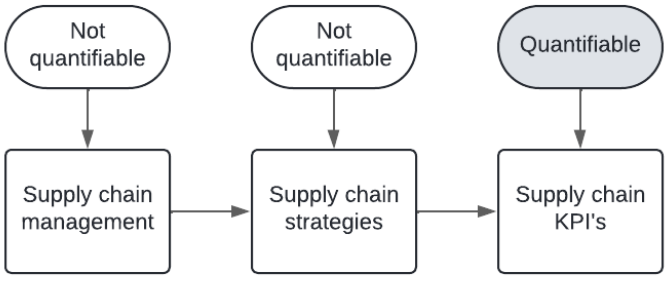

Figure 2: For effective supply chain management, numerous supply chain strategies can be chosen for different elements of the chain. These can be measured with the help of supply chain KPIs.

2.3. Supply chain strategies

To control the supply chain in an organization, various routes can be taken to achieve the desirable supply chain where the "weakest link in the chain" is actually strong. These different routes can be identified as supply chain strategies. It is important that organizations have a clear strategic thinking in order to organize the complex supply chain, for the reason that it enhances the global competitiveness (Qi et al., 2009). As of today, there is no universally agreed supply chain strategies that exist. However, no one can ignore the attention to for example lean vs agile or efficient vs responsive studies. For instance, there are supply chain strategies like the Agile responsiveness strategy through mass customization and the lean responsiveness strategy through the Just in Time (JIT) philosophy (Birhanu et al., 2014). However, these are examples of general strategies of the supply chain. In this research the focus only lies on the flow of materials and information towards the firm that is needed to produce or create the organizations' product or service which can be put in the "purchasing element" from paragraph 2.2. The focal point is thus not the general strategies in the supply chain like lean or Agile, but more specific supply chain strategies like vertical integration and different kinds of outsourcing that can be related to the purchasing element. This has various reasons;

1. An in-depth investigation of the purchasing element of supply chain, with related supply chain strategies like vertical integration.
2. Because of the limited time to finish the research (max 20 weeks for the thesis), it is not realistic to have an in depth understanding of all the four key elements of the supply chain and have qualitative and/or quantitative data for supply chain strategies like Agile.
3. Arguably the most important reason, is the practical contribution to organizations. These organizations struggle with the question to "make or buy" their (sub)products (Cánez et al., 2000). This question revolves around the most important thing in business, that is earning money. However, with the lean thinking in mind, it is currently unknown what the contribution is to waste reduction from the make or buy strategies from the supply chain.

Based on these reasons, the focus of the supply chain strategies is on the "purchasing element". Within this element, the focus is on the following strategies which are explained in the next paragraph:

- Vertical integration of components (make)
- Outsourcing of components from different locations (buy)

2.3.1. Vertical integration of components

Vertical integration is one of these strategies for getting the materials or information that is needed to create the organizations product or service. This strategy is all about the integration of supply chain steps which can take place forwards or backwards in the chain. When vertical integration is forwards, usually a retail company further along the chain is acquired. For backward integration, the examination of the "make or buy" decision is made whether the choice is to acquire raw material themselves, or not (Lafontaine & Slade, 2007). In this research, the focus will be on backwards integration for the reason that the interest is in gaining materials and information for the end product or service. If backwards integration is implemented, material is acquired by the organization themselves which means the (sub)products don't have to be bought and this usually comes with numerous advantages. For instance, vertical integration means that there are more steps of the supply chain under the organizations roof and supervision, rather than that they are under control by the supplier (Monsur & Yoshi, 2012). Also, the stability of operations, better inventory control, the stability of operations and the ability to charge lower prices on final products are benefits from this strategy. Vertical integration undoubtedly has also downsides. These downsides typically are the lack of specialization, inflexibility of operations and the lack of direct competitive pressures on the costs of intermediate products (Lehtinen, 2010). Porter (1980) further elaborates that if organizations are vertically integrated, new competitors are having a hard time because the advantages of vertical integration can elevate entry and mobility barriers. New entrants in the market are almost forced to be vertically integrated if they will compete, otherwise they will face a serious disadvantage due to the fact that the vertically integrated organization has the benefits of lower costs and lower external risks. Also, the new competitor has to overcome the high costs of becoming vertically integrated, without the guarantee that it will make profit in the end (Porter & Strategy, 1980).

2.3.2. Outsourcing of components

Where with a vertical integration strategy, the components are produced in house, for outsourcing this is the opposite. The definition of outsourcing is the procurement of products or services from external organizational sources. Usually, outsourcing is done because organizations believe that other organizations can create these products or services much faster, cheaper or better. This allows organizations to focus on the things that they can do best (Lankford & Parsa, 1999). An advantage of outsourcing is that organizations indirectly benefit from the full utilization of external suppliers' investments, specialized professional capabilities and innovations. The organization does not have to put time in these matters and can delegate their time to other essential core activities (Quinn & Hilmer, 1994). Many researchers agree that whenever organizations can concentrate on their core activities

central to its value proposition, it will increase the competitive position of the firm. Another advantage of outsourcing is the increased flexibility. The contracts and the jobs of the outsourcer and employees depends on the ever-changing business environment (Tayauova, 2012). Disadvantages of outsourcing are the lack of customer focus, due to the fact that the vendor may have to serve many organizations at once and the risk of exposing confidential data and technology (Aswini, 2018). According to (Reitzig & Wagner, 2010), hidden costs are also a downside of the outsourcing strategy. Existing product knowledge because of the outsourcing activities and the extra administrational costs are examples of these type of costs (Garaventa & Tellefsen, 2001). When an organization chooses to outsource a part of their process, the outsource process can be taken place in different areas of the world. If the consideration is that the organization is in Europe, the following strategies can be described:

- Onshore outsourcing (acquiring the (sub)products locally)
- Nearshore outsourcing (acquiring the (sub)products in Europe)
- Offshore outsourcing (acquiring the (sub)products outside of Europe)

The recent international COVID-19 crisis has underlined the vulnerability of many supply chains across the world. As a response to this, many organizations are “onshoring” their processes again (Studley, 2021). Processes which have been moved to other nations are done in house or for instance locally. Advantages of local procurement are besides that the communication lines are much shorter compared to international procurement, also the contribution to the local economy (Young, 2022). There are also no cultural barriers, and the organizations share a common language which is also a huge advantage of onshore outsourcing compared to the other outsourcing types (Chakravarty et al., 2014). When opting for the nearshore outsourcing strategy to for instance Eastern Europe if the organization is located in the Netherlands, the labor costs are much lower than in the Netherlands, and the products does not have to be transported overseas which is the case with offshoring. (Meyer, 2006). Even though the long transportation time is the bottleneck with offshoring, the labor costs and the product costs are usually much lower (King, 2006).

2.4. Supply chain KPIs

To measure the performance of the supply chain strategies, organizations can make use of KPIs to ensure optimal performance and efficiency (Staver, 2019). When supply chain strategies are made, KPIs provide valuable insights into how various disciplines in the supply chain are running. Organizations can make informed, strategic decisions on which road to take based on the KPI values (Pérez-Álvarez et al., 2018). For the supply chain KPIs, there are three main constraints (Senol et al., 2021):

- Time
- Cost
- Quality

To cover these 3 constraints, in this research 2 KPIs for each constrain will be taken for the purchasing part of the supply chain. Logically, there are countless KPIs for each constrain which can be used for this research. However, the more KPIs are used, the more overlap there is in the data. This data is usually also difficult to interpret. Brint et al (2021) has researched the performance of using 28 KPIs vs 8 KPIs. The 20 extra KPIs showed little extra precision for the actual end results, which makes simplicity the ultimate sophistication in a short timeframe (Brint et al., 2021).

2.4.1. Supplier (not) on time delivery - SNOTD [Time]

The supplier (not) on time delivery measures the % of orders which are delivered "on time" by the supplier, based on the agreed upon delivery date. When deliveries are well-timed, the idle times in the supply chain will be minimized (Forslund & Jonsson, 2010). This KPI will be logically placed in the "time" constraint.

2.4.2. Purchasing process time - PPT [Time]

In this research, the purchasing process time is the total process time the purchasing department is spending on the process on buying raw materials from suppliers. Delays in this procurement process can create waste which can cost a company a lot of man hours (Nugroho et al., 2021). For different make or buy strategies, these delays can be logically divergent. Longer processes have a higher chance of delays, which creates more waste.

2.4.3. Transportation costs per unit – TCPU [Costs]

The transportation costs per unit measures the average cost per for transporting each unit of a product. When this KPI is monitored, organizations can use this KPI value to reconsider transportation methods or routes to reduce costs (Sahin et al., 2009).

2.4.4. Purchasing costs [Costs]

Purchasing costs are logically the expenses from buying materials or services that are needed to produce. Purchasing costs can be drained by buying the same product for a cheaper price. Also, the purchasing process can be optimized due to efficient negotiations and documentation (Rubin & Carter, 1990).

2.4.5. Inventory turnover [Quality]

The inventory turnover is an KPI that measures how often the stock will be sold and replaced within a specific timeframe. When the inventory turnover is high, it shows efficient inventory management, reducing holding costs and providing cashflow for an organization. The inventory turnover ratio is vital in the supply chain performance and cannot be left out. This is due to the fact that this KPI is a measure of the organizations' ability to use resources effectively and efficiently (Rao & Rao, 2009). The inventory turnover KPI is linked to the quality constraint. For instance, Etienne (2005) establishes that there is a direct link between inventory and quality responsiveness. Also, a higher inventory turnover indicates efficient inventory management which shows that an organization has high process quality (Agüero-Barreto et al., 2023).

2.4.6. Supplier quality performance - SQP [Quality]

Because of the increase of reliance on suppliers and the growing complexity of products, the importance of having suppliers that are delivering good quality products with no defects is essential (Zeng et al., 2008). The supplier quality performance KPI measures the product quality that suppliers bring to the table. If there are a lot of defects and the quality is poor, processes will be disturbed which eventually will cost a lot of money.

2.5. External risks

Another essential factor for investigating the different supply chain strategies on waste reduction are external risks. Even though this factor is not identified as a KPI, it is too important to overlook. External risks in the supply chain are factors that are out of direct control of an organization. For example, a pandemic can make the world a whole different place, which will lead to transportation methods becoming unavailable (Karatas et al., 2022). Also, natural disasters and wars can influence the supply chain. When organizations assess these external risks, the chance of external disruptions in the process are minimized (Simchi-Levi et al., 2015). Because the outsourcing strategies and to a lesser extent vertical integration, are influenced by these external risks, they are included in this research.

2.6. The connection between lean theory and supply chain management

From the period of 2005 till now, lean is an often-used theory to optimize the supply chain. In Scopus, a library where authoritative research with reliable data can be found, 2756 reports are found that are about lean in the supply chain (Scopus, 2024). An example of a research that uses lean in supply chain management is research of (Tortorella et al., 2017) where the approach is to emerge the supplier and customer element, in order to improve the competitiveness beyond the organizational boundaries (Flynn et al., 2010; Frazzon et al., 2015). This is aligned with supply chain management and lean, since

it analyses the flow of goods from the supplier through the chain to the end user. The outcome of this research is that it is essential for organizations to do improvements not only based on a narrow perspective where the focus lies on internal issues, but to do continuous improvements with a connection to the supply chain context. With this approach, organizations can monitor potential benefits or disadvantages to the value stream much better.

Another research within these reports is the article of (Villareal et al., 2012), in this study, the waste reduction principle of lean is applied to improve the supply chain to achieve a high level of chain efficiency. The main outcome of this research is that the warehouse and transportation activities in the distribution process must work synchronized, and not as separated activities. Waste cannot be eliminated from a limited view, where it is wholly disconnected from the supply chain context (Alvim & Oliveira, 2020).

What cannot be found within the reports on Scopus or any other database, are articles that are connecting supply chain strategies like vertical integration, with the lean thinking theory with the specific focus on waste reduction. As a result of this, a conceptual model is built to visualize the relationship between these variables. This model is visualized in figure 3. In this model, the connection between the supply chain KPIs and the type 2 forms of waste is shown, these variables indirectly link the key principles of this research: the supply chain strategies and the elimination of waste. Waste has direct cost impact when eliminated (Kosasih & Doaly, 2020a). Which is why this is besides that 6 forms of waste can be linked to the chosen KPIs is the essential parameter from the lean theory.

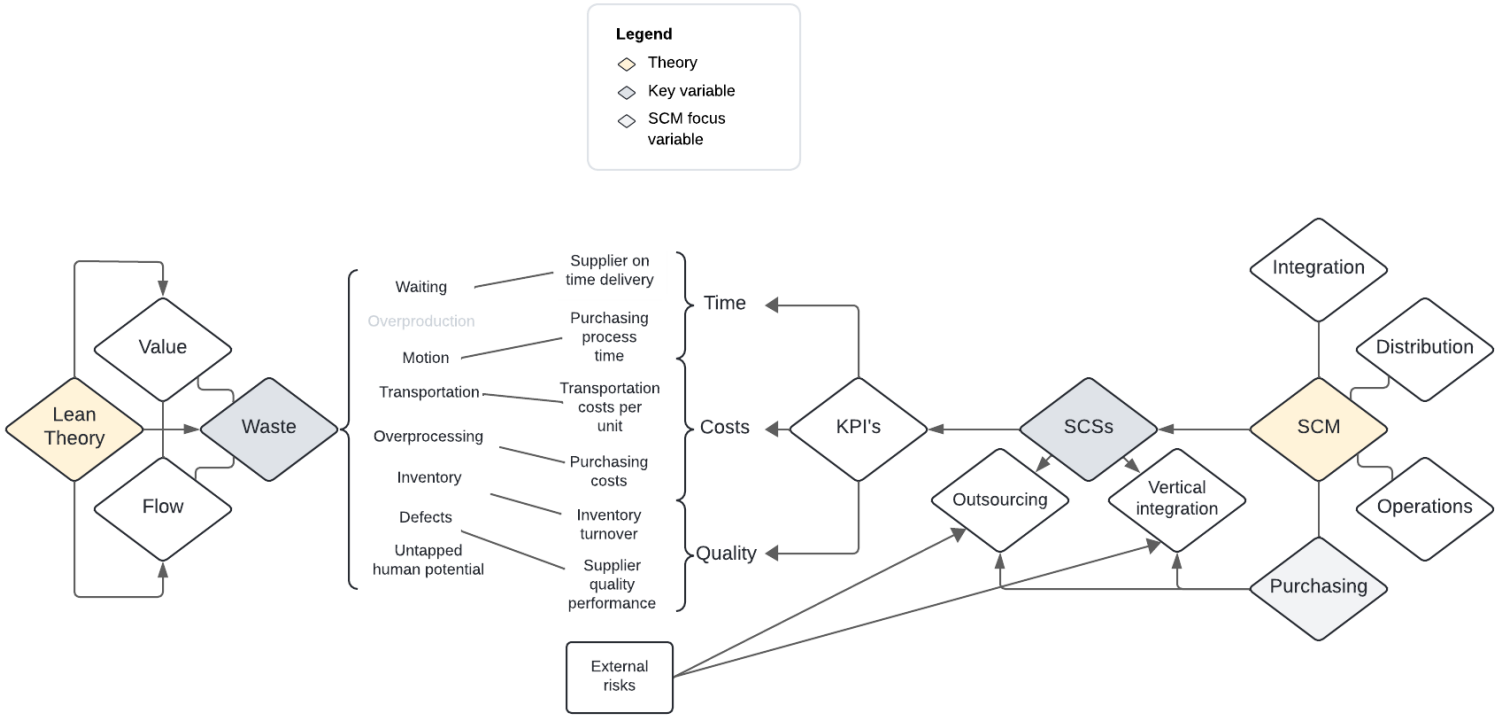

Figure 3: The conceptual model that visualizes the connection between supply chain KPIs and the elimination of waste.

Every supply chain KPI is linked to one form of waste from the lean theory. Arguably, there are more relationships between the forms of waste and the supply chain KPIs, but these are not shown. For instance, the "transportation" type of waste can also be linked to supplier (not) on time delivery. The negative side effect from this way of identifying relationships is that multicollinearity will be introduced which makes it hard to interpret the end results, which is why multicollinearity is better to avoid (R. Grewal et al., 2004). Every KPI will therefore be linked to the most suitable form of waste.

Waiting; Waiting for people, materials, or information to go to the next step in the process (Smith, 2014). This variable is linked to the *supplier (not) on time delivery*, because when suppliers deliver when they should, the flow of people, materials and information is smooth without waiting waste (Grout, 1998). The "waiting" waste could also be connected to the "purchasing process time" KPI, but because this KPI is already connected to the "motion" waste, this possible relationship will create multicollinearity and is thus not created.

Overproduction; Producing more than customer demand, leading to potential obsolescence and excess inventory (Smith, 2014). For this investigation, it cannot be linked to any KPI. This is because overproduction is not a part of the purchasing element from the supply chain management.

Motion: Unnecessary movement of materials, information, and people, which leads to inefficiencies (Smith, 2014). The "*purchasing process time*" KPI is connected to this form of waste, because the longer purchasing process times for a strategy can be linked to inefficiencies in movement. Motion can of course also be connected to the supplier (not) on time delivery. But because the relationship between "waiting" and "supplier (not) on time delivery" is already there, it will be a double relationship which is why it is left out of this conceptual model.

Transportation; Excess movements of products, people, or information. This can result in increased costs (Smith, 2014). High *transportation costs (per unit)* can indicate inefficient transportation routes, methods, or movements (R. C. Anderson & Claus, 1976).

Inventory: Excess inventory requires additional storage space, may lead to obsolescence and the most important thing for organizations is that it locks up the financial resources, or the primary working capital. A high *inventory turnover* indicates efficient use of inventory (Rao & Rao, 2009b).

Overprocessing; Process that includes non-value adding steps, that leads to inefficiencies (Smith, 2014). High purchasing costs can be the outcome of complex supplier negotiations and excessive documentation that are all forms of *overprocessing* (Rubin & Carter, 1990). Also, too many intermediaries (Edelman & Wright, 2015) and unnecessary specifications for products can increase the purchasing costs.

Defects: Any (product) error that occur during the process, which leads to customer dissatisfaction and extra costs (Smith, 2014). This parameter can be directly linked to *supplier quality performance*, because quality problems with the products from the supplier can be directly linked to the "defect" waste.

Untapped human potential: This type of waste is a general form of waste which can be suited into any KPI. In every process, there is a chance that the right people are put at the wrong tasks, which makes mistakes inevitable.

Also, the external risk factor is important in this research. Because of VUCA world, where uncertainties are certain it is an essential variable to include. Organizations struggle with things like COVID-pandemic (Jomthanachai et al., 2022) and more recently the attacks on ocean vessels in the Red Sea (Notteboom et al., 2024) which has a huge influence on the whole supply chain. However, this factor cannot be seen as a KPI because it is not measurable. In the methodology section, the influence of these external risks in this research will be described.

3. Methodology

This chapter will support in answering the research question, while it provides a description of the research design, how data is collected and how it is analyzed. It serves as a roadmap how this research will be conducted.

3.1. Research design

Like the research question stated, the aim of this research is to understand the relationship between the different make or buy supply chain strategies and waste reduction. Supply chain KPIs will help with measuring the performance of the strategies based on waste reduction. To dive deeper in this understanding, a mixed-methods analysis will be used to generate the most valid answer, because the best out of the quantitative and qualitative data can be combined (Sandelowski, 2000). For the qualitative part, the focal point is to gain knowledge about the experiences and knowledge from organizations about outsourcing and vertical integration, and how they link with the supply chain KPIs and waste reduction. The focus of the quantitative part will be on designing a simulation model where the correlation between the independent variables, the different values of the supply chain KPIs for each make or buy strategy, and the dependent variable, waste reduction, will be checked.

3.1.1. Conducting interviews with manufacturers – Qualitative part

To provide a holistic understanding of the waste reduction in the supply chain, the focus can not only lie on data. The need for experiences of people is just as essential (Barrett & Twycross, 2018). To understand the relationship between waste reduction and make or buy supply chain strategies, it is essential to get qualitative data because this will offer a broader and more complete way of defining the relationship between them. The method for gaining the qualitative data is to conduct interviews with manufacturers in similar industries, for getting experiences in the same branch which will help in comparing the data. Different industries usually have different challenges, which is why manufacturers from the same industry are chosen. The interviews will align with the observational study from the quantitative part, and this will generate a representative view of the relationship of the chosen supply chain strategies and waste reduction.

According to (Marshall et al., 2013) the recommended minimum number of interviews for gaining enough qualitative data ranges from 6 to 50. In qualitative data, data saturation is a key concept. This occurs when new interviews do not provide additional insights in comparison to the interviews that are held. When “data saturation” is achieved, no more interviews will be held (Fofana et al., 2020). When the 6-point mark is reached, there will be reflected if the data saturation is achieved, if not, more

interviews will be conducted till a point when data is saturated, or the results are sufficient to answer the research question properly.

3.1.2. Company X – Quantitative part

"Information about the organization where the quantitative data is from is left out in this public paper."

Since the goal of this research is to explore the relationship between supply chain strategies and waste reduction, for the quantitative part an observational study is conducted. This is because observational studies give an in-depth understanding of the phenomena studied in a real-world manufacturing context, where the data is not manipulated which Is the case at experimental studies. Observational studies also often result in findings that are more generalizable in broader contexts, which means that the outcomes may offer insights for manufacturing organizations with diverse supply chain structures (Lomax, 1982).

3.1.3. Visual representation of the research design

To give a better understanding of the mixed method analysis that will be conducted, a visual representation of the research design is shown in figure 4. This figure demonstrates the procedure which has the aim to get insight into the relationship between the different forms of waste from the lean theory and the supply chain KPIs from the supply chain management theory.

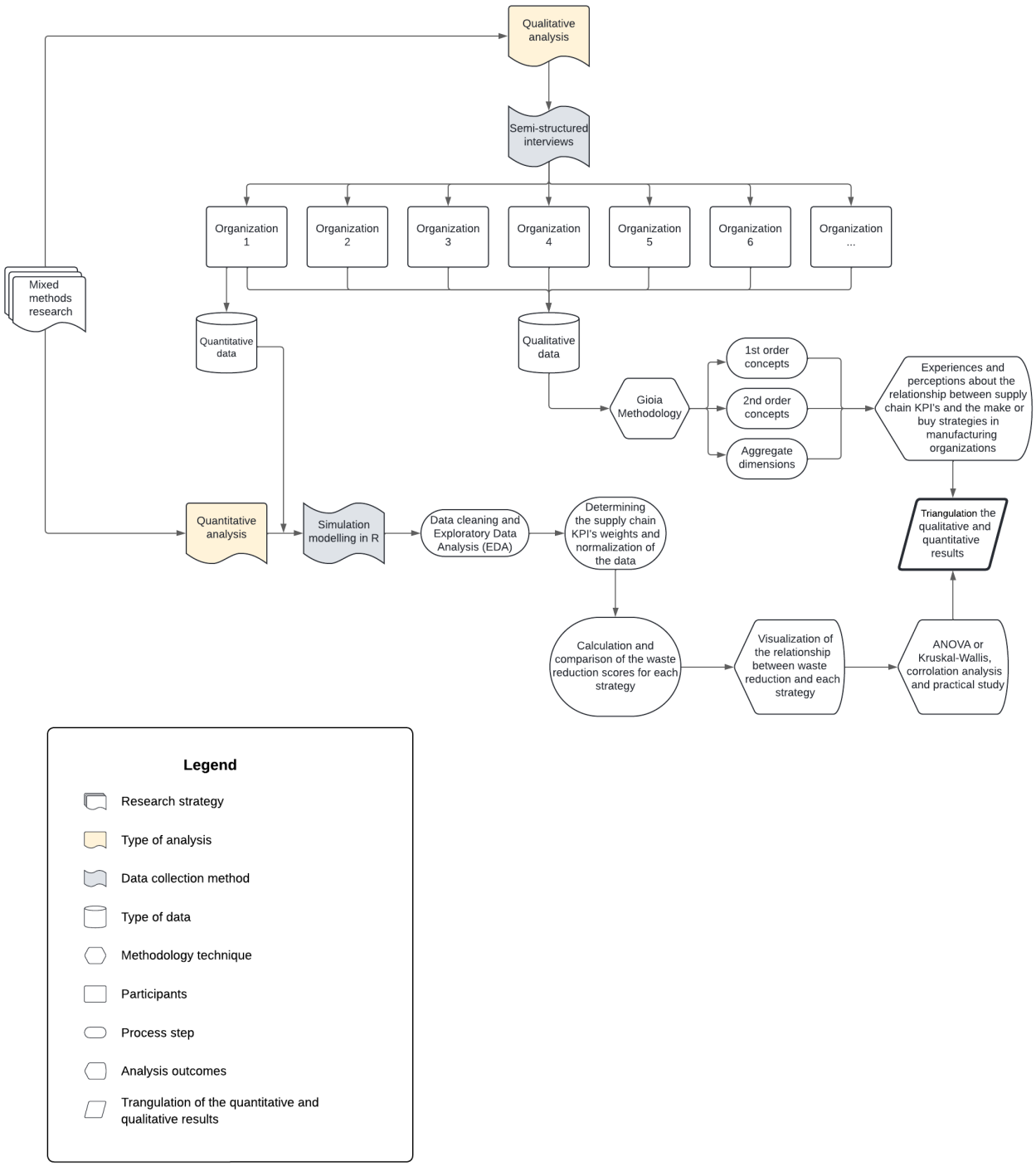

Figure 4: Visual representation of the research design.

3.2. Data collection

Because of the mixed methods approach, the data collection can be divided in two elements: the quantitative part and the qualitative part.

3.2.1. Qualitative data collection

For the qualitative part, at first the participants should be identified. The participants that will be interviewed are people from manufacturing companies whose work is related to the supply chain of their company. General information about the respondents can be found in table 1.The six organizations that will participate are interesting to interview, because of their international experience in the supply chain and manufacturing as core activity. The organizations are however chosen randomly and are based on the willingness to cooperate. This can result in selection bias and non-response bias, where the current sample is not representative for the total population (Tripepi et al., 2010). This is because "the potential participants" that did not want to cooperate, can have a much different attitude towards doing business, and also the supply chain.

Table 1: General information about the respondents.

Participants	Position	Experience within the Supply Chain
Manager 1	Supervisor Supply Chain	9 years
Manager 2	Operational director	30 years
Manager 3	Ad-interim Supply Chain Manager	16 years
Manager 4	Supply Chain Manager	± 25 years
Manager 5 & 6	Purchasing Manager – Supply Chain Manager	12 years – 20 years
Manager 6	Purchaser	3.5 years

With these participants a semi-structured interview will be held. The choice for semi-structured interviews is because the combination of structured questions and unstructured exploration will help in answering complex issues (Wilson, 2014). With this method, respondents can respond flexible in their own way even though the questions will give them guidelines. The questions that are asked are about the experiences with outsourcing and vertical integration strategies, in relationship with the waste reduction per strategy based on the KPIs that are stated before in this research. The interview-format with all the questions can be found in Appendix A. The ethical considerations from these interviews are taking into account by sending a written consent to all the participants before the interview will take

place, to obtain an informed consent of the participant, but also to protect their privacy and minimize the possible harm for the participants. The informed consent format can be found in Appendix B and is written in Dutch because all participants are Dutch. The idea behind this is that this informed consent will be better understood.

3.2.2. Quantitative data collection

The data that is used is based on the six supply chain KPIs below.

- Inventory turnover (no unit)
- SNOTD (in %)
- Transportation costs per unit (TCPU) (in €)
- Purchasing costs (in €)
- Purchasing process time (PPT) (in €)
- Supplier quality performance (SQP) (in %)

For the external risks that are also influencing the outcomes of the strategies, there is no KPI. The assumption is that the external risks will be laid out in the SNOTD KPI. If another external risk KPI would be added to the KPI, the chance of multicollinearity will be too high. This will create unrealistic results.

3.3. Data analysis

3.3.1. Qualitative data analysis

The data from the semi-structured interview will be used in the "Gioia Methodology" coding approach, where the goal is to capture the interviewee's understandings. At first, transcripts are created in the first order concept, where open coding is used. From each interview, these codes from the first order concepts can be generalized into second order concepts, where the goal is to cluster similar codes into categories. At last, the aggregate dimensions can be created, the categories from the second order will be sorted into this 3rd order concept (Magnani & Gioia, 2023). This multi-step analysis process gives the possibility to get a deeper understanding of the relationship between supply chain strategies on waste reduction in a structured way, based on the experiences and perceptions in manufacturing organizations. The outcome of the qualitative analysis will be combined with the quantitative analysis, with the goal to understand the relationship between the supply chain strategies and waste reduction.

3.3.2. Quantitative data analysis

The quantitative data analysis will be done in R, version 2024.04.02, which is a statistical program which helps people with analyzing, summarizing and displaying data (Braun & Murdoch, 2021). The first step in R is to clean the data that is coming from the database. In this phase, inconsistencies, missing

values, or outliers will be clarified for the supply chain KPI data. To estimate which datapoints are outliers, the following formula is used in R (Silva et al., 2019):

$$Outlier = \{x \mid x < Q1 - 1.5 * IQR \; or \; x > Q3 + 1.5 * IQR \quad (1)$$

Where:

$$Q1 = First\ quartile\ (25th\ percentile)$$
$$Q3 = First\ quartile\ (75th\ percentile)$$
$$Interquartile\ range\ (IQR) = Q3 - Q1$$

After the data cleaning, the weights for the supply chain KPI's are determined. These weights are essential, because it cannot be assumed that every supply chain KPI will have the same influence on waste reduction. Like is stated before, waste reduction has a direct relationship with cost elimination (Kosasih & Doaly, 2020b). Because of this, the waste weight can be determined based on the cost implications per supply chain KPI. This will be examined based on the available data and will be done as follows:

$$SNOTD_{weight} = \frac{Costs\ of\ safety\ stock + fly\ costs}{Total\ costs} \quad (2)$$

Whenever the supplier is not on time to deliver the products on time, companies must either take products out of the (safety) stock or fly products to the company in order to produce on time and stick to the planning. The safety stock costs are determined at the purchasing price of the product.

$$Purchasing\ process\ time_{\ weight} = \frac{Total\ worked\ hours * hourly\ cost\ rate}{Total\ costs} \quad (3)$$

For the PPT the total worked hours per strategy is multiplied by the hourly cost rate of the purchasing employees.

$$TCPU_{\ weight} = \frac{Transportation\ costs}{Total\ costs} \quad (4)$$

The transportation costs per unit are based on the weight in Kg per unit. This is calculated by multiplying the weight of the product times the costs of transportation per area. Because the costs of transportation per unit what depends on the saturation of the container load ,the transportation costs will be calculated for 4 container loadings: 1000 kg, 10.000kg, 17.500kg and the maximum weight of 28.000kg.

$$Purchasing\ costs_{\ weight} = \frac{Purchasing\ costs}{Total\ costs} \quad (5)$$

The purchasing costs per unit are based on the available data.

$$Inventory\ turnover_{\ weight} = \frac{Stock\ costs}{Total\ costs} \quad (6)$$

With:

$$Stock\ costs = 0.2 * Purchasing\ price$$

The stock costs are estimated at 20% of the purchasing price. In this analysis, this methodology is followed. The product price is therefore multiplied by 20% of its value.

$$SQP_{\ weight} = \frac{costs\ when\ a\ product\ is\ defect}{Total\ costs} \quad (7)$$

The "costs when a product is defect" is defined at all the billable costs.

After the weights are calculated, the supply chain KPI data must be normalized that will be done with the help of codes in R, in order to calculate the end waste reduction score per strategy. Normalization of the data is a crucial step in data analysis, when the data has different volumes and units. If this is the case, samples cannot be compared directly because of the different scales and will have a disproportional amount of influence on the outcome (Walach et al., 2018). For the KPIs in this analysis, there are three different scales (%, €, and ratio). This means that data normalization is necessary to gain reliable results. This can be done with the help of the "min-max" normalization method, which is a linear transformation on the data, which scales it into an analytical range. After the transformation, the datapoints will fall within a range of 0 to 1 with no scale (Sree & Bindu, 2018). The formula for the "min-max transformation" is as follows (Ali et al., 2014):

$$x' = \frac{x - \min(x)}{\max(x) - \min(x)} \quad (8)$$

With:

$$x' = normalized\ value \qquad x = original\ value$$
$$\min(x) = minimum\ value \qquad \max(x) = maximum\ value$$

The normalization of the score will be multiplied with the weight score. The calculation of the waste reduction score per strategy after weighting and normalization of the data, is as follows:

$$\begin{aligned} &Waste\ reduction\ [per\ strategy] \\ &= \big((SNOTD\ (x') * weight) + (Purchasing\ process\ time\ (x') * weight) \\ &\quad + (TCPU\ (x') * weight) + (Purchasing\ costs\ (x') * weight) \\ &\quad + (Inventory\ turnover\ (1 - x') * weight) \\ &\quad + (SQP\ (x') * weight)\big) \end{aligned} \tag{9}$$

For the inventory turnover score the formula is adjusted. This is because the higher the inventory turnover, the lower the waste should be. This is why 1 minus the normalized score is realized. After the waste reduction score per strategy is determined, the relationship between the strategies and waste reduction will be visualized in R based on an ANOVA or Kruskal-Wallis and correlation analysis. An ANOVA will be used if the data is normally distributed. If not, the Kruskal-Wallis is used. Also the underlying supply chain KPI relationships will be shown in a correlation matrix. To check if the outcomes are significant, the p-values and standard errors will be reviewed for each strategy (Shrestha, 2019).

3.4. Reliability and validity

Because this research follows the mixed method approach, the reliability and validity of this research is split up into a qualitative and quantitative part. The interviews that are held with experienced people from different manufacturing organizations have to give a holistic view about how supply chain strategies and KPIs influence the total waste in the chain. To get reliable data, all of the interviews are carried out based on the interview format from Appendix A. Because the same questions were asked, the acquired data can be identified as consistent. With the help of the Gioia methodology, the interviews are transcribed and coded in a systematic manner which will lead to reliable concepts and aggregate dimensions. The validity of the qualitative part is guaranteed by linking back the answers of the respondents to them to verify their answer. Also the most important constructs in this research, supply chain strategies, supply chain KPIs, forms of waste and external factors are also key in the interview question format. For the quantitative part, the reliability is ensured by doing statistical significance tests and looking at the dataset in general to see whether the data is skewed or not. Like is stated before, also outliers and missing values will be eliminated because this will influence the reliability level. The validity of the quantitative part is ensured by determining the KPIs and the weight determination of this KPIs by discussing these variables with internal experts from the logistics and purchasing departments.

Together, the mixed-method analysis will provide a higher level of validity due to methodological triangulation. The qualitative results provide more contextual insights and has a more explorative nature. The quantitative results are logically more data driven. Combining these methods will give the research a better valid fundament, because experiences and perceptions can be combined with hard data.

4. Results

The aim of this research is to explore the relationship between the supply chain strategies in this paper and their effects on waste reduction. Another goal is to create a simulation model in R to quantitatively analyze the impact of the supply chain strategies/KPIs on waste reduction. In this section, qualitative relationship between the strategies and waste reduction will be shown. Additional to these results, the outcomes of the quantitative model in the simulation program "R" will be described.

4.2. Qualitative analysis results

The qualitative results are gained by following the scheme from figure 4. With the help of the Gioia methodology and supply chain professionals from manufacturing organizations the quotes from the interviews can be transformed into aggregate dimensions. These dimensions serve as broad concepts which summarize the results. In this analysis, the aggregate dimensions are determined as follows:

- Impact of supply chain strategies on waste reduction
- Influence of the supply chain KPIs on waste reduction
- Influence of external risks on supply chain strategies

Even though the aggregate dimension "The impact of supply chain strategies on waste reduction" is of course crucial for answering the research question "*To what extent do "make or buy" supply chain strategies impact waste reduction in the manufacturing sector?* the other aggregate dimensions are as well essential for answering this question. This is because a strategy is chosen based on its underlying factors, like the supply chain KPIs and the influence of external factors within the strategies. To explain these aggregate dimensions, the second-order concepts and first-order codes are described for each of the dimensions. All of this can also be linked to the conceptual model of figure 3, where a connection is made between waste reduction from lean and the supply chain strategies. This is done by connecting 6 forms of waste directly with the supply chain KPIs, which are essential to measure the supply chain strategies. Also, the model states that the external factors play a huge role for the strategies and waste. This is why the aggregate dimensions, and its underlying factors are not only important for answering the research question, but also for the connection with the conceptual model.

4.2.1. Influence of supply chain strategies on waste reduction

The first aggregate dimension that is going to be explained is the "impact of supply chain strategies on waste reduction". The data structure for the set-up of this dimension can be found in figure 5. Figure 5, and the similar figures in this report after this, are constructed based on the quotes from the interviews with the 6 supply chain professionals in the manufacturing area. The set-up from this

structure can be found in the header of the figure. The “strategy” header explains the supply chain strategy, which is related to the statement from the 1st order concept. The “count” header shows the quantity of interviews the statement is mentioned. Furthermore, the 1st order concept is described. The first order concepts are statements from the interviews that can be linked directly or indirectly with the quotes from the interviews. The second order concepts represent the generalization of specific statements that are related to each other. The last concept, the aggregate dimension, is in this case “the impact of the supply chain strategy on waste reduction”, where in the end all the statements can be linked to.

The data analysis of the interviews revealed that the impact of the supply chain strategy on waste reduction can be divided into six second-order concepts. Before the second-order concepts are described, at first the primary supply chain strategies for the organizations are stated:

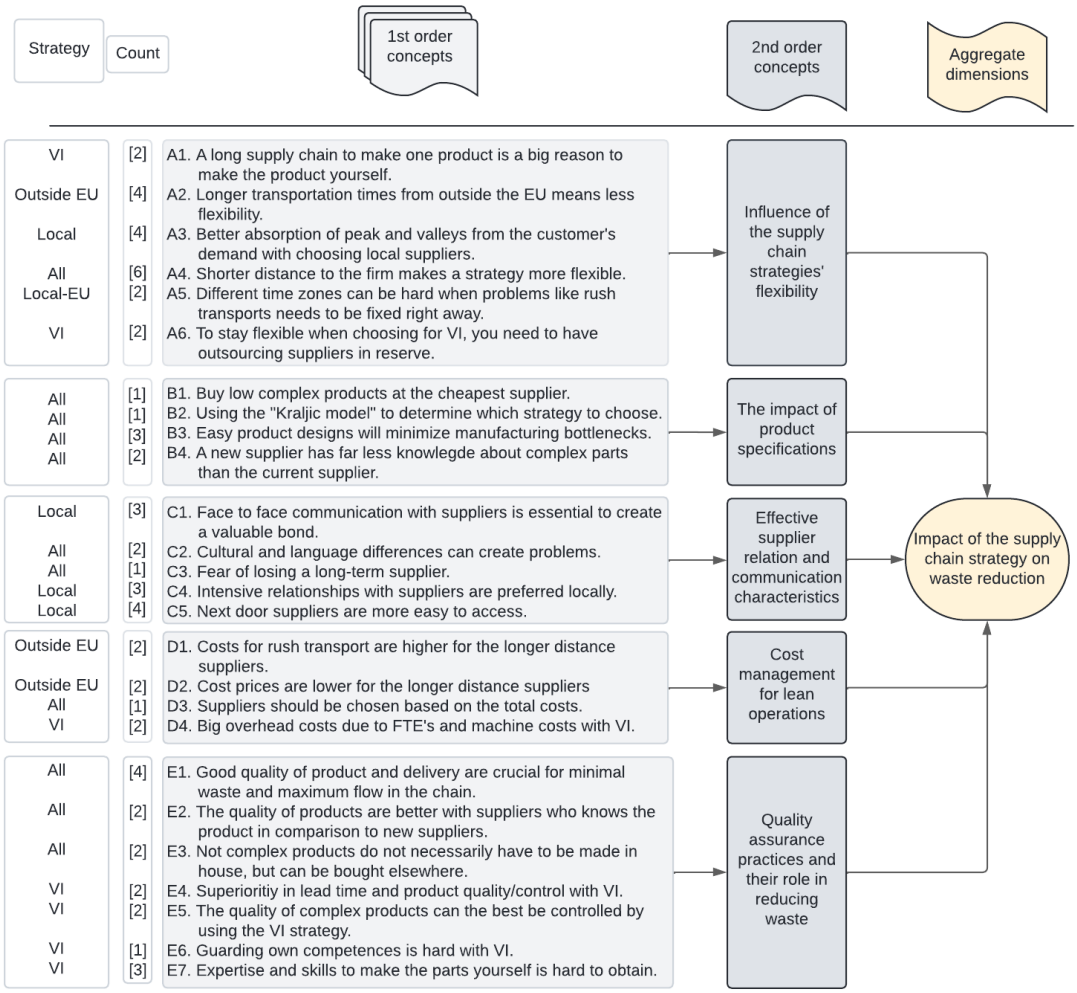

Figure 5: The data structure for the aggregate dimension “impact of the supply chain strategy on waste reduction”.

The first second-order concept that has a crucial role in the impact of a supply chain strategy on waste reduction is the supply chain strategies’ flexibility. Within the interviews, the flexibility of the

supply chain has been identified as a crucial factor why a strategy is chosen. From some of the interviewee's perspectives, this is caused by the dynamic world where manufacturers need to adapt to. There are different ways however how manufacturers adapt to this dynamic world around them and how supply chain professionals would handle this situation. Some respondents are certain in their decision that to be the most flexible strategy is local sourcing. This is because these respondents think that the shorter distance to the firm makes them more flexible (A4.) because there is less physical distance has to be bridged in order to get their parts or raw materials. Long physical distance of the companies is also stating longer transportation times (A2.), which are identified by some respondents as less flexible due to the longer lead times compared to organizations which are around the corner. This also makes it harder to adapt to peak and valleys in the customer's demand, when the supplier is in outside the EU (A3.). A quote from one of the interviewee's states the following about this:

"As an organization, you can absorb better the peak and valleys of the customer with a local strategy. For instance, if the sales are less than expected, you scale down your production. But the stuff on the boat from for instance China is something you cannot stop of course. So, if we would choose this strategy, we either have a lot of inventory and safety stock (so a lot of waste), or an unhappy customer because we are unreliable in delivery"

Another example of the difference in flexibility between the strategies is the set up in rush transports, when the organization has to adopt to the dynamic world around them. With local and EU suppliers, this is far easier to set up (A5.). According to two respondents who talked about this, it is due the different time zones form the supplier of outside the EU. A quote from the respondent who are outsourcing primarily from outside the EU strengthened this statement:

"We cannot call our supplier at every moment in the day, usually their working day ends when it is around 11 o'clock in the morning here. Which means if something in the afternoon happens, the chance that they are not in office is high."

Not only in the outsourcing strategies there are flexibility differences, also with vertical integration and outsourcing strategies in general there are contrasts. To extent flexibility in the chain, parts that can be produced only with the help of "a lot" of suppliers can also be vertical integrated, to reduce the risk of the part not being delivered (A1.). However, even though organizations make a part themselves, backup suppliers are essential, if for instance machines need maintenance or are broken (A6.).

The impact of product specifications

Product specifications have also impact in which strategy is chosen. Respondents who talked about product specifications argued that the low complex/cheap products can be the best bought at the cheapest supplier, which is usually the supplier from outside the EU **(B1.)**. This is mainly because the risk can be minimized since there are normally a ton of suppliers nearby who can supply the same product in a short time span. The following quote supports this explanation:

"Because if I would like to buy a screw for instance, I don't need to be that flexible. Because if the Chinese supplier cannot deliver, I can still get it locally. Because the price is also low for such products, it is not that big of a deal."

To determine which strategy is suitable for a product, the "Kraljic" model can be used according to the same respondent who mentioned the last quote **(B2.)**. This model identifies, based on financial impact and supply risk, which supplier should be chosen. For this respondent, the organizations' whole strategy is based around this model. However, if an organization switches from supplier because of for instance this model, they need to consider that a new supplier has far less knowledge about complex parts than the current supplier **(B4.)** Because long relationships with suppliers can lead to a point where manufacturing processes of suppliers are optimized a lot, the cost price of the product can be lowered with will lead to a cheaper purchasing price for the buyer **(B3.)**. A quote from the interviews supports this:

"They can look at our products and can see which product parts take a lot of time, we can adjust the products, so they make it more easily. And because of these kinds of things, the costs are getting cheaper."

Effective supplier relation and communication characteristics

Besides the impact of product specifications on the strategy choice and waste reduction, the relationship and communication style with the supplier is also an important factor. Three respondents mentioned that face to face communication or physical meetings with suppliers is essential to create a valuable bond **(C1.)**. When manufactures see the supplier a lot physically, the respondents had the feeling that they gained more personal bondage which can lead to more motivation at suppliers to get the job done, and vice vera. This is also why intensive relationships are preferred locally **(C4.)**. However, choosing for local suppliers is not only about the better personal bondage. Other important factors are that local suppliers are better accessible than EU or outside EU suppliers **(C5.)**, and the cultural and language differences with other countries which can create problems **(C2.).** A quote from one of the interviewees states how important the relationship with the supplier is to their organization:

"I guess the relationship part is the main difference between the different strategies because we will never have the same relationship with a Chinese supplier than with the supplier in the area. In terms of waste reduction, I think the Chinese supplier will never be more motivated to deliver on time for instance than the supplier around the corner who I have a personal bondage with."

Some of the respondents also fear to lose their long-term supplier **(C3.)**, which are making complex/valuable parts for them that cannot be bought simply elsewhere because there are no alternative suppliers. Also, the good relationship with trust plays an important role in why companies don't want to lose a supplier.

Cost management for lean operations

Besides that, rush transports from outside of the EU taking longer like is stated earlier, it is also obviously costlier. This is because rush transport from outside the EU, it is usually done by plane **(D1.)**. Even though the outside the EU strategy has a lot of cons that are already described, the cost price of the products that are bought from for instance China are usually significantly lower than the products that are bought from the EU or locally **(D2.)**. Even though the cost prices are lower, it is important that a strategy will be chosen based on the total costs **(D3.)**, like the following respondent states:

"From the total costs point of view, you want to calculate the best possible choice based on the purchasing costs and the inventory costs. What you often see that the lower price from for instance China, is compensating the higher inventory cost compared to other outsourcing methods."

The cost price of a product when an organization is making it themselves, is lower according to the organizations that is using VI in their supply chain. However, organizations must make big investments in machines and also have big overhead costs due to more FTE's and machine costs which is why not all of the organizations are implemented VI in their supply chain **(D4.)**. The companies that have implemented VI integration in their supply chain, have done this with products that have very high-quality standards and/or cannot be bought easily at another supplier.

Quality assurance practices and their role in reducing waste

That the quality of the product is essential can already be derived from the last Alinea. However, quality cannot only be related to the physical product itself. Most respondents (4) mentioned that the quality of the product, but also delivery, are crucial for minimal waste and maximum flow in the chain **(E1)**. Respondents state that a lot of rework must be done, when the quality of a product is not the way it should be. According to the respondents, the rework includes for instance ordering new products and

adjusting the production planning, that takes a lot of time. The following quote of one of the respondents is strengthening this:

"The impact of defects in our process is like I stated before very high, so it is essential that we don't have quality issues. It creates a lot of waste when the quality of a product is not good. Consequences of quality problems are the chance of a NOTD to the customer and waiting time in the production area."

What is also stated indirectly earlier in this paragraph, is that long-term suppliers have better quality than new suppliers because of their knowledge about the product **(E2.)**. Which means that a supplier who is involved for a long time, has gained an advantage if there should be chosen between suppliers again.

Two respondents, also the one who implemented VI, claims positive effects like that this "make" strategy create superiority in both lead time and product control/quality **(E4.)**. This is because the unreliability factor of suppliers is minimized due to buying only raw materials instead of products. Also, the quality of the products can be better controlled with VI because it is done by themselves, even though this can also be bought elsewhere if the quality of the supplier is acceptable **(E3. E5.)**. However, when it is done by the organization itself, the expertise and skills must be at the organization **(E7.)**. At this point in time, getting these skills is not easy for companies as is mentioned in the following quote:

"With vertical integration, it is hard to get the qualified personnel. There is little appetite for working as a machining operator, and it is something else to get good personnel in machining. So, that is also something you must deal with when you want to do vertical integration. Also, with grinding and wire-EDM, that is a dying race, however we do this at the highest level. So, it is very hard to find people who can actually give value to us in these processes."

Also guarding these competences and skills, when they are inside the company is hard nowadays **(E6.).** A lot of companies are paying high wages to get skilled personnel. Besides this "old" skilled engineers who are almost going to retire and maintain a lot of knowledge must hand over their knowledge to the new generation, otherwise this expertise will be lost.

4.2.2. Influence of the supply chain KPIs on waste reduction

The second aggregate dimension that has an essential role in answering the research question are the influence of the supply chain KPIs on waste reduction. Because these KPIs give a view of the underlying variables which drives the supply chain strategy choice, it is important to understand how manufacturing organizations think about these KPIs to answer the research question, because it will

give insight in what the waste differences are among the strategies based on the KPIs, which KPIs are crucial for waste reduction and how this waste in different areas can be controlled.

In figure 6, the structure is the same as figure 5. The only difference is that the related KPIs are connected to the 1st order concepts, and not the strategy. This goal of this column is to give an idea about which KPI can be connected to the statement, which gives the reader more overview.

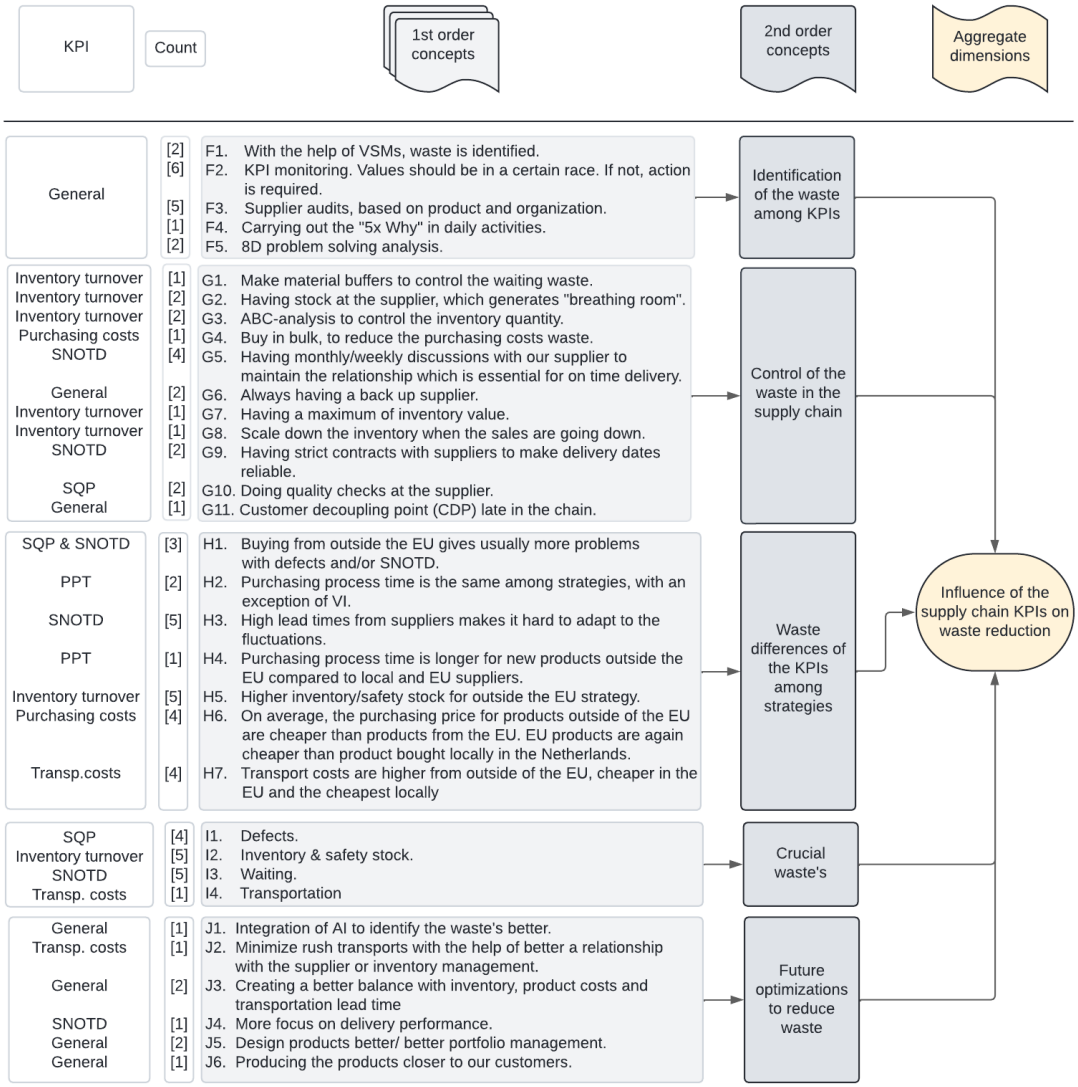

Figure 6: The data structure for the aggregate dimension "Influence of the supply chain KPIs on waste reduction".

Identification of the waste among KPIs

Among all the respondents, KPIs are used in some way to track for instance their supplier on time delivery rate, inventory and defect rate from the bought products **(F2.)**. Logically there are differences in how these important operations are measured, but every manufacturer is monitoring KPIs in some way. Why this monitoring is important, can be clarified with the following quote from an interview:

"We improved our supply chain by monitoring the chain with the help of KPIs. With this way, we can steer in the right direction."

Also, manufacturers are auditing new suppliers if they are going to be involved in the supply chain of the organization **(F3.)**. With the help of KPIs and for instance the 8D analysis **(F5.)** the suppliers are monitored, if these indicators demonstrate negative numbers for the supplier, they will be audited more often. If the supplier scores well, they will logically be audited less. For instance, with supplier defects, this is done in the following way at one of the manufacturers:

"The defect will go through a 3D, 5D or an 8D analysis. If the defects are repeated a lot, then it will go in the 8D. If the defects are still coming, then the supplier will go into a improve program. The suppliers are categorized from A-E, which means that how better the score. How less they are audited."

Besides this, one "lean" organization try to identify waste with the help of the "5x Why", where the goal is to find the root cause of problems/waste **(F4.).** Also, some respondents use "Value Stream Mapping (VSM)" in order to visualize the waste in the complete supply chain **(F1.).**

Control of the waste in the supply chain

Identifying waste in the chain is a completely different thing than actually controlling the waste to a minimum. Respondents mentioned multiple cases in how they try to control the waste. What was interesting, is that respondents talked a lot about how to reduce inventory which was seen as a big waste. To reduce or minimize the inventory and safety stock levels, two of the respondents have stock at their supplier or external party **(G2.).** Because of this inventory costs can be shared with the supplier. Also, delivery risks are more spread with this, which is explained in the following quote:

"Also, the lead time part is an important one. If we have to wait 8-12 months for these heat exchangers, the demand for the customer can fluctuate very hard. Which means that you cannot absorb the changes from the customer very easily. We spread this risk by having inventory at an external party here in the city. If we call-off some exchangers, then we get the invoice. So, this is for spreading the risk."

Also, material buffers inside the production area **(G1.)**, the ABC-analysis to control the inventory quantity **(G3.)**, having a maximum inventory value **(G7.)** and scale down the inventory when the sales are going down **(G8.)** are mentioned by the respondent to control their inventory (turnover).

For other KPIs, like the SNOTD, the relationship between the supplier and organization is mentioned once again as very essential for the on-time delivery **(G5.)**. Because of the factors that are also mentioned before, like the personal bondage which motivates the supplier more. Also, strict contracts

with the supplier what forces them to deliver on time because of e.g. high inventory costs, is an option to control the supplier on time delivery (G9.). The following quote supports this:

"We try to reduce on working capital, and safety stock is of course killing for this part. So, we try to steer on the right supplier date. We have also contract with suppliers that they will deliver on a specific date."

Contrasted to reducing the inventory waste, is buying parts in high volume or bulk (G4.). This often reduces the purchasing price that much, that it is weighting up against the higher inventory costs according to this respondent:

"We try to buy in bulk of course, to minimalize the purchasing costs per product. Because our organization is very big, we can do this. This can lead to in extreme cases of discounts of around 25% of the cost price, which outweigh the inventory costs."

For the defect waste, some respondents mentioned that the products they buy are already checked with for instance their own checklist at the supplier, to minimize the risk of quality problems with the bought products (G10.).

Other general comments in this section were that it is important to have a backup supplier, in case VI or the main supplier is giving problems with production or/and delivery (G6.). Also setting the "customer decoupling point (CDP)" late in the chain is mentioned as a nice tool to control wastes better. When products are standardized and made modular, organizations can reach higher turnovers do to the fact that parts can be implemented in not one, but different products for different customers (G11.).

Waste differences of the KPIs among strategies

Even though the KPIs have different kinds of waste, the waste of the KPIs also differentiate per strategy. Commonly known differences that are also mentioned by some of the respondents are that on average, the purchasing price is cheaper for the parts from outside the EU compared to the EU and local strategy (H6.). However, for transportation costs it is the other way around. Because of the longer distance, the costs are usually higher for product outside the EU and the cheapest for local supplier (H7.).

For the SNOTD, most respondents mentioned that with when the lead times are high, usually from the suppliers from outside the EU, the adaptation to customer fluctuations are not easy (H3.). The following quote from one of the respondents strengthens this:

"When we buy from China, we need to order 12 weeks before we need it. In these 12 weeks, our customers can shuffle a lot with their demand, which is for us very hard to adapt to. Of course we have our safety stock, but these are of course also costs. Also, a customer can demand more products at a late stage, which means that we are moving into trouble."

Also, defects are much more detected in products from outside the EU, compared to other strategies **(H1.)**:

"I think if you buy straightaway from China, you have two big bottlenecks: defects and Lead time/on time delivery. If you have a few defects from China, you'll get in trouble. Because of this, your inventory is getting higher and things like that."

For the purchasing process time KPI, some respondents argue that there is no difference between the buying time for different areas **(H2.)**. This is mainly because after a while part are bought automatically and the suppliers know the product after a while. However, for new products the process time is longer compared to local and EU suppliers **(H4.)**. The following respondents explains why:

"Also, the suppliers know our products, which makes this purchasing process time the same among the strategies. If you have a new supplier from China compared to other strategies, it is harder because you need to communicate the shipping, product specs etcetera."

For the inventory turnover KPI, the biggest difference is that for the products from outside the EU, the safety stock and inventory is usually higher according to some of the respondents **(H5.)**. This is due mainly because the of the longer lead time which makes it hard to react on fluctuations like is stated before.

Crucial waste's

All the respondents are asked which type of waste from figure 3 are the most crucial and have the most influence in choosing a supply chain strategy. Most of the respondents stated, that waiting in any form is crucial **(I3.)**. Why the waiting waste is seen as so important, can be explained with the following quote of one of the respondents:

"For purchasing, it is waiting on suppliers and defects of the products you buy. Being busy with going after suppliers who are late or products that are bad is taking up a lot of time. We try to tackle this sometimes with having a slightly higher inventory, which is not always that nice if you look at the inventory costs in general."

Also, the inventory and safety stock are identified as an KPI which is pushing hard on the total waste in the chain **(I2.)**. Why this inventory waste is identified as important, can be pulled out the following quote:

"We don't have that much inventory, because it costs us too much money. Because of the needed space, but also of the "dead money" that comes along with it."

The "dead money" is indicated as working capital which is invested in stock. Because of this, organizations cannot use this to for instance innovations.

Also, the "defect" waste is considered as important **(I1.)**:

"This is because our first KPI is quality deviation from products. When a defect is there, a lot of rework is needed to make everything right. We want flow in our processes. Which is very important. When there are defects, there is a disruption in this flow which means that these defects are killing for delivering our products on time."

The last-mentioned important waste is the transportation waste. Which is mentioned by the respondent where the main strategy is to outsource from outside the EU **(I4.)**. The reason for mentioning this KPI is the fact that the long lead time, has a lot of effect on the day to day business for this organization Besides that adoption to demand fluctuations is harder which means that the inventory is usually higher, there is even more "dead money" because the bought products are in transit for 6-7 weeks:

"For instance, if we order a product from China, we already have it in our books as our inventory if it is on the boat, usually it costs 6-7 weeks to get all the material here. Right now, with the Suez Canal issue it already a minimal of 8 weeks, which means that I have 8 weeks of inventory on the boat, that has literally no use because I don't have it here at the organization."

Future optimizations to reduce waste

The respondents from the interviews had various thoughts about how the waste in their chain could be more reduced. Where one respondent mentioned implementing new technological innovations like AI, to make better choices in their chain **(J1.)**, are others more focused on reducing rush transports and delivery performance because it saves a lot of money **(J2. J4.)**. According to these respondents, this can be done with a better supplier relationship or better inventory management.

Organizations also want more insight in the balance between inventory costs, purchasing costs and transportation lead time to create an optimum situation in relation to these KPIs **(J3.).** Besides this, some

of the respondents mentioned that they wanted to produce closer to their customers in order to reduce their own transportation risks to the customer **(J6.)**:

"For us, maybe minimizing the transportation to the customers. Because we do that a lot more than getting trailers from eastern Europe. A distribution warehouse in central Europe would reduce a lot of lead time and transportation risk to the customer for us."

The last noteworthy mentioning was the optimization of product itself **(J5.)**. Making designs easier is not only good for standardization, but also for access to suppliers:

To make the design easier, you can minimize the bottlenecks for manufacturability which saves money. Another extra positive effect of this is that you can immediately have more supply sources.

4.2.3. Influence of external factors on waste reduction

External risks in the supply chain are factors that are out of direct control of an organization, like is also stated in paragraph 2.5. In this section, it is explained how the manufacturers are dealing with these factors. In figure 7, the data structure for this last aggregate dimension is shown.

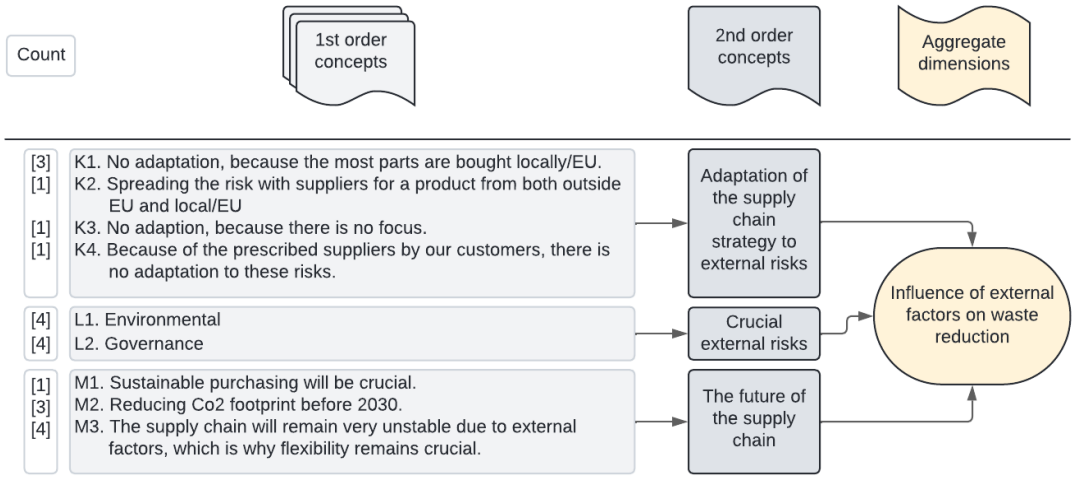

Figure 7: Data structure for the aggregate dimension "Influence of external factors on waste reduction.

Adaptation of the supply chain strategy to external risks

Most of the respondents did not adapt their strategy to the external risks around them. This was because the organization did not have a specific focus on these external factors **(K3.)** or had prescribed suppliers by their customers **(K4.)**. For the others, Among the respondents however, it was mainly because the main sourcing method is buying locally **(K1.)**. A respondent stated the following about adaptation of their strategy:

"I think we buy directly from China in only 1% of the time. For environmental reasons we need to make reports of how much we import from outside the EU, and that is for us almost nothing. Because we buy locally, we hardly notice these factors, so we don't adapt our strategy to it."

The respondent whose organization did adapt their strategy to the external factors, is doing a mixed outsourcing method to reduce the risks of non-delivery **(K4.)**. If one supplier from the EU or outside EU cannot deliver on time due to external factors, they can switch to the local supplier.

Crucial external risks

The respondents where ask which type of risks, environmental, social, governance or operational risks, they found was the most important and have the most influence in the supply chain. From the answers, there can be concluded that environmental **(L1.)** and governance risks **(L2.)** are seen as important. The following quotes from one of the respondents is describing problems they have with the governance risks.

"Because of these external events, our logistics department has to work over hours in the Christmas period in order to fix the Suez Canal problem for instance. As a company, you don't have influence on these kinds of events, but you have to deal with them."

The future of the supply chain

One of the reasons that a big part of the respondents identified the environmental risks as highly influential on the supply chain, is that in the future organizations need to adapt to the European Union goal of reducing emissions by at least 55% (European Union, 2024). Reducing the CO2 footprint and sustainable purchasing is something that is seen as a key factor that organizations have to adapt to in the future supply chain **(M1. M2.)**. Also, the thought is that the supply chain remains very unstable due to these external factors **(M3.)**, which is why the flexible competence of an organization to the world around them will be crucial:

"I think disruptions in the chain, like wars and negative influences will stay. Which means that you have to be flexible when these events occur. When you are not flexible, the customer will leave you for someone who is."

4.3. Quantitative analysis results

In this section, the quantitative steps from this figure 4 are followed. This will lead to the quantitative results of this research. In the quantitative results, the KPI "purchasing process time" is not included.

4.3.1. Data cleaning and exploration

The raw data contains 490 observations and 26 variables. This data is cleaned through removing the outliers and missing values ("NA") from the dataset. It is essential to remove these data anomalies for reliable and accurate results. Missing values can create bias results and outliers have a big influence on estimating statistics like the average and standard deviation of the population (S. K. Kwak & Kim, 2017). For deleting the missing values, no formula is used. For deleting the outlier's formula 1 is used from paragraph 3.3.1. Only the outliers for the KPI "purchasing costs" and "Inventory turnover" are removed, because this information is generated straight from the data system. The SNOTD, transportation costs per unit and SQP values cannot contain outliers, because these values are the actual representation of the situation.

After removing the missing values and outliers, the dataset is minimized to 417 observations within the same amount of variables. A concise description of the products that are in this dataset after the data cleaning can be found in Table 2. The analyzed products have different purchase price ranges to gain representative and generalizable results of the complete product portfolio. A full description of all these products can be found in Appendix C.

Table 2: Concise view of the used dataset in R.

Not included in this paper due to confidentiality reasons.

In Table 3 & 4, the descriptive statistics of the KPIs can be found per supply chain strategy. This data is based on the supplier and costs data of the products from Appendix C. For the purchasing costs, the latest available product prices (May 2024) were taken. A disadvantage of the purchasing costs data is that company X does not have enough data for the higher price ranges for every strategy. In the conclusion section, this will be discussed more deeply of how this influences the results. For the SNOTD, TCPU, Inventory turnover and the SQP data, data is gathered from the period of January 2023 until May 2024. For the transportation costs (TCPU) the prices are shown for a container load of 10.000 kg. This will also be the case for the rest of the data which will be shown.

Table 3: Summary of the descriptive statistic scores per KPI for each strategy.

Not included in this paper due to confidentiality reasons.

Table 4: Summary of the descriptive statistic scores per KPI for each strategy (continuation).

Not included in this paper due to confidentiality reasons.

4.3.2. Normalization of the data and applying the weight factors

After the data has been normalized, the normalized scores can be multiplied with the weight factors in order to get the waste scores per supply chain strategy. The normalization scores and the weight factors of the KPIs are calculated based on formulas 2-8 from paragraph 3.3.1 for each of the 417 products independently. In table 5 and 6, a summary of the normalized scores is shown. In table 7 and 8 a summary of the weight factors per KPI are described.

Table 5: Summary of the normalization scores per KPI for each strategy.

Not included in this paper due to confidentiality reasons.

Table 6: Summary of the normalization scores per KPI for each strategy (continuation).

Not included in this paper due to confidentiality reasons.

Table 7: Summary of the weight factors per KPI for each strategy.

Not included in this paper due to confidentiality reasons.

Table 8: Summary of the weight factors per KPI for each strategy (continuation).

Not included in this paper due to confidentiality reasons.

Table 7 & 8 demonstrate the weight factors per KPI. These tables revealed the crucial importance of the SNOTD KPI and the purchasing costs KPI on the waste reduction score, which is the case for every strategy. This indicates that controlling the SNOTD and the purchasing costs are essential for minimizing the waste in the chain. This is in contrast to the SQP weight, which has minimal impact on the waste score. The main reason for this is that the SNOTD and the purchasing costs are far more important than this variable. The transportation costs per unit and the inventory turnover are more important than the SQP weight factor, but also much less than the SNOTD and purchasing costs variable. The reason why these two weights are the most important for reducing waste in the chain, can be explained with the following example from the analyzed dataset from a financial point of view:

Purchasing price	€5.80
Total costs	€13.32

The SNOTD weight is calculated by adding the costs of safety stock and flying costs. The safety stock costs per unit is the same as the purchasing price of one product. Thinking logically, if the supplier fails to supply the raw materials in 100% of the time, an organization must have 100% of the raw materials in safety stock. If it is 50%, half of the raw materials should already be in the organization in order to produce the end products for the customer. In this case, it means that the SNOTD weight can be calculated as follows for this specific case.

$$SNOTD_{weight} = \frac{Costs\ of\ safety\ stock + fly\ costs}{Total\ costs} = \frac{€5.80 + 0}{€13.32} = 0.44$$

For the transportation cost per unit weight, simply the transportation costs per unit can be taken. For this example, the prices for a container loading of 10.000kg will be used.

$$TCPU_{\ weight} = \frac{Transportation\ costs}{Total\ costs} = \frac{€0.55}{€13.32} = 0.041$$

For the purchasing costs weight, also the purchasing costs can be taken:

$$Purchasing\ costs_{\ weight} = \frac{Purchasing\ costs}{Total\ costs} = \frac{€5.80}{€13.32} = 0.44$$

The inventory turnover weight is based on 20% of the purchasing price according to company X's guidelines.

$$Inventory\ turnover_{\ weight} = \frac{0.2 * Purchasing\ costs}{Total\ costs} = \frac{0.2 * €5.80}{€13.32} = 0.087$$

The SQP weight is based on the defect's costs. This is divided by the quantity of raw material for the specific item that are bought in a period of January 2023 and May 2024.

$$SQP_{\ weight} = \frac{costs\ when\ a\ product\ is\ defect}{Total\ costs} = \frac{€568.88/54800}{€13.32} = 0.0001$$

4.3.3. Average waste scores per supply chain strategy

The distribution of the waste scores per strategy are calculated based on formula 9 from paragraph 3.3.1. This is done by multiplying the normalization scores per product times the weight factor. Figure 8 shows the average waste score per supply chain strategy.

Figure 8: The waste scores per strategy based on the used dataset.

Not included in this paper due to confidentiality reasons.

4.3.4. Statistical tests

To determine if these waste score results are statistically significant, an ANOVA or Kruskal-Wallis test can be executed. Generally, in the academic world, a p-value with a value below 0.05 is established as statistically significant. When this is the case, the "null hypothesis", where there is no difference between analyzed groups can be rejected (S. Kwak, 2023). The ANOVA-test is used when the dataset is normally distributed. If the data is non-parametric the Kruskal-Wallis test is used (Liu, 2015). This can be determined with the help of the Shapiro-Wilk test that tests for normality, and the Levene's test which tests for equalness in the variances to determine the differences between groups (Gastwirth et al., 2009; González-Estrada & Cosmes, 2019). If both of these tests have an outcome with a p-value above 0.05, the data is normally distributed (Shapiro-Wilk test) and has equal variances (Levene's test) across the analyzed groups. In this situation the ANOVA-test is used to determine the statistical significance of the waste scores. If not, the data is not normally distributed with not equal variances, which means that the Kruskal-Wallis is used. The null hypothesis for these tests is that the data is normally distributed and there are equal variances across the groups. Table 9 shows the results for the Shapiro-Wilk test and the Levene's test in R. The Levene's test has only one p-value, because it focusses on the equality of the variances between groups which involves all of the strategies. For the Shapiro-Wilk test, the normality level of every strategy is measured.

Table 9: P-values of the Shapiro-Wilk test & Levene's test.

Strategy	Shapiro-Wilk test	Levene's test
EU	6.13e-06***	2.2e-16***
Local	9.62e-08***	
Outside EU	8.15e-08***	
VI	2.82e-05***	

***. Correlation is significant at the 0.001 level.

The results from table 9 show that the null hypothesis which states that the data is normally distributed, and the variances are equal, can be rejected. This means that the Kruskal-Wallis test has to be performed to check the statistical significance of the waste reduction scores. In table 10, the scores for the Kruskal-Wallis test can be found.

Table 10: Description of the Kruskal-Wallis score and the Dunn-test scores.

Kruskal-Wallis test	*Strategy*	Dunn-test "Bonferroni"	Dunn-test "Holm"	Dunn-test "bh"	Dunn-test P-value unadjusted	Significant? (P-value <0.05)
2.09e-10***	EU - Local	5.21e-01	8.68e-02.	8.68e-02.	8.68e-02	No
	EU - Outside EU	3.21e-02*	1.71e-02*	1.02e-02*	8.56e-03**	Yes
	Local - Outside EU	3.20e-04***	1.60e-04***	8.01e-05***	5.34e-05***	Yes
	EU - VI	5.58e-11***	4.65e-11***	2.79e-11***	9.30e-12***	Yes
	Local - VI	5.07e-06***	3.37e-06***	1.69e-06***	8.44e-07***	Yes
	Outside EU - VI	2.47e-18***	2.47e-18***	2.47e-18***	4.12e-19***	Yes

*. Correlation is significant at the 0.05 level.

**. Correlation is significant at the 0.01 level.

***. Correlation is significant at the 0.001 level.

The p-value of 2.09e-10 from the Kruskal-Wallis test indicates that there are significant differences in waste scores for the groups. Because this is answer is too general, a post-hoc test is done to determine if the differences between specific strategies are also significant. Therefore, the Dunn test is used. Within the Dunn test, there are various methods that can be used. In this research, the "Bonferroni", the "Holm" and the "Holm-Bonferroni (bh)" are analyzed. However, the Bonferroni method will be used. This method is chosen because the Bonferroni method has the strictest control on false positives, which will lead to the most reliable p-value (Pohlert, 2014). This method indicates that for all of the pairs there is significant difference in the waste score, except for the comparison of the EU and Local strategy.

4.3.5. Correlation analysis

To determine how the strong the KPIs are related to each other, a correlation analysis can be made. For the "Pearson's correlation analysis", linear relations between the KPIs are tested. The correlation coefficient (Pearson's R) is showing how strong the relationship is between the variables. This value variates from -1, where there is a perfect negative relationship and 1, where there is a perfect positive relationship. The value 0 is suggesting that there is no linear relationship at all. If there are very strong relationships, this can be a sign of multicollinearity (Senthilnathan, 2019). If these strong relationships are there the chance is high other variables are forgotten or the dimensions of the KPIs are not set sufficiently. This is why multicollinearity in research has to be avoided. The Pearson's R values and the associated p-values for the comparison between the KPIs are found in table 11.

Table 11: Outcomes of the correlation analysis.

Strategy	SNOTD	TCPU	Purchasing costs	Inventory turnover	SQP
SNOTD	1	0.52***	0.51***	-0.08***	0.02
TCPU	0.52***	1	0.62***	-0.12	0
Purchasing costs	0.51***	0.62***	1	0.04	0
Inventory turnover	-0.08***	-0.12	0.04	1	0
SQP	0.02	0	0	0	1

***. Correlation is significant at the 0.001 level.

Table 10 describes that there are 3 moderate positive significant correlations between the comparisons of the SNOTD and the TCPU (0.52), the TCPU and the purchasing costs (0.62) and the SNOTD and purchasing costs (0.51). The correlation between these variables cannot be identified as strong because then the correlation should be higher than 0.7 (Ratner, 2009). Even though it is not critical enough to determine multicollinearity, it cannot be denied that there is a moderate correlation between some of the variables that can contain multicollinearity, because of the values that are higher than 0.4. The other relationships between the variables are considered as weak and or not significant.

4.3.6. Practical example

Not included in this paper due to confidentiality reasons.

5. Conclusion & results

To answer the research question *"To what extent do "make or buy" supply chain strategies impact waste reduction in the manufacturing sector?"* the conceptual model from the theory section is tested based on the qualitative and quantitative results from chapter 4. The conceptual model from the theory section is visualized again in figure 11.

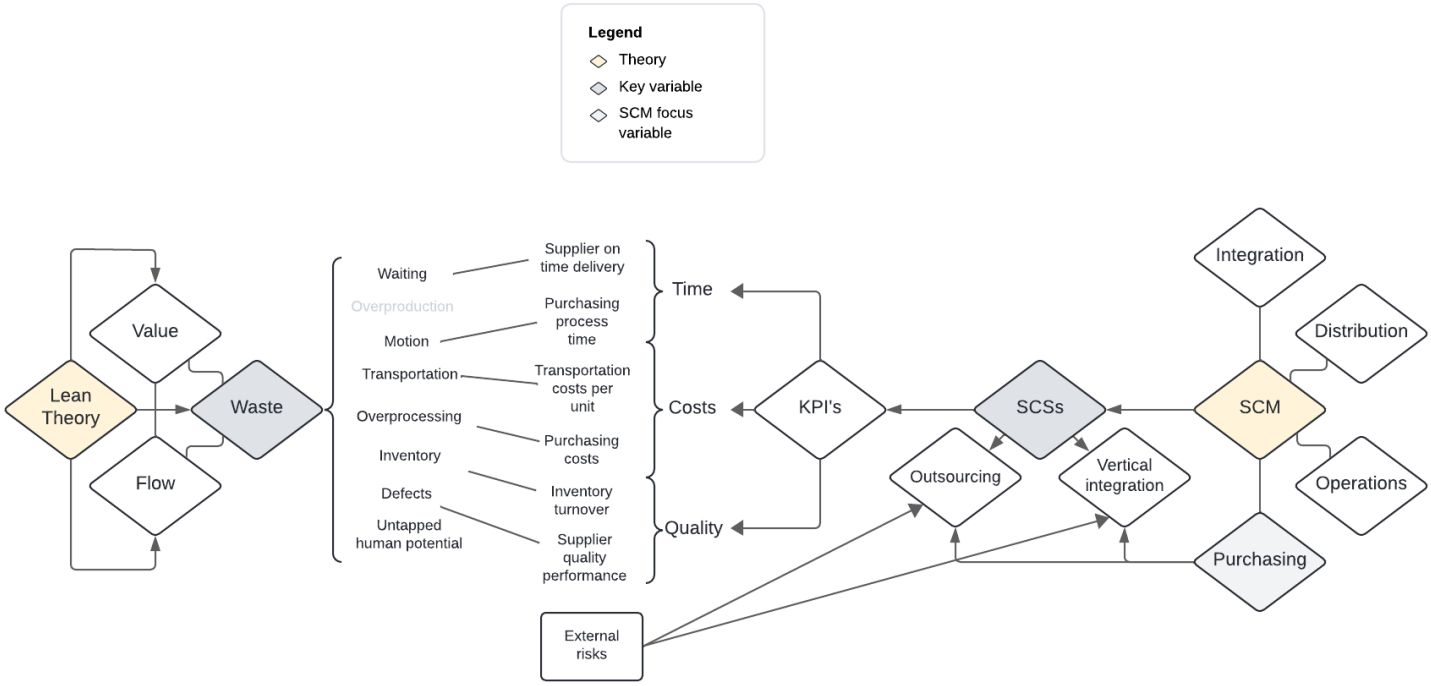

Figure 11: The conceptual model from the theory section, which connects the supply chain strategies with the waste principle from the lean theory with the help of KPIs.

From the qualitative point of view of this research, the extent in which supply chain strategies impact waste reduction is based on the underlying characteristics from each strategy. Four of the six respondents choose for local outsourcing for getting their (raw) material to their organization. This is mainly because of the flexibility of this strategy. Because the customer's demand can fluctuate over time, the manufacturers have time when they choose for this local strategy to adapt to these fluctuations. Compared to other strategies, an intensive valuable relationship is much easier to set up with local suppliers than other suppliers. This is because face to face contact is far easier to arrange, and there are no cultural/language differences that have to be bridged. Because of this, the feeling among the local respondents is that they have a much better personal bondage with the local supplier compared to suppliers in another area. Because of this bondage, these suppliers are more motivated to deliver and be reliable. If organizations choose for the outside the EU strategy, the lead time/transportation distance is much longer, which is why it is much harder to adapt to these demand changes according to the respondents. Even though the purchasing price is generally much lower for

this strategy, the reliability of the suppliers delivery is whimsical which is why inventory levels are much higher compared to the other strategies. If the inventory levels are high, the working capital that is useless is determined as a big waste among some of the respondents. This all together, is why the "waiting" and "inventory" waste is identified as crucial amongst the respondents. Beside these wastes, the defect waste is marked as a crucial factor to minimize the risk in the chain. Whenever defects pop up, the rework time is high to actually fulfill the customers demand. This disruption costs a lot of time and effort, which is why it as marked as an important factor to control in the chain. For the strategies, respondents generally mentioned that the quality of products is worse from the outside the EU suppliers, compared to local and EU suppliers. The "motion" waste, which is connected to the "purchasing process time" KPI is identified as the same for each strategy, except for the VI strategy because of the less purchasing orders. The "untapped human potential" waste is not mentioned at the interviews, so no qualitative conclusion can be drawn how much influence this has on waste, and what the difference is of this KPI among the strategies.

Respondents state that the environmental and governance risks are having a big influence of how the supply chain is shaped, which is one of the reasons why suppliers from outside the EU are less reliable than the other strategies. According to the respondents the world will remain very unstable in the future. This is based on the past events like the Suez Canal war and corona, which negatively affected the supply chain for organizations. Also, future CO2 reductions that have to be made before 2030, is an essential factor which cannot be left out with choosing a strategy with the least waste. That the external risks are different from outside of the EU, EU and local (Netherlands) supply chain strategies, can be quantitatively strengthened with the "supply chain risk" indicator from the "Country Risk.io" database. This organization determines this indicator based on environmental, social, governance and operational data which is acquired at databanks like the World Bank, United Nations and Financial Action Task Force (FATF) (CountryRisk.io, 2024). This indicator is shown in figure 12.

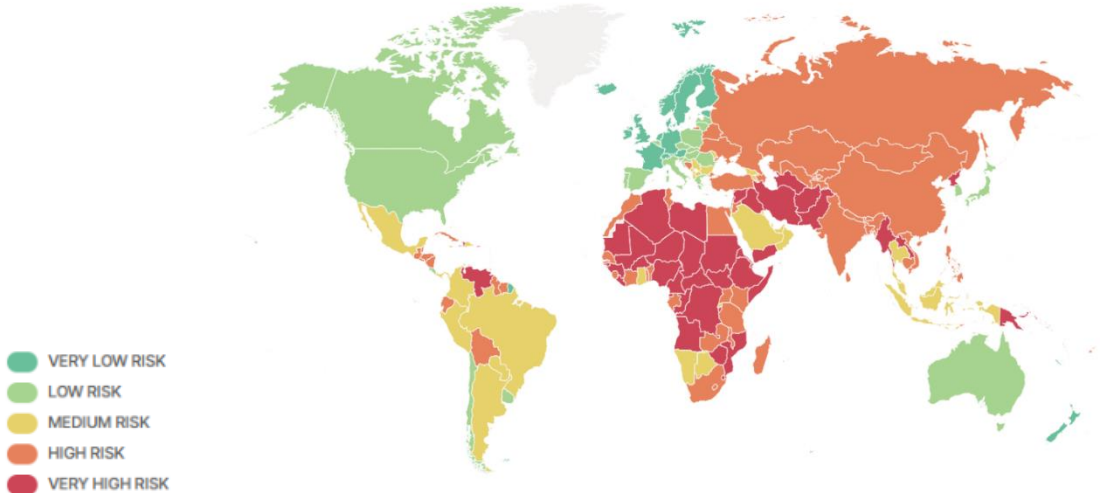

Figure 12: Supply Chain risk indicator per country (CountryRisk.io, 2024).

Thus, comparing the values of the respondents and the theoretical model, all the KPIs except for the purchasing process time are influencing the waste reduction per strategy in some way. However, the weight of each KPI is determined as different. The respondents answers suggested that the "Waiting", "Inventory" and "Defect" waste were the most influential and important. The theoretical model shows that the "SNOTD", "Inventory turnover" & "SQP" KPI can be linked to these wastes. The quantitative analysis will show, based on actual data, if these KPI's are the most important:

The most important conclusion from the quantitative analysis are not the actual output scores from the R analysis or practical example. The most important and useable results where the actual weights of each KPI and how much influence they have on the total waste. Like is mentioned at the beginning of this chapter, it is not the strategies itself which influence the total waste, but it's underlying factors. The quantitative analysis showed that the SNOTD and the purchasing costs KPI have an influence of on average around 88% in the total waste score. Consequently, controlling these KPI's will contribute extremely for waste reduction for manufacturing organizations. Comparing the quantitative weights with the respondents answers of waste they found important, the only difference is that the SQP value is not an important waste in the quantitative analysis. This is due to the fact that the defects costs are streamlined across all the bought products, which is why the costs per unit were very low for this KPI. Factors like time are not included in the defect costs which can be a reason why this KPI is quantitively not that influential. However, the qualitative insights are for the other wastes and KPIs in line with the quantitative analysis. Inventory, waiting and the purchasing costs variable is something that is found important in both analysis results.

In conclusion, *the extent to which "make or buy" strategies impact the waste reduction* is based on the strategies underlying factors, especially the SNOTD and purchasing costs. Monitoring these KPIs will result in data that give manufacturing organizations strategic directions in which strategy to choose. Zooming out to the strategies, concluded can be these KPIs differ among the strategies based on distance. Usually the purchasing costs of a product are lower for longer distance suppliers. However, the reliability of the delivery is worse compared to suppliers who are near. This is why monitoring the KPIs are essential for determining which strategy is the best, because generalization within a strategy is hard because not every supplier, product or "make" activity is the same.

With an eye on the future, external factors like CO2 reduction and possible disruptions in the world like wars will have a big influence into which strategy will contain the least waste, and of course the lowest costs. Long term relationships will lead to more motivation to deliver on time and simpler product designs that will help the supplier with manufacturability which will drain the purchasing price.

6. Discussion

This study is focused around to what extent make or buy supply chain strategies influences waste reduction in manufacturing organizations. In this section, the theoretical and practical implications of this research are described. Also, the limitations and advisable future researches are described.

6.1. Theoretical implications

This research contributes to academic knowledge by providing empirical data on the influence of specific supply chain strategies on waste reduction. Qualitatively, the experiences of the respondents give an understanding of which constructs are important for waste reduction in different strategies. Besides the influences of each KPI, the respondents named more constructs that have influenced in the waste reduction per strategy. Factors like the relationship with the supplier, cultural differences and product innovation are giving a more holistic meaning that have influence on the supply chain KPIs and strategy. Quantitatively, this research offers insights in how underlying KPIs per strategy, are influencing the supply chain. The weight determination of the KPIs can give theories the right approach of how the KPIs is influencing waste reduction per strategy in general.

Comparing the results of this paper to current literature, there are numerous outcomes what are in line with other papers. For instance, (Melton, 2005b) states that implementing lean in organizations is something that is important to release working capital and increase the supply chain speed. Thinking about waste and the supply chain strategies, this paper states that working capital has a high influence on waste and is essential to control. With lean thinking, for instance monitoring KPIs and navigate when necessary this can be done. Also, this paper states that there are differences in the researched KPIs for the supply chain strategies. For instance, the quality of products can be better controlled with the vertical integration strategy and cost savings in the long run can be made because the purchasing costs and SNOTD KPIs, which are essential, can be controlled. The paper of (Plum et al., (2017) describes that vertical integration has its pros, like general costs savings and quality improvement, and its cons like available domestic sources which is in line with this paper.

Also the results of this research bring something new to the literature. This is because current researches has not connected the waste principle from the lean theory to vertical integration and different forms of outsourcing what is visualized in the conceptual model from figure 3. At last, the interdisciplinary nature of this research where strategic management, logistics and procurement are incorporating contributes to a holistic understanding of the supply chain in general, which can lead to new theories about how supply chain KPIs in different strategies interact with the help of the mixed method results from this paper.

6.2. Practical implications

Practically, the results will help manufacturing organizations with choosing the right make or buy supply chain strategy, expressed through KPIs, on waste reduction. By understanding how the supply chain KPIs per strategy impact waste reduction in their own organization, organizations can streamline processes and enhance overall supply chain performance that will help in gaining competitive advantage. In this company specific case, the results showed that the purchasing costs and the SNOTD KPI had a huge influence on the total waste score, which is directly linked to costs. It is essential for organizations to determine which KPIs are essential in their own work field, to reduce the most waste by choosing the best strategy. Controlling these KPIs can be done in multiple ways. Managers from manufacturing organizations could use dashboard to monitor all these KPIs, in order to tell which strategy is for them the most cost effective. Advisable is not to look only on the historical data, but also look to the strategies' KPIs and think what it could be in the future. For instance, the purchasing price for local sourcing is usually the highest among the strategies. However, this can be drained by having an intensive, long term relationship with the local supplier and think about how products could be manufactured more easily with better quality. The second practical contribution to manufacturing organizations around us, is that the influence of external factors at the suppliers' reliability cannot be denied. In the future, environmental laws that lead companies to reduce CO2 drastically, will strengthen the general effect of external factors even more. Organizations can pre-sort their strategy on these external factors, to stay competitive.

6.3. Limitations & future research

Even though this research can make valuable contributions to the academic and practical world around us, it has limitations which cannot be ignored. The first limitation of this research is that in the quantitative part direct comparisons between products could not be made because of the limited available data. Because of this, mostly products with different price-scales had to be compared with each other. Even though the purchasing costs are normalized, which means that the prices will fall between a range of 0-1, the descriptive statistics showed that the purchasing costs e.g. for different strategies were not realistic. Even though the waste scores give a good general understanding of how much waste there is in each strategy, the best methodology would be to compare the same products with each other to have more certain conclusion. Future research that follows this methodology can provide possibly a more realistic solution. This is why the most useful result in this research is the weight determination of the KPIs.

Another limitation of this research is that the purchasing process time KPI is not included in the quantitative analysis, due to lack of hard data. The difference of this KPI for outsourcing methods and VI is something that has to be explored in future research.

The last limitation of this research is the low SQP influence in the quantitative analysis, where this is mentioned in the qualitative analysis as a crucial waste. Because factors like standstill in production and time are not included in this research, factors like the SQP KPI does not have the influence that it should have on the total waste score. Future research, where the costs of e.g. time and standstill in production are included within this KPI should contribute to better results.

The last advice for future research is to determine what the effect is of external factors on the reliability from suppliers outside the EU. If the external influence is high on the reliability, this means that the SNOTD KPI cannot be controlled for this strategy. Also the influence of the CO2 reduction law on waste should be determined in order to choose the best strategy for the future. Manufacturers should not row harder, but think cautiously about their strategy based on the past, and the future.

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Appendices

Appendix A – Interview format

Interview code:	Date:
Interviewer:	
Interviewee:	
Company:	Profession:

Introduction

At first, the interviewer is to explain who he is and why this interview is held.

Background information

Question 1: Can you describe your role and responsibilities within your company?

Question 2: Can you explain how long you have been working in the manufacturing sector and the supply chain management sphere?

Supply chain strategies

Question 3: Can you describe what experiences you have with strategies like vertical integration and different kinds of outsourcing (onshore, nearshore and offshore?

Question 4: Have you experience with switching from different strategies? If yes, what prompted these changes?

Question 5: Which factors do you consider as important, for choosing a strategy like vertical integration or different kinds of outsourcing?

Waste reduction

Question 6: How does your company define "waste" in the chain?

Question 7: Which initiatives did your company has implemented to reduce this waste?

Question 8: Which types of waste (inventory, motion, transportation, over processing, waiting, defects and untapped human potential are the most challenging for your company?

Question 9: What are the main differences in terms of waste reduction between the strategies we talked about earlier?

Supply Chain KPIs and waste reduction

Question 10: How does your company measure inventory turnover, and how has this impacted waste reduction?

Question 11: How does your company measure supplier (not) on time delivery and how has this influenced the waste reduction?

Question 12: How does your company measure the purchasing process time, and how has this impacted waste reduction?

Question 13: How does your company measure the supplier quality performance and how does this impact defects and overall waste?

Question 14: How do changes in your purchasing strategy affected waste reduction?

Question 15: Which steps have you taken to reduce the transportation costs per unit, in order to reduce waste/costs?

External factors

Question 16: How do external factors like environmental, social, governance and operational risks influence your supply chain strategy?

Question 17: How does your company adapt its strategy to these factors?

Future

Question 18: How did your company improve its supply chain by reducing waste?

Question 19: What future plans do you have to reduce waste in your supply chain?

Question 20: What do you think will happen in the supply chain in the coming 5-10 years?

Additional questions

Question 21: Are there any experiences about waste reduction and the named supply chain strategies that you want to share?

Question 22: What are your recommendations for other manufacturers to reduce waste in the chain?

Closing

Thank you for your time!

Appendix B - Informed consent

Informatieblad voor onderzoek

Analyzing the impact of make or buy supply chain strategies on waste reduction in manufacturing organizations

Doel van het onderzoek

Dit onderzoek wordt geleid door [Chiel Vossebeld]

Het doel van dit onderzoek is om de ervaringen van maakbedrijven te verkrijgen over Supply Chain strategieën, waste reductie en de relatie tussen deze twee variabelen.

Hoe gaan we te werk?

U neemt deel aan een onderzoek waarbij we informatie zullen vergaren door:

- U te interviewen en uw antwoorden te noteren/op te nemen via een audio-opname/video-opname. Er zal ook een transcript worden uitgewerkt van het interview.

Uitsluitend ten behoeve van het onderzoek zullen de verzamelde onderzoeksgegevens worden gedeeld met

Potentiële risico's en ongemakken

- Tijdens uw deelname aan deze studie kunnen u vragen worden gesteld die u als (zeer) persoonlijk kunt ervaren, vanwege de gevoelige aard van het onderwerp. Wij stellen deze vragen enkel en alleen in het belang van het onderzoek. U hoeft echter geen vragen te beantwoorden die u niet wilt beantwoorden. Uw deelname is vrijwillig en u kunt uw deelname op elk gewenst moment stoppen.

Vergoeding

U ontvangt voor deelname aan dit onderzoek geen vergoeding.

Vertrouwelijkheid van gegevens

Wij doen er alles aan uw privacy zo goed mogelijk te beschermen. Er wordt op geen enkele wijze vertrouwelijke informatie of persoonsgegevens van of over u naar buiten gebracht, waardoor iemand u zal kunnen herkennen.

Voordat onze onderzoeksgegevens naar buiten gebracht worden, worden uw gegevens zoveel mogelijk geanonimiseerd, tenzij u in ons toestemmingsformulier expliciet toestemming heeft gegeven voor het vermelden van uw naam, bijvoorbeeld bij een quote.

In een publicatie zullen anonieme gegevens of pseudoniemen worden gebruikt. De audio-opnamen, formulieren en andere documenten die in het kader van deze studie worden gemaakt of verzameld, worden opgeslagen op een beveiligde (versleutelde) gegevensdrager van de onderzoeker

De onderzoeksgegevens worden bewaard voor een periode van [10 jaar]. Uiterlijk na het verstrijken van deze termijn zullen de gegevens worden verwijderd of worden geanonimiseerd zodat ze niet meer te herleiden zijn tot een persoon.

De onderzoeksgegevens worden indien nodig (bijvoorbeeld voor een controle op wetenschappelijke integriteit) en alleen in anonieme vorm ter beschikking gesteld aan personen buiten de onderzoeksgroep.

Vrijwilligheid

Deelname aan dit onderzoek is geheel vrijwillig. U kunt als deelnemer uw medewerking aan het onderzoek te allen tijde stoppen, of weigeren dat uw gegevens voor het onderzoek mogen worden gebruikt, zonder opgaaf van redenen. Het stopzetten van deelname heeft geen nadelige gevolgen voor u of de eventueel reeds ontvangen vergoeding.
Als u tijdens het onderzoek besluit om uw medewerking te staken, zullen de gegevens die u reeds hebt verstrekt tot het moment van intrekking van de toestemming in het onderzoek gebruikt worden.
Wilt u stoppen met het onderzoek, of heeft u vragen en/of klachten? Neem dan contact op met de onderzoeksleider:

Chiel Vossebeld
c.vossbeld@student.utwente.nl

Tot slot heeft u het recht een verzoek tot inzage, wijziging, verwijdering of aanpassing van uw gegevens te doen bij de onderzoeksleider.

Door dit toestemmingsformulier te ondertekenen erken ik het volgende:

1. Ik ben voldoende geïnformeerd over het onderzoek door middel van een separaat informatieblad. Ik heb het informatieblad gelezen en heb daarna de mogelijkheid gehad vragen te kunnen stellen. Deze vragen zijn voldoende beantwoord.
2. Ik neem vrijwillig deel aan dit onderzoek. Er is geen expliciete of impliciete dwang voor mij om aan dit onderzoek deel te nemen. Het is mij duidelijk dat ik deelname aan het onder- zoek op elk moment, zonder opgaaf van reden, kan beëindigen. Ik hoef een vraag niet te beantwoorden als ik dat niet wil.

Naast het bovenstaande is het hieronder mogelijk voor verschillende onderdelen van
het onderzoek specifiek toestemming te geven. U kunt er per onderdeel voor kiezen wel of geen toestemming te geven. Indien u voor alles toestemming wil geven, is dat mogelijk via de aanvinkbox onderaan de stellingen.

3. Ik geef toestemming om de gegevens die gedurende het onderzoek bij mij worden verzameld te verwerken zoals is opgenomen in het bijgevoegde informatieblad. Deze toestemming ziet dus ook op het verwerken van gegevens betreffende mijn gezondheid/ras/etnische afkomst/politieke opvattingen/religieuze en of levensbeschouwelijke overtuigingen/lidmaatschap van vakbond/seksueel gedrag/seksuele gerichtheid en/of over mijn genetische gegevens/biometrische gegevens.	JA □	NEE □
4. Ik geef toestemming om tijdens het interview opnames (geluid / beeld) te maken en mijn antwoorden uit te werken in een transcript.	□	□
5. Ik geef toestemming om mijn antwoorden te gebruiken voor quotes in de onderzoekspublicaties.	□	□
6. Ik geef toestemming om mijn echte naam te vermelden bij de hierboven bedoelde quotes.	□	□
7. Ik geef toestemming om de bij mij verzamelde onderzoeksdata te bewaren en te gebruiken voor toekomstig onderzoek en voor onderwijsdoeleinden.	□	□
Ik geef toestemming voor alles dat hierboven beschreven staat.	□	

Naam Deelnemer: Naam Onderzoeker:

Handtekening: Handtekening:

Datum: Datum:

Appendix C – Dataset

Not included in this paper due to confidentiality reasons.