Improving the Service Level by Implementing a Nearshoring Sourcing Strategy

Bachelor Thesis

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Colophon

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Management Summary

The research was concerned with improving the service level of the spare-parts department of the company by implementing a nearshoring sourcing strategy. Nearshoring is the practice of relocating production to nearby countries, especially in preference to more distant ones (Oxford Languages, 2022).

Three main issues were discovered that led to the low service level in the first place. The first is insufficient documentation of the parts, which stems from the lack of a proper naming convention. This also leads to the difficulty of multiple IDs existing for similar or equal parts, which causes an increase in the complexity of the supply chain. Secondly, the current ordering program causes delays in the shipment, as it does not enable the responsible employees to correctly identify the locality of the supplier, leading to suppliers being mistakenly identified as being based in China or surrounding countries, which in turn leads to the supplier sending the requested order to the HQ in China, even if the supplier is located closer to the Netherlands. The order is then repackaged in the HQ and sent to the warehouse in the Netherlands, which is a cost-expensive, non-sustainable, and time intensive process. Finally, the last issue discovered is the mainly Chinese supplier base. About 95% of the suppliers are based in China, leading to long lead times of about six months on average. The research was primarily concerned with solving the latter issue.

To shift the supplier base to a more local one, thus reducing the lead times and increasing the service level, it was first investigated what factors need to be fulfilled for a nearshoring strategy to be advantageous by conducting a systematic literature review. Through creating an exhaustive list and comparing it to the data the company has available, the factors Confidentiality, Complexity, Value, Volume, and Weight have been chosen. A part must not entail sharing confidential data with the new supplier; its production process needs to be simple; its value should be low, and its volume and weight should be high in comparison to fully benefit from the advantages that a nearshoring sourcing strategy has to offer in comparison to offshoring.

Next, suitable supplier selection criteria were identified through a literature review. The criteria Quality, Price, Financial Position, and Service were chosen. Additionally, at the company's request, Sustainability has been added to the list. All criteria have been made measurable by adding attributes to each, as seen in Table 1.

Following this, a literature review provided insight into the possibilities of Multi-Criteria Decision Analysis, which is concerned with helping in the decision-making process when more than one variable is involved. It was determined that the Analytical Hierarchy Process (AHP) should be used to determine the weights of the supplier selection criteria and their respective attributes due to its compensatory properties, meaning that poor scores can be compensated with better ones, and ability to quantify qualitative statements and intuitions successfully, the latter of which has been identified as an essential factor in the supplier evaluation. The weights of the criteria and attributes can be seen in Table 1.

Next, AHP was applied again twice to determine the scores for the glass and body parts supplier. Supplier D has been determined to be the most suitable supplier for the glass parts and Supplier E for the body parts. The results followed the intuition of the decision-maker, i.e., the determined ranking reflected his preferences. A sensitivity analysis of the results was performed to check how sensitive the results to changes are, e.g., to changes in the subjective perception of the decision-maker, and to increase confidence in the model. The outcome showed that no sensitive criteria or attributes can be found, meaning that major shifts in the preferences would be necessary to change the outcome of the model.

Finally, the implementation plan showed the necessary steps the company needs to take next. The implementation of a categorisation is crucial to evaluate supply chain metrics properly. It is recommended for this to follow the naming convention of other OEMs (Original Equipment Manufacturers) like Volkswagen. The ordering program needs to be updated with a supplier ID and

information on the location of the supplier to avoid future mix-ups of the locality of the supplier. The parts should be ranked with the help of an impact factor, measuring how big of an impact a change in the sourcing strategy of a part can make, and a feasibility factor, measuring how feasible parts are for nearshoring (See also Chapter 6 for a more detailed explanation on the calculation of it). The supplier for the parts should then be changed, starting with the highest ranked ones. The supplier evaluation should be done by the person responsible for the shift of the respective part, which would be either the Team Leader of the Procurement Department or the Purchaser, using the AHP model, and a re-evaluation should be conducted after one or two years. The various tasks needed to perform the shift are outlined in more detail in Section 6.5.

Criteria	Criteria Weight	Attributes	Attribute Weight
Quality	29%	Percentage Rejections	10%
		Product Performance	90%
Price	14%	Quantity Discount	28.6%
		Cost	57.1%
		Transport Cost	14.3%
Financial Position	2.6%	Credit Rating Policy	100%
Service	46.4%	Delivery Speed	18.9%
		Dependence	4.1%
		Flexibility Delivery Schedule	15.5%
		Flexibility Production Volume	22.2%
		Ability for Modifications	9.8%
		After-Sales Service	9.9%
		Availability Spare Parts	19.6%
Sustainability	8%	Environmental Competencies	38.6%
		Green R&D	11.3%
		Green Manufacturing	27.4%
		Green Packing and Labelling	22.7%

Table 1: Supplier Selection Criteria and Attributes and their corresponding Weights

Acknowledgements

Dear Reader,

Before you lies the report I wrote for my bachelor assignment of the study Industrial Engineering and Management at the University of Twente, with the whole research taking place from March till July 2022.

I decided to conduct an assignment situated in the field of procurement after my experience with the fourth module of the first study year, which was concerned with Supply Chain Management. There, the excellent organization by Dr Engin Topan and the inspiring teaching methods of Dr Frederik Vos sparked my interest in SCM in general and in procurement more specifically. For the latter, especially the multidisciplinary environment and the impact on a company's performance were notably intriguing.

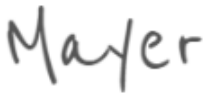
Thus, I was extremely grateful that after reaching out, my external supervisor, Mr op de Laak, offered me the possibility to conduct research in the field I am so interested in. Throughout the whole period, I learned a wide range of new things. I was enabled to translate the theoretical knowledge I gained in university into practice, and I honestly could not have wished for a better external supervisor for the project.

Furthermore, I would like to express my gratitude to my first university supervisor, Dr.Ir. L.L.M. van der Wegen. Whenever I submitted a draft, I could be sure that every sentence, every word will be read carefully and valuable feedback will be provided. This also extends to my second supervisor, Dr Engin Topan, who continuously made me question my work, in a good way. Both helped me progress my assignment further and make the best out of it.

Lastly, I would like to thank my family for supporting me in my actions, even if it meant moving abroad.

This thesis marks the end of my three-year journey as a student at the University of Twente. Now I am looking forward to the challenges that lie ahead.

Enschede, 12.07.2022



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Chapter 1 Introduction

In this chapter, the background of the research will be covered. Section 1.1 briefly introduces the company, followed by a description of the context in Section 1.2. Section 1.3 covers the problem identification of this assignment, which then leads to Section 1.4, the research objectives and goals. Section 1.5 discusses the research questions and, while doing so, also describes the plan of approach and research design. Next, the intended deliverables are presented in Section 1.6. Finally, Section 1.7 provides a reading guide.

1.1 Company Description

The company for which this assignment is conducted for, is, next to other things, a major manufacturer of electric vehicles of all kinds.

1.2 Context Description

The electric and commercial vehicles aftersales department of the company, which is concerned with providing their existing customers with support in the form of technical assistance and spare parts, and for which this research will be conducted, is currently worried about their achieved service level, which is only at around 75%, in contrast to the targeted 95%. The service level is defined as the percentage of orders that can be fulfilled from their warehouse without delay and has been measured over nine months, as the new ERP system was implemented nine months prior. The company has decided to make its sourcing strategy more local and improve subsequent processes to tackle this problem. Currently, around 95% of the suppliers are based in China, which results in a lead time of, on average, six months, made up of a three-month production time and a three-month shipping time.
Additionally, the company faces issues with the internal ordering process, which leads to parts from local suppliers being shipped to the headquarters in China instead of the warehouse in the Netherlands where it is supposed to be. The respective parts will then be sent back from China to the warehouse. This leads to high unnecessary costs through increased shipping fees, possible stock-outs, and lower customer satisfaction.

1.3 Problem Identification

To better understand the issue at hand, the following part analyses the underlying problems and their causes to determine the core problem. The main objective of this research is finding a solution to this core problem.

1.3.1 Problem Context

First, we start with the problem context, where every main issue will be elaborated upon to strengthen understanding of the underlying problem. All of the information has been gathered through interviews with the relevant stakeholders in the company.

1) Improvable Documentation

In general, it can be said that the improvable documentation stems from a lack of logic in the working process of the R&D department, which is responsible for it. To illustrate the issue, we give the following example: Customers are offered a wide range of choices and customisation when ordering an electric vehicle. This includes, for example, the possibility of custom parts that are more according to the customer's requirements, such as windows with different dimensions or shades than the normal ones. Currently, every new incoming order is treated as a new project. The products that have been ordered are being documented. Still, no attention is being paid to whether the specific product has already been manufactured in the past with the same specifications. To stay with the example of the window: A customer in the past may have once ordered black tainted windows with standard measurements. This ordered window then gets assigned an individual ID by the enterprise software. However, if another customer would order the same kind of window, it would not be linked to the prior one but instead

receive its own ID. Because of this, multiple IDs exist in the company's files, which are essentially the same stock-keeping units. This leads, among other things, to a massive complication in supply chain planning, added stock value, and increased complexity in warehouse management, as the increased number of IDs subsequently increases the underlying variability of the demand compared to a single one.

2) Inefficient Ordering Process

The current way the ordering process works is that an employee of the company decides that a replacement for a specific part needs to be ordered and then forwards the request to the assigned responsible person, depending on whether the supplier for this particular part is based locally (in the European Union) or in Asia, most likely China.
However, to judge the locality of the supplier, the employee needs information that is in some cases either insufficient, unavailable, or inconclusive. For example, data might be missing entirely or be written in a foreign language. The whole process is depicted in Figure 1.1.

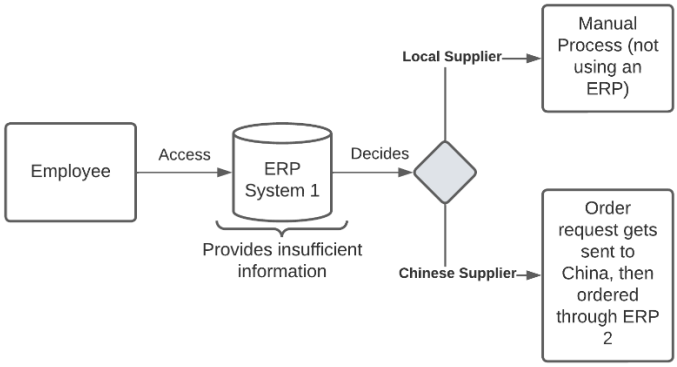

Figure 1.1: Current Ordering Process

In the worst case, this can lead to the in the context description mentioned issue that a local supplier is mistakenly identified as a Chinese one, which leads to the parts being sent to the Chinese HQ and possible stockouts due to the unexpected long lead time.

Furthermore, this process involves the usage of two ERP systems. One is being used at the branch in Europe, and another is in the HQ in China. This makes integration and communication more difficult as a result.

3) Mainly Chinese Suppliers

At the moment, about 95% of the company's suppliers are based in China. The high resulting lead time of about six months leads to low flexibility, increased storage cost, and a lower service level that can be provided to the customers. As the customer incurs a cost for every day their vehicles are not running, missing spare parts results in low customer satisfaction.

1.3.2 Core Problem

The problems are mapped into a problem cluster, see Figure 1.2 for this, which allows for easier identification of the core problem. It shows that the low service level stems from the issues mentioned above.
According to Herkeens, the core problems must have no cause themselves, be influenceable, and the most important one should be solved, which has the most significant impact (Heerkens, 2017). Thus, the core problem that will be worked on is the mainly Chinese supplier base of the company, with their inherent high lead times and, therefore, their impact on the service level.

The improvable documentation, which has the multiple IDs and the insufficient naming convention as its cause, is partly out of reach of this research as it is a management issue that requires pressure from higher up and is thus not influenceable for the researcher. An advice will be given for this. Given that the inefficient ordering process, which involves the ordering program, and the issue with the multiple ERP systems are relatively easily solvable, these issues will be covered, but not focused on in this research.

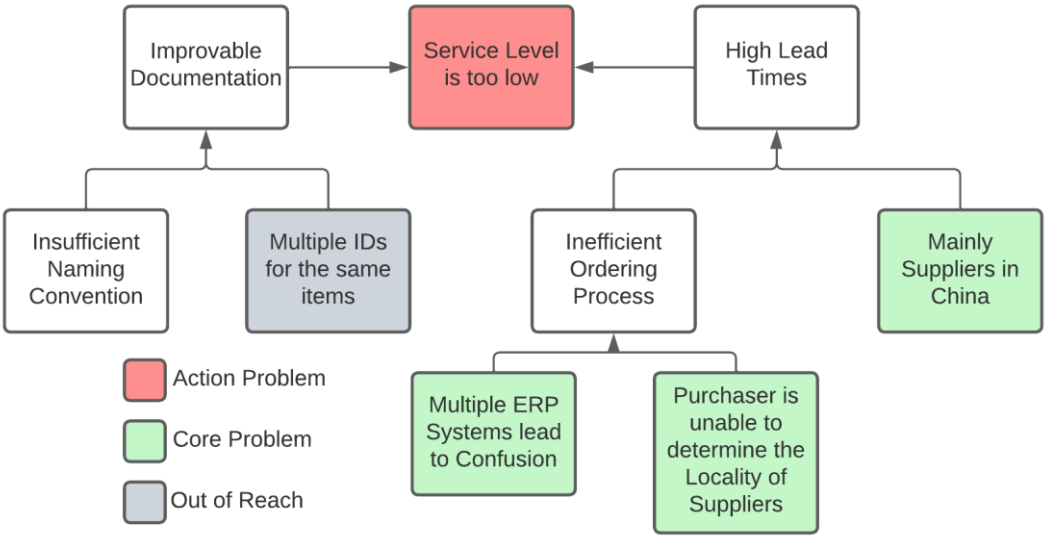

Figure 1.2: Problem Cluster

1.4 Research Objectives and Goals

The objectives and goals of the research are elaborated upon in this part. The problem identification phase revealed that the company's service level needs to be increased and that the issue of it being too low mainly stems from their long lead times, which in turn are caused by their Chinese supplier base, which has been identified as the core problem. Thus, this research investigates how the company can manage the shift to a nearshoring sourcing strategy and how they should approach this. The intended deliverable is a framework that guides the approach to achieve this. As described in part before, the overall optimisation of the ordering process only plays a side role. This is done to keep the scope of the research clear while still making use of the ease of fixing the problems and their relevance to the overarching low service level

The final deliverable will be twofold:

It provides a framework for the company and other readers with points to consider when thinking about implementing a nearshoring strategy. The main topics will be a selection of supplier selection criteria and how AHP can be used in the decision-making process.

In the other way, it applies the established framework to a specific example to demonstrate its usefulness.

To achieve the above-mentioned research objectives, the main research question is formulated as follows:

> *How can a Nearshoring Sourcing Strategy improve the Service Level of the After-Sales Department?*

1.5 Research Questions

Four further sub-questions must be covered first to answer the main research question. They will be listed and elaborated upon, and a plan of approach to answering them will be presented. Their order represents the order of the process that will be conducted. Additionally, the research design is described wherever necessary. The general structure is separated into two parts: The first part, which includes research questions one and two, is the general part of the framework that forms the basis of the approach and can be reused by the company without conducting the steps again. The second part, which includes questions three and four, applies the previously gained knowledge to a practical example and provides further recommendations using the findings of the research.

1. *What factors determine whether a nearshoring sourcing strategy is advantageous?*
   Even though a nearshoring sourcing strategy is, in theory, without limitations, there are practical limitations to be found. One can think here about confidentiality, such as the need to share sensitive data about products or production processes, or a lack of suppliers. Thus, it is necessary to establish factors to consider when determining whether nearshoring a certain part or product is beneficial.
   To answer this question, a qualitative descriptive approach will be followed by conducting a systematic literature review as a means of data gathering. At first, various papers will be compared to establish a list of factors that need to be considered according to the different authors. Points of attention here are the main characteristics a part or product should possess to be eligible. These will then be summarised with a detailed explanation, as this information will be used as input in the following sub-questions. Based on this, the data processing is done by reviewing and summarising the different papers.
   Brown identified five criteria for evaluating the validity of systematic literature reviews: Purpose, Scope, Authority, Audience, and Format (Brown, 2006). This framework will guarantee validity wherever literature reviews will be applied.

2. *What are the supplier selection criteria that should be considered?*
   This question aims to establish supplier selection criteria to provide a ground for the next question and for the company to use in future applications of this framework. A literature study will be conducted to determine these selection criteria. As the research design is, in its essence, the same as in the first question, it will be thus not repeated anymore. This research question will be further divided into two parts:

   2.1 What supplier selection criteria does the scientific literature consider to be valuable to use?
   Here, the information will be gathered as described above.

   2.2 What supplier selection criteria should the company use?
   This question serves to decide on suitable criteria based on the previous question. A responsible stakeholder will make the decision on behalf of the company.

The following research questions mark the beginning of the second part of the framework. The basis established through the last research questions will now be applied to a chosen product category.

3. *How can Multi-Criteria Decision Analysis be applied to make a well-grounded decision in selecting a supplier?*
   Multi-criteria decision analysis (MCDA) aims at supporting the decision-making process. However, many methods exist that each have different areas of application. By introducing and investigating the field of MCDA, this research question aims to determine the correct method to use and then apply it to establish the supplier selection criteria and suppliers for two parts or categories. Thus, it will be further divided into the three sub-questions seen below.

   3.1 What MCDA-method should be chosen to determine the decision maker's preferences at the company?
   3.2 What is the preference of the decision maker at the company towards the supplier selection criteria and attributes using the chosen method?
   3.3 What is the preference of the decision maker at the company towards the supplier based on the supplier-selection criteria and attributes, using the chosen method?

4. *How can the changes efficiently be implemented and what further steps need to be taken?*
   At this point, conducting all the previous steps delivered us the final result, namely a set of supplier selection criteria and suppliers for specific parts or categories. However, the company will need to repeat the process for the rest to fully shift to a nearshoring sourcing strategy. This research question shall thus investigate what the best plan of approach for this will be, using the previously gained knowledge and experience from the process, and make a recommendation.

1.6 Deliverables

This project's deliverables consist of a solution to the in the problem context mentioned issues. The following will be provided:

- A framework for the company to use to shift to nearshoring, which includes:
  - An overview of the advantages and applicability of nearshoring as a sourcing strategy
  - Factors to consider when choosing parts for a nearshoring strategy
  - Supplier selection criteria to consider
  - A description and application of how the chosen MCDA-Method can be applied to determine weights for the criteria and to select a supplier
  - The weights of the chosen criteria and attributes
  - A final recommendation on choosing a supplier for a specific part/category
  - An implementation plan describing the following steps that need to be taken
- A project report describing the process and findings
- An improved ordering process, in the form of a business process model, and an improvement to the current ordering program.

1.7 Reading Guide

For a better overview over the chapters, a reading guide will be now provided.

Research Question / Topic	Treated in
Research Methodology and Background	Chapter 1
Theoretical Framework	Chapter 2
RQ 1: What factors determine whether a nearshoring sourcing strategy is advantageous?	Chapter 3
RQ 2: What are the supplier selection criteria that should be considered? (Including sub-questions)	Chapter 4
RQ 3: How can Multi-Criteria Decision Analysis be applied to make a well-grounded decision in selecting a supplier? (Including sub-question)	Chapter 5
RQ 4: How can the changes efficiently be implemented and what further steps need to be taken?	Chapter 6
Conclusion and Discussion	Chapter 7

Chapter 2 Theoretical Framework and Literature Review

This chapter aims to present and explain existing theories on purchasing by selecting, evaluating, and comparing the most relevant ones. Section 2.1 provides an overview of the terminology and discusses it. Section 2.2 is concerned with the general structure of the purchasing system. Next, Section 2.3 discusses the localisation terminology, such as domestic or global, relevant for this assignment and further elaborates on nearshoring. Finally, Section 2.4 introduces a possible framework for selecting suppliers while considering multiple criteria.

2.1 Purchasing, Procurement, and Sourcing

To start, it is essential to distinguish between purchasing, procurement, and sourcing, as these terms are often used interchangeably. Throughout the literature and experts, no generally accepted opinion exists, with people using different definitions for these terms. (Chopra, Sustainability and the Supply Chain, 2019) defines purchasing and procurement as "[…] the process by which companies acquire raw materials, components, products, services, or other resources from suppliers to execute their operations.", which makes purchasing and procurement a subset of sourcing, which he defined as "[…] the entire set of business processes required to purchase goods and services.".

(De Boer & Telgen, 2010) gave a similar, although simpler and broader definition of purchasing, which is merely everything followed by an invoice, meaning that purchasing covers all the steps, from defining what needs to be ordered to selecting a supplier, up to the aftercare.

In contrast to that, many other sources, such as (Roy R. , 2022), made the following distinction: Procurement is the entire set of business processes, purchasing is restricted to only making and receiving payments, and sourcing is finding a source from where the parts/products can be procured. Thus, purchasing and sourcing are subsets of procurement. The Institute of Supply Management defined sourcing as a strategic component concerned with identifying sources for products or services. At the same time, procurement is seen as the umbrella term for the whole cycle. On the other hand, purchasing is, as the name indicates, more related to the acquisition of the items (Cavinato, 2022).

As it becomes clear now, there is a disagreement between the concrete functions behind the different terms. For example, Chopra sees sourcing as the umbrella term for all buying related activities in a company, whereas for Telgen *et al.*, it is purchasing, and procurement elsewhere. To keep things unambiguous, it has been decided together with the company for which the assignment is conducted for, to use procurement as the umbrella term for all business functions related to buying, sourcing as the term for the first few steps of the procurement process that are related to identifying what should be bought and by whom, and purchasing as the term for the business functions involved in the latter steps, such as controlling and monitoring.

2.2 The Purchasing Process

(De Boer & Telgen, 2010) divide the purchasing process into primary (BOM, Bill of Material) and indirect (MRO/NRP, Maintenance, Repair and Operations / Non-Product-Related). The former is concerned with directly relevant products and parts for the production process, such as raw materials or machines, whereas the latter acts as more of a supporting function, such as for office supplies. The exact distinction here, however, relies on the industry. For an electric vehicle manufacturer, office supplies are mostly merely an indirect purchase, while an office supply shop would consider it a direct purchase. This relativity is essential to consider, as spare parts, with which this assignment is mainly concerned, could be seen as indirect purchases. However, being the main function of the respective business unit, it is a direct one.

Telgen *et al*. structure the purchasing process into six steps, ranging from tactical purchasing functions to operational ones (see Figure 2).

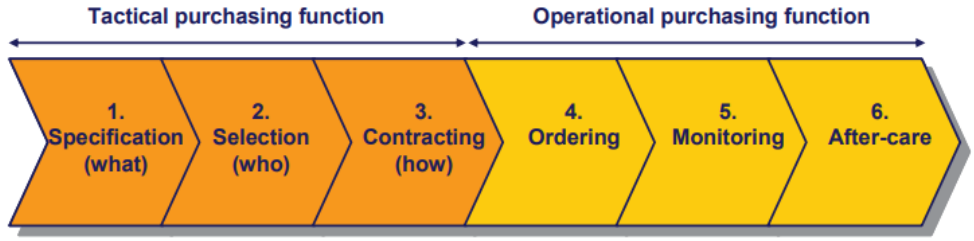

Figure 2: Basic Purchasing Process as shown by (Telgen, 2017)

The six steps by (Telgen, 2017) will now be covered in more depth, although most attention will be paid to the first two, as they are the most relevant for the assignment:

1. **Specifying**
   The first step covers the question of "what" should be bought and thus provides a basis for the following steps. Here, all requirements that a product and a supplier must fulfil are listed, making careful preparation mandatory, as carelessness would negatively affect subsequent steps. The authors further divide here into functional and technical specifications, where functional specifications describe, as the name indicates, the intended use or function of a product, and technical specifications outline concrete characteristics of it. For example, a functional specification for a computer screen might be that a product is being looked for that allows displaying information. On the other hand, a technical one would provide precise specifications such as size, resolution, or components that need to be included. After the specifications are clear, the next step involves deciding on supplier selection criteria to evaluate the possible suppliers. This step will be covered in more depth in Chapter 4.
2. **Selecting**
   The second step is concerned with the question of "who" should be chosen as the supplier, which entails inviting suppliers to make an offer and then evaluating the participating ones based on the selection criteria selected in the previous step. A distinction can be made here between public procurement, meaning the purchasing of governmental institutions, and private ones by companies. The former often requires public announcement and a transparent selection procedure, while the latter is frequently done through branch-specific media. This way, either new suppliers can be found, or already existing ones can be invited to participate in the selection by composing a proposal based on the program of requirements.
3. **Contracting**
   In the contracting phase, one or multiple suppliers have already been selected, and the question arises "how" the contract conditions should look like. These conditions get negotiated, and specifications such as the price, mode of transport, aftersales services, etc., should have been made clear.
4. **Ordering**
   "Ordering is the actual requesting of a delivery" and can be done either one-off or in repeated batches, which is more often the case.
5. **Monitoring**
   Monitoring involves supervising and controlling the process after the order has been placed, which entails processing invoices and payments, following up on deliveries etc. The overall goal is to check whether the achieved services and performances match the contractually agreed upon.
6. **After-Care**
   Finally, servicing is a possible phase entered if, during step four or five, problems arise, such as a late delivery, that need to be solved in collaboration with the supplier.

Contrary to many popular beliefs, the most gain to be made in the process is not in the negotiation phase but in the specification one. This is because clearly defining what is needed can have more impact on the final price than negotiating it. For example, when looking for a pen, deciding that a simple plastic ballpoint one is sufficient is more cost advantageous than trying to negotiate a 5% discount for a Montblanc pen. The impact of the different phases on the total cost can be seen exemplary in Figure 2.1. In this specific example, the difference between the cost for a cheap plastic ballpoint in comparison to a more expensive pen would be 500%, whereas the choice of a supplier would only have a 50% impact on the total cost.

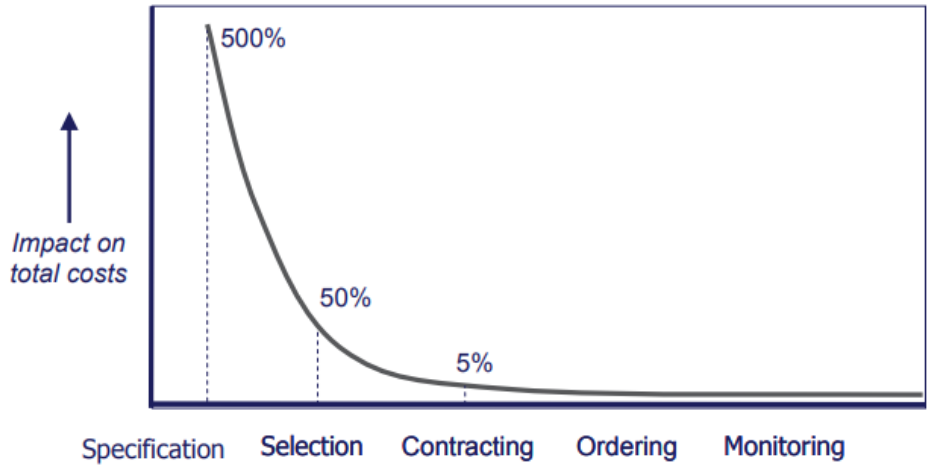

Figure 2.1: Impact of the Purchasing Steps on the Total Cost as shown by (De Boer & Telgen, 2010)

This highlights the importance of this assignment, which is mainly concerned with the first two steps of this framework and its possible impact on the total cost.

2.3 Relocation and Nearshoring

This subsection covers the terminology of the locality and provides more information on nearshoring.

In procurement, a distinction can be made between various strategies that depend upon the distance to the company's home country. Global sourcing (or overseas outsourcing) has been defined as sourcing across geopolitical boundaries, and the same holds for international sourcing (Moncyka & Handfield, 2005). On the other hand, domestic sourcing describes the practice of buying goods and services within the home country's borders (Jin B. , 2010). Again, the same definition also applies to local sourcing. However, local and regional sourcing can also be seen as sourcing within closer proximity than domestic sourcing, e.g., sourcing from the town or region the company is situated in, which entails that local sourcing and regional sourcing are subsets of domestic sourcing. An overview can be seen in Figure 2.2. As the aspired sourcing method for this assignment entails a shift from Asian (Chinese) suppliers to European ones, it becomes apparent that none of these terms presents a perfect fit for the issue at hand. The aspired strategy is neither fully global nor entirely local.

This introduced the need for different terminology. Nearshoring is defined as "relocating some previously offshored manufacturing activities so that they are now close to previous core locations, but not so close as to suffer from disagglomeration effects" (Piatanesi & Arauzo-Carod, 2019). It is similar to onshoring, which is, however, focused on reintroducing business functions and processes that previously have been abroad back to the home country. This makes it apparent that nearshoring is the adequate term for the operation conducted in this assignment. Additionally, the vehicle industry has also been identified as a promising one for nearshoring (McKinsey Global Institute, 2012).

Figure 2.2: Outsourcing-Insourcing Shift as covered by (Hartman & Ogden, 2017)

As also illustrated in Figure 2.2 and stated by (Hartman & Ogden, 2017), a shift toward more local sourcing strategies is becoming apparent. Global sourcing has been seen as the pinnacle of procurement for a long time. However, recent findings have changed the narrative after identifying various issues such as the higher likelihood of supply chain disruptions (Kang & Cho, 2001) or that the expected benefits have been too optimistic (Gylling, Heikkila, Jussila, & Saarinen, 2015). Compared to the anticipated ones, this shortfall of results resulted in a correction, which led to companies moving back their production facilities or supplier locations closer to them (Kinkel, 2014). Nearshoring is a relatively recent trend, popularised through combining the advantages from both worlds, global and local sourcing. It is appliable when the gained benefits from having production facilities or suppliers closer to the company outweigh the usual advantages of offshoring, but not to an extent where a more radical, for example, local, sourcing strategy would be beneficial. Its benefits are the same as for a more local strategy, such as the lower risk of supply chain disruptions or greater control, but not to the same extent. Vice versa, its disadvantages compared to a global sourcing strategy are also comparable to the local sourcing strategy, such as higher production cost, but not to the same degree. Or, to put it in easier words: It is moving "[…] to countries that are quite cheap and very close rather than very cheap and far away" (Economist, 2005). It is thus characterised as an intermediate strategy (Piatanesi & Arauzo-Carod, 2019).

On a more practical side, (Slepniov, Brazinskas, & Waehrens, 2012) conducted a series of case studies to identify patterns and approaches of manufacturers in the nearshoring process. They concluded that, even though there are no "one-size fits all" way, the similarity could be found that it is not an investment-free process, and significant resources were required for vendor development. (Van Hassel & Vanelslander, 2021) identified various factors that play into the decision, such as the value or weight of a product. For example, the higher the product's weight, the greater the benefits from a more local procurement strategy. Furthermore, he concluded that transport costs do not have the most significant share in the total cost of ownership but can play a decisive role in influencing lead time and stock costs. The supporting factors will be covered in more depth in Chapter 3.

2.4 Supplier Selection Framework

The core of the problem are the long lead times caused by the global sourcing strategy with its suppliers in Asia. A shift to a nearshoring sourcing strategy shall be conducted to fix this, which also necessarily induces switching the suppliers. Selecting a supplier involves the consideration of many criteria, which makes it necessary to use a fitting framework for the supplier selection with multiple criteria.

(Telgen, 2017) has identified five essential steps to follow to decide on the objectively best supplier.

1. **Which criteria are to be used?**
   This step is concerned with identifying suitable supplier selection criteria for the procurement process. These can be quantitative, like price or liquidity, or qualitative, such as communication barriers or reputation. In choosing them, the goal is to reflect the overall goal of the procurement process properly.
2. **How to combine the criteria?**
   The second step covers what consequences poor scores should have. The options here range from wholly compensatory, such as in the case of AHP, to non-compensatory methods such as PROMETHEE and ELECTRE. It is possible to allow for just some degree of compensation, as done in NAIADE
3. **The relative importance of the criteria**
   The third step assigns a weighting to the available criteria. Various methods exist for this, ranging from simple ones such as simply giving each criterion an equal weight to more sophisticated ones.
4. **How to score the criteria?**
   After establishing the criteria and their weights, it is necessary to award points to the different suppliers on the criteria to conclude. This can be done in several ways. The most common ones are assigning points on a relative or absolute scale. However, other forms, such as using Multi-Decision Criteria Analysis methods, are also available.
5. **Who wins?**
   Independent of the choice of the scoring method, the end result will be some kind of ranking of the suppliers. Logically, the highest-ranking supplier will be chosen, but it is also possible to award multiple suppliers.

Chapter 3 Nearshoring Sourcing Strategy

This systematic literature review aims to identify the factors that the scientific literature deems essential to consider when implementing a nearshoring sourcing strategy. In doing so, we aim to find an answer to our first research question: "*What factors determine whether a nearshoring sourcing strategy is advantageous?*". In Section 3.1 the necessary literature review is conducted, which is then summarized in Section 3.2. Next, Section 3.3 brings up additional points that should be considered for this assignment in addition to the previously determined ones. Finally, Section 3.4 provides a conclusion.

3.1 Literature Review

The rise of the 21st century has also seen an increase in the procurement function of the business. More and more companies realised the competitive advantages of an efficient procurement process and its impact on profit. The total spend volume of the procurement department of the total turnover can range up to 98% in industries such as trade and averages at about 60%-70%. Using this, it is possible to show that a 5% reduction in purchasing costs can lead to the same increase in profit as a 30% increase in turnover (De Boer & Telgen, 2010). Over time, global procurement has been seen as the pinnacle of procurement, stemming from various benefits such as the reduced cost price. However, in recent times more and more doubt came up about this statement, for example, through the findings of (Kang & Cho, 2001) that identified various issues involved with a global procurement strategy, such as logistical problems, language and culture barriers and decreased responsiveness. This highlights the importance of the purchasing department and the necessity to devise a proper strategy for it forms the ground for this research, which aims to investigate what factors need to be kept in mind when thinking about implementing a (more) local sourcing strategy.

(Chopra, Supply Chain Management, Strategy, Planning, and Operation, 2019) describes the concept of volume-based tailored sourcing, which can be advantageous for companies that source mainly from overseas. The advantage of such a strategy heavily based on overseas production is that the company can profit from the lower cost of producing there. However, the lead times are usually higher because of the long distance, which increases the overall cost. It also increases the risk of running out of stock, which requires a higher safety inventory to mitigate that effect. He proposes a combination of both an inexpensive overseas source and a local supplier. Through this, the advantages of both worlds can be combined, where the local source can be used to keep safety inventory low. This combination is most effective if the overseas supplier is used for general, expected replenishment, and the local supplier is a quick and reliable source in the case of unexpected demand.
Furthermore, according to Chopra, it can also be advantageous to use closer situated suppliers in the case of low-volume products with highly uncertain demand, in contrast to products with high demand and high certainty. Supporting factors for such a strategy are then listed by him which are shown here (Chopra, Supply Chain Management, Strategy, Planning, and Operation, 2019):

1) High Demand Volatility
2) Low Value, High Volume, High Weight-to-Value Ratio
3) High Rate of Product Obsolescence
4) Engineering/Design Support
5) High Rate of Innovation/Product Variety
6) High Impact of Supply Chain Disruption
7) High Inventory Cost
8) High Desired Quality

In her article "Achieving an optimal global versus domestic sourcing balance under demand uncertainty", the author Jin Byoungho describes the decision between sourcing globally and domestically as a trade-off between agility and cost. This can be mitigated by implementing a strategy that uses both simultaneously. It is important to note here that even though the article covers domestic sourcing, which is sourcing from its own country, the author states explicitly that "the concept of domestic sourcing also applies to regional sourcing". Even though nearshoring is not completely a domestic sourcing strategy, the added benefits and disadvantages are shared, just to a lesser extent for both sides. Four factors which determine the applicability of this sourcing strategy have been identified by her (Jin B. , 2004):

- **Demand:** *The greater the demand uncertainty, the higher the portion of domestic sourcing required in a mixture of global and domestic sourcing strategies*
- **Information and Manufacturing Technology:** *The greater the contribution of information and manufacturing technologies to the manufacturing phase, the higher the portion of domestic sourcing that may be used*
- **Local Subcontractor Clusters:** *The higher the local subcontractor clusters a firm has, the higher the portion of domestic sourcing in its balance of global and domestic sourcing strategies*
- **Long-term relationship with a subcontractor:** *The higher the long-term relationships with subcontractors a firm has, the higher the portion of domestic sourcing in its balance of global and domestic sourcing strategies*

It is important to note that these are not hard conditions but that one should instead take a holistic view. For example, smaller volumes may still be best sourced from a close supplier despite having a relatively certain demand.

Ivanov, Tsipoulanidis and Schönberger cover the advantages of local sourcing over global sourcing and vice versa in their book "Global Supply Chain and Operations Management". According to them, the purchasing benefits of global sourcing that stem from the low-cost price of the bought items can easily be eliminated through the need for larger lot sizes or high lead times, which, as discussed earlier, also affect safety inventories and total cost of ownership. In addition to the already known factors, they also identify further points to consider, such as the added benefits through shared norms and standards between the buying company and the supplier, the same currency, just-in-time deliveries, and overall lower risk for disruption. This comes with the price of a smaller selection to choose from and, thus, possibly, lower bargaining power. Furthermore, to make a decision, they acknowledge the need for proper categorisation of the needed goods: "[…] per commodity and part, a reasonable strategy has to be determined by evaluating the corresponding opportunities and risks" (Ivanov, Tsipoulanidis, & Schönberger, 2019).

(Porter, 1990) identifies the implied benefits of a more local procurement strategy in the innovation and upgrading phase. This has several possible reasons as an explanation. However, according to Porter, the most important one is the working relationship between the suppliers and the companies, which is very close in this environment. This close relationship, in turn, can give companies competitive advantages through means of novel ideas, faster access to information and various other insights that would not be available otherwise. Furthermore, the technical efforts of the suppliers can now be influenced by the company, which has been made possible by the close (in terms of proximity) work relationship between the supplier and the company. In this way, both parties can benefit through shared projects and joint contributions to problem-solving. According to Porter, these benefits could not arise in a global setting, as they are, according to him, caused through close social interaction and thus decrease over distance.

The final article considered is from Marshall L. Fisher, titled “What is the right supply chain for your product?”. His relevant main points are categorising your products into functional and innovative. The statement is that the functional product has a predictable demand, while the innovative one is unpredictable. They are listed with further attributes that help classify them, such as product variety. Next, physically efficient and market-responsive supply chains get compared. The description is very similar to the one already given by Chopra. These categorisations will then be used to match the product category and the sourcing strategy. An innovative product, for example, one with unpredictable demand, should be matched with a market-responsive supply chain instead of a physically efficient one. The same principle applies to the functional product (Fisher, 1997).

3.2 Summary Literature Review

The authors identified various factors to consider when implementing a nearshoring sourcing strategy. A consensus that can be drawn is that a nearshoring strategy can have various advantages compared to a global one. A global sourcing strategy should not be seen as the peak of procurement but merely as an option to consider.

More local sourcing strategies have their most significant advantage in their increased responsiveness that results from the short lead time, leading to more flexibility on the buyer side and lower risk for disruption. The short lead times make less safety stock necessary, which decreases the total cost of ownership. Further points of consideration that favour a more local strategy are factors such as a shared currency, no or less cultural differences, shared norms, and standards. Finally, through the shorter distances over which products get transported, less strain is put on the environment, which is in line with this assignment and the goal of the company.

Next, the authors agree that there are no “one-size fits all” approaches and that a holistic view must be taken when deciding on a sourcing strategy. The opinions of the authors regarding the factors that need to be considered in this holistic view partially overlap and complement each other. However, no disagreement seemed apparent; the choice differed, which can be explained by the different main focuses the authors set. Introduced by De Boer & Telgen and Kang & Cho, the importance and influence of the purchasing department on the overall operations of a company became apparent, together with the evident trend going from a global sourcing strategy towards a more local one. Chopra, for example, provides an extensive overview of attributes that a product or part should have to qualify for more local sourcing. Byoungho partially overlaps with what Chopra states, for example, their shared view that the inherent demand of the product is a factor that plays a significant role in considerations. Products with low demand are less predeterminate for such a sourcing strategy, while a high demand speaks more in favour of a global sourcing strategy. Byoungho also identifies a good relationship and high availability of suppliers in the region as supporting factors, which Chopra did not mention. This is in line with the findings of Porter. He identified proximity to the supplier as a factor of competitive advantage, as it leads to more cooperation, leading to better relationships between the buying company and the supplier.

Mentioned by Ivanov *et al.* is the concept of the total cost of ownership, a more holistic view of sourcing, which considers more factors than merely the purchase price of an item, such as the cost of transportation and storage. As the other articles did, they advocate the need for a proper analysis or classifications of the needed products, as there is no one-fits-all solution. Especially interesting is the article by Fisher was the categorisation in functional and innovative product categories, which led to the next step of choosing the right sourcing strategy, which may be local. This is in line with the other papers about the trade-off between agility and cost. Like Chopra and Byoungho, too, he focused more on the attributes of products in this context. Furthermore, contrary to Chopra and Byoungho, which mainly covered prerequisites for local sourcing, Invanov *et al.* focused more on the overall advantages of such a strategy. An overview of the identified factors favouring a nearshoring strategy is provided in Table 3.

High Demand Volatility	High Volume
Low Value	High Weight-to-Value Ratio
High Rate of Product Obsolescence	Increased Need for Engineering/Design Support
High Rate of Innovation/Product Variety	Increased Impact of Supply Chain Disruption
High Inventory Cost	High Desired Quality
High Contribution of Information and Manufacturing Technologies	Long-term Relationship with Subcontractors
Established Local Subcontractor Clusters	High Average Margin of Error in the Forecast

Table 3: Supporting Factors for a Nearshoring Sourcing Strategy

3.3 Additional Points to consider

Two more factors have been identified through consultation with the company and will need to be considered in addition to the in the previous subsection established ones, namely confidentiality and the price to minimum order quantity ratio, or complexity so to say. They will be more elaborated upon in this section.

Next to other things, the company also produces electrical components, some of which are used in their vehicles. They are producing these components themselves in China and shifting the production to a European manufacturer would require sharing sensitive data and blueprints with that manufacturer for him to start producing. Naturally, the company is not willing to do this, which automatically makes confidentiality a hard criterion to consider in this case when shifting to a nearshoring sourcing strategy.

Furthermore, practical considerations need to be kept in mind, such as the relation of price to minimum order quantity and the complexity of the manufacturing process of the part in consideration. It is in the nature of the spare parts industry that most of the times the number of spare parts required is not equal to the number of parts produced during manufacturing. To give an example of this: To manufacture 1000 vehicles, 1000 rear bumpers will be required. However, only a tiny fraction of these vehicles will need to have their rear bumper replaced during their lifetime. Thus, it is necessary to consider the economic feasibility of changing the supplier, as the new supplier will need to set up a production process for the part. This feasibility can be judged by considering the manufacturing process required for it. The more complex it is and the higher the initial investment for setting it up, the less suited it is to be sourced through a new supplier. For example, most of the parts that form the vehicles body, the hull, are simply sheet metal bent to the correct form. This does not require any additional machinery or similar on the supplier's side, as merely a readily available piece of sheet metal is inserted into a bending machine. However, on the other side, the manufacturing process for a rear bumper is more complicated. Injection-moulding is being used for this, which entails viscous plastic being inserted under high pressure into a, most likely, metal mould. Creating such a mould is an expensive endeavour requiring very high production numbers to justify the initial investment. In the case of spare parts sourcing, this is most likely not the case. Thus, it is necessary to evaluate the relation between the price of the part, its demand, and the minimum order quantity that would justify the cost of production.

3.4 Conclusion

Even though all of the factors are logical and should be kept in mind when considering a local sourcing strategy, practical limitations for this assignment and this specific case apply. Data is not available for all of the factors or challenging to obtain due to the nature of the used ERP system. This limitation will be discussed in Chapter 7. The used factors will thus be:

- Confidentiality/Sensitive Information
- Complexity/Price vs MOQ
- Value
- Volume and Weight

Chapter 4 Supplier Selection Criteria

Whereas the previous chapter established the factors on which parts should be evaluated on their nearshoring feasibility, this chapter aims to establish the supplier selection criteria used in the supplier evaluation and in doing so, find an answer to research question 2: "*What supplier selection criteria should be considered?*". For this, first the sub-question 2.1 (*"What supplier selection criteria does the scientific literature consider valuable to use?"*) will be covered in Section 4.1 through a literature review, which gets concluded in Section 4.1.1. Next, sub-question 2.2 (*"What supplier selection criteria should the company use?"*) will be treated in Section 4.2. It additionally entails determining attributes for the selection criterion "Sustainability" in Section 4.2.1 and an overview of the final supplier selection criteria and their respective attributes in Section 4.2.2.

4.1 What Supplier Selection Criteria does the Scientific Literature consider to be valuable to use?

According to (Weber, Current, & Benton) it appears that traditionally, the net price was the most crucial criterion used, after which delivery and quality came. This was the result after reviewing 74 academic papers on the supplier selection criteria after Dickson established a list of 23 critical factors in 1966. The three main ranked ones stayed the same, while others became outdated with time.

This makes it apparent that a closer look needs to be taken into more recent literature to accommodate this shift in preferences, which is also in line with the findings of (Muralidharan, Anantharaman, & Deshmukh, 2002).

Specifically for the spare parts industry, (Ishak & Wijaza, 2020) determined nine supplier selection criteria together with 55 sub criteria that experts use by applying the Delphi method, namely "quality, delivery, warranty and complaint services, price, manufacturing capability, quality management system, audit documentation, design and development capabilities, and cost reduction.".

(Handfield, 1994) established a series of supplier selection criteria for evaluating domestic and foreign suppliers through a survey. Domestic, in this case, meant that the supplier is situated in the USA. Independent of the locality, quality is the most important criterion when assessing a supplier, followed by cost and trust. See also Table 4.

International	Domestic
1. Quality (1.8)	1. Quality (1.8)
2. Cost (2.1)***	2. Trust (1.9)**
3. Trust (2.3)	3. Schedule reaction (2.0)***
4. Product technology (2.6)	4. On-time delivery (2.1)***
5. Process technology (2.7)	5. Established in USA (2.2)***
6. Ability to modify product (2.8)	6. Process technology (2.2)**
7. On time delivery (2.9)	7. Product technology (2.3)
8. Schedule reaction (3.3)	8. Lead time (2.4)***
9. Leadtime (3.5)	9. Ability to modify product (2.7)
10. Established in USA	10. Cost (2.8)
** = significantly less at $p < 0.05$ (unpaired t-test)	
*** = significantly less at $p < 0.01$.	

Table 4: Criteria for Evaluating Suppliers according to (Handfield, 1994)

Similar to what Dickson did in 1966, (Cheraghi, Dadashzadeh, & Subramanian, 2004) conducted a literature review on the most used supplier selection criteria of over 110 research papers published between 1990 and 2001. According to their findings, quality, delivery, and price are the three most essential criteria to consider, in that order. Furthermore, their results showed that a significant change in the requirements was noticeable after 1990, suggesting that with the upcome of modern technology such as the internet, a shift away from traditional criteria has been caused. According to them, one of the expected main effects of this is the erosion of price as a criterion.

Seven selection criteria, along with several attributes for each, have been provided by (Min, 1994). They are:

- Financial Terms
- Quality Assurance
- Perceived Risk (Political stability etc.)
- Service Performance
- Buyer-Supplier Partnerships
- Cultural and Communication Barriers
- Trade Restrictions (Tariffs etc.)

Proposed by (Min, 1994) and as seen in (van Groenewoud, 2010), a four-level model to approach the evaluation process is recommended. The structure starts with level one, the overall goal. To assess the suppliers based on it, criteria are introduced on the second level, which are then refined into attributes on the third level. According to him, the attributes need to be used, as it is difficult for a decision maker to handle more than seven to nine criteria in the decision-making process. This also allows for a proper definition of sometimes vague terms, such as quality, by operationalising them in a measurable way. In this case, for the example of financial terms, he proposes to take cost, freight terms, and payment terms as indicators for the criterion. Finally, on the fourth level, the possible supplier alternatives are listed.

Finally, coming back to (Muralidharan, Anantharaman, & Deshmukh, 2002), they have identified nine different supplier evaluation criteria and their indicators.

- Quality
- Delivery
- Price
- Technical Capability
- Financial Position
- Past Performance Attitude
- Facility
- Flexibility
- Service

4.1.1 Conclusion Literature Review

The writers' views on the criteria that should be considered partially overlap and complement each other; nevertheless, no dispute was apparent; only the choice differed, which may be explained by the authors' distinct main focuses. What becomes clear from the papers is that although many factors seem to be essential, quality, delivery, and price are almost always featured and ranked as vital throughout history. Other criteria, however, that have been important in past times lost their relevance.

Due to the overwhelming number of possible criteria to consider, a first selection must be made. It has been decided to use the model by Muralidharan *et al.* to propose to the company. This is because their model builds upon the study by Weber *et al.*, which is the most comprehensible review of academic papers on supplier selection criteria found by the researcher. Although the model of Min also uses the findings of Weber *et al.* as a foundation, Muralidharan *et al.* model has been chosen as their focus was more on mechanical components, which is in line with this research assignment.

4.2 What Supplier Selection Criteria should be the Company use?

A summary of the general supplier selection criteria identified in the last step, together with their respective attributes, has been shown together with an explanation and reasoning for them to the relevant decision maker at the company for the person to select a set that should be used to proceed further. This was conducted to ensure that the chosen criteria are in harmony with the company's way of working and increase the acceptance of the model and its components. The final selection was Quality, Price, Financial Position, Service, and Sustainability. Service has been, as wished by the company, composed out of the criteria Service, Flexibility and Delivery from the original framework. Although not part of the initial criteria identified in the literature review, sustainability was included as a criterion following the company's request, as it is in line with their environmental goals

4.2.1 What are suitable Attributes to express Sustainability in a Supplier Selection Process?

The previously conducted literature review did not yield sustainability as a criterion. However, it was chosen as one. This makes it necessary to complete another literature review to find relevant attributes that can be used to express sustainability in the supplier selection process.

The Cambridge dictionary defines sustainability as "the quality of causing little or no damage to the environment and therefore able to continue for a long time" and sustainability, specifically in a business context, as "the idea that goods and services should be produced in ways that do not use resources that cannot be replaced and that do not damage the environment" (Cambridge Dictionary, 2022). According to (Chopra, Sustainability and the Supply Chain, 2019), it has become a key priority in supply chain management in the 21st century, fulfilling the demand from environmentally conscious consumers. According to him, the extended supply chain, so the supply chain outside of the respective companies, has the most significant environmental impact, making it necessary to have a careful procurement process and work together with the suppliers to have the most significant effect on it. Integrating sustainable practices into the company's procurement department is one of the most effective ways to have a positive environmental impact (Sarkis & Dhavale, 2015). Not acting upon it can even cause considerable risks, such as negative public opinion and customer defection, leading to a decrease in sales. Sustainability, however, is a relatively broad term. It falls under the umbrella of Corporate Social Responsibility (CSR), which is concerned with the activities companies perform to have a better impact on the world. CSR can generally be categorised into three pillars: Environmental, Social, and Governance. This distinction is essential, as further research will focus only on the environmental aspect (Chopra, Sustainability and the Supply Chain, 2019).

In their paper "An integrated framework for sustainable supplier selection and evaluation in supply chains" (Luthra, Govindan, Kannan, Mangla, & Garg, 2015) performed an extensive literature review to identify sustainable supplier selection criteria, which were categorised into the three above mentioned groups. An overview of the relevant environmental criteria they specified can be seen in Table 4.1.

Number	Criterion	Attribute/Definition
1	Environmental management systems	The structure, planning and implementation of supplier policies for environmental protection
2	Green design and purchasing	Incorporating eco-friendly practices at the design and purchasing stages
3	Green manufacturing	The consumption of raw materials and energy should be minimised while producing the product.
4	Green management	The capability of product to maximize the environmental performance and management
5	Green packing and labelling	The capability of suppliers to take environmental considerations for packaging and labelling
6	Waste management and pollution prevention	The raw material is such that wastage and pollution should be minimum while producing the product
7	Environmental costs	The raw material and product should add minimum costs and damage to the environment
9	Environmental competencies	Supplier's capability of using environmentally friendly materials, implementing clean technologies, and reducing pollution effects
10	Green R & D and Innovation	The capability of suppliers to provide efforts on research and development activities to innovate new cleaner technologies, processes, practices, and methods

Table 4.1: Sustainable Supplier Selection Criteria identified by (Luthra, Govindan, Kannan, Mangla, & Garg, 2015)

Once again, these criteria were presented to a relevant decision maker at the company to select. The finally chosen criteria for sustainability were:

- Environmental Competencies
- Green R&D Innovation
- Green Manufacturing
- Green Packing and Labelling

4.2.2 Overview of the Final Selection and Definitions

This subsection presents an overview of all the criteria chosen to serve as supplier selection criteria in this framework, together with a definition of them and their attributes as given by the original authors where applicable and wherever it is necessary. For this, see Table 4.2.

Number	Criterion	Attributes
1	Quality	Percentage rejections Product performance (reliability, accuracy…)
2	Price	Quantity discount Cost Transport cost
3	Financial Position	Credit rating policy
4	Service	Delivery Speed Dependence Flexibility in the delivery schedule Flexibility in production volume Ability to accommodate modifications in designs After-sales service Availability of spare parts
5	Sustainability	Environmental competencies Green R&D Innovation Green manufacturing Green packing and labelling

Table 4.2: Final Selection of the Supplier Selection Criteria and their corresponding Attributes

- Percentage rejections describes the number of parts that are rejected by the company compared to the total number of parts received
- Product performance measures to what extent the product fulfils its goal. In general, it must meet the original equipment manufacturers' requirements
- Quantity discount is measured as a percentage values. Transport cost is the cost inflicted with the transportation of the goods to the company. Cost is the purchasing price per unit
- The financial position evaluates the credit rating policy by consulting a commercially available credit report. It is either a green light from the financial department of the company or not
- Delivery Speed is measured as the average lead time in weeks or days, depending on what is more applicable in the context
- Dependence describes the extent to which the prospective supplier would be dependent on the company. The less dependent, the better
- Flexibility in the delivery schedule and flexibility in the production volume indicate, how well changes regarding the delivery and number of parts requested can be accommodated
- Ability to accommodate modifications in designs describes the flexibility of the supplier regarding technical specifications. The more modifications can be done, the higher the score
- After-sales service describes the extent to which customer support is offered after purchasing
- Availability of spare parts describes whether spare parts are – and how well they are – available, by measuring the extent to which the supplier is able and willing to store parts at his own location for the company
- Environmental competencies describe the "supplier's capability to use environmentally friendly materials, implement clean technologies, and reduce pollution effects."
- Green R&D Innovation describes the extent to which the supplier is capable of producing progress in the environmental sector, such as through improved processes or practices

- Green manufacturing is measured as the extent to which the supplier incorporates measures to minimize its consumption of energy and raw materials while producing the product
- Green packing and labelling, as the name indicates, measures the extent to which a supplier can provide environmentally friendly packaging

A precise operationalization using scales or grading rubrics has not been performed and is not intended by the company, as it would require adapting these constantly. For example, the delivery times of the possible suppliers for part A might range from two to five weeks, while the delivery times for part B might be from four to eight weeks. These changes cost time and effort which is not in line with the goal of the aftersales department to move fast.

Chapter 5 Multi-Criteria Decision Analysis

In this chapter, Multi-Criteria Decision Analysis will be used to determine the preferences of the company towards the supplier selection criteria and the suppliers and thus answer the third research question "*How can Multi-Criteria Decision Analysis be applied to make a well-grounded decision in selecting a supplier?"* together with the respective sub-questions.

First, an introduction to MCDA and its background will be given in Section 5.1. The previously gained knowledge is then applied in selecting an MCDA-method to proceed further with in Section 5.2. The chosen method will be presented and elaborated upon in more detail in Section 5.3. Next, Section 5.4 applies the method to determine the weighting of the supplier selection criteria, attributes, and the scores of the suppliers. Finally, Section 5.5 performs a sensitivity analysis on the results.

5.1 Introduction to Multi-Criteria Decision Analysis

This section aims to provide information on the theoretical background of multi-criteria decision analysis processes, which will be used in this research to generate the weights of the chosen supplier selection criteria and attributes and the decision on a particular supplier.

In general, MCDA has been described as: "An umbrella term to describe a collection of formal approaches which seek to take explicit account of multiple criteria in helping individuals or groups explore decisions that matter. (Belton & Stewart, 2002)"

First, a general introduction to MCDA will be given by introducing the involved steps, as described by (Tobiszewski & Bystrzanowska, 2018) and (Schoon, 2019). Essentially, the multi-criteria decision analysis process comprises numerous steps that build on each other. During each step, it should be possible to go back when new alternatives become apparent during the process. An overview can be seen in Figure 5.

The initial step is to define the decision problem. First and foremost, the entire evaluation objective should be defined to convey the decision's purpose entirely and unambiguously. The following stage determines all potential stakeholders involved in it.

Next, alternatives that are accessible for selection inside the given choice problem need to be established, together with all relevant criteria and sub-criteria. Attention needs to be paid that the criteria are complete, relating to the degree they meet the overall objective, operational, relating to the degree they can be measured, decomposable, relating to a criterion's ability to be broken down into further parts or attributes, non-redundant, meaning the criteria are mutually exclusive, and of minimum size, meaning that the set of criteria should be kept as small as possible (Keeney & Raiffa, 1993).

The next stage in the multi-criteria decision analysis framework is to weight the specified goal criteria. The weighting indicates how strongly the factors are taken in the examination.

The previously conducted steps allow the researcher to choose and apply a specific MCDA algorithm, whose results will be interpreted, and a choice made based on the alternatives given.

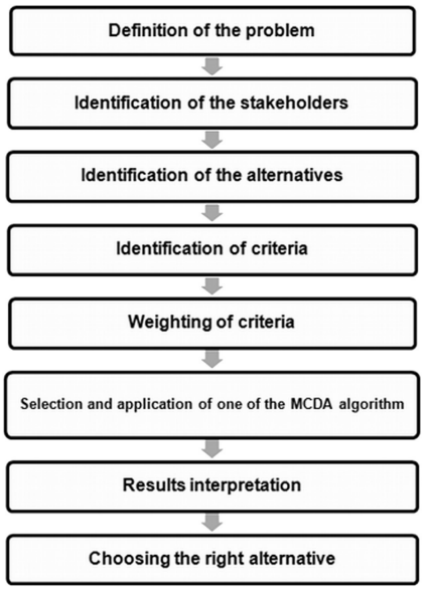

Figure 5: MCDA-Steps as taken from (Tobiszewski & Bystrzanowska, 2018)

For the first step of the framework, the definition of the problem (Roy B. , 1996) has identified a structure consisting of different types of "problematics" that can be encountered when defining a problem:

- The choice problematic: It is concerned with finding the best option out of a set of alternatives by reducing this set as much as possible until "all but one action [remain] that would be at least as good as all those which had been eliminated".
- Sorting problematic: Here, characteristics are being tried to be established by sorting the alternatives into predefined categories.
- Ranking problematic: An ordering procedure is being tried to establish, which allows ranking the alternatives in a particular order by decreasing preference.
- Description problematic: Options and consequences are being tried to be described

5.1.1 MODM and MADM

The use of MCDA methods allows non-quantitative variables to be included. This avoids difficulties associated with the qualitative assessment of certain factors, such as motivation or wellbeing. MCDA methods thus make it possible to include various aspects that can be quantitative and qualitative and are suitable for decision support about complex problems whose interrelationships and consequences are manifold and challenging to survey. They aim to improve the decision maker's understanding of the decision problem and structure it to enable a more well-founded decision (Rao, 2007).

Within MCDA methods, a distinction is also made between the two areas of Multi-Objective Decision Making (MODM) and Multi-Attribute Decision Making (MADM). These differ primarily in the design of the alternatives and the resulting outcomes. In MODM methods, an optimal solution is determined using mathematical procedures from a continuous (uncountable) set of other options, considering several objective functions. MADM methods, on the other hand, compare a discrete (countable), clearly definable set of already known alternatives. As there is a clearly defined set of supplier selection criteria and suppliers we desire to choose from, our problem thus is a MADM problem.

5.2 Selection of an MCDA-Method

To conclude which MCDA-method is the most suitable one for the problem at hand, an overview of the alternatives is necessary. For this, (Pearman, Nemery, & Ishizaka, 2012) identified the most common ones together with their areas of application, sorted by the type of the problems identified by (Roy B. , 1996). They are shown in Table 5.1.

Choice problems	Ranking problems	Sorting problems	Description problems
PROMETHEE	PROMETHEE	FlowSort	GAIA
ELECTRE I	ELECTRE III	ELECTRE-Tri	FS-Gaia
UTA	UTA	UTADIS	
AHP	AHP	AHPSort	

Table 5.1: MCDA problems and methods identified by (Pearman, Nemery, & Ishizaka, 2012)

MCDA will get applied to determine the weights of the chosen supplier selection criteria, their attributes, and to establish the decision maker's preferences toward the available suppliers based on them. As it is intended to establish a ranking between the alternatives, the issue has been defined as a ranking problem. To choose an appropriate MCDA method for it, we will first look at the available alternatives for the ranking problem and then compare them.

PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluations) belongs to the group of the outranking methods (Ortiz & Aledo, 2018), meaning that it is not wholly compensatory, so bad scores on a criterion cannot be made up by a better ranking on a different criterion. This excludes PROMETHEE from the selection, as a wholly compensatory method is being looked for. A wholly compensatory method allows, as the name suggests, to compensate bad scores on one criterion with better scores on another one, which has been deemed advantageous in the context of supplier selection. The same holds for ELECTRE I. UTA uses additive utility functions (Lagreze & Siskos, 1982). As its application lies in the field of MODM problems, while we deal with a MADM problem, it will also be excluded, which leaves us with AHP. The procedures behind it will be described in more detail in the following section.

5.3 AHP

Here, more background about the primary tool used will be provided. The Analytic Hierarch Process is a multi-criteria decision-making method that can calculate the weights of criteria, deriving ratio scales from paired comparisons. This is done either using quantitative or qualitative input such as subjective opinions, feelings, preferences, etc. While doing so, it allows for minor inconsistency in judgement. The overall process can be broken down into the following scheme, as covered by (Winston, 2003):

Step 1: Defining the Objective. In our case, we want to establish a ranking of the supplier selection criteria.

Step 2: Structuring of the elements in criteria, sub-criteria, etc.

Step 3: Creating a n x n decision matrix based on the chosen criteria, where n is the number of criteria used. With this, a pairwise comparison of the elements is conducted, where the entry A_{ij} in row i and column j of A indicates the relative importance of i over j. The importance is measured by an integer scale ranging from one to nine, where for each integer, an interpretation is provided. The scale can be seen in Table 5.2. Furthermore, the condition that for all i, $A_{ii} = 1$ needs to hold.

$$A_{ij} = \begin{bmatrix} A_{11} & \cdots & A_{1n} \\ \vdots & \ddots & \vdots \\ A_{n1} & \cdots & A_{nn} \end{bmatrix}$$

Value of a_{ij}	Interpretation
1	Objectives *i* and *j* are of equal importance.
3	Objective *i* is weakly more important than objective *j*
5	Experience and judgement indicate that objective *i* is strongly more important than objective *j*
7	Objective *i* is very strongly or demonstrably more important than objective *j*
9	Objective *i* is absolutely more important than objective *j*
2, 4, 6, 8	Intermediate values – for example, a value of 8 means that objective *i* is midway between strongly and absolutely more important than objective *j*.

Table 5.2: Interpretation of Entries in a Pairwise Comparison Matrix as taken from (Winston, 2003)

Step 4: Normalization of the results. Every element of the matrix is divided by the respective column total.

$$C_{ij} = \frac{A_{ij}}{\sum_{i=1}^{n} A_{ij}}, \begin{pmatrix} C_{11} & \cdots & C_{1n} \\ \vdots & \ddots & \vdots \\ C_{n1} & \cdots & C_{nn} \end{pmatrix}, i, j = 1, 2...n$$

Step 5: Calculate the weights by taking the sum of the normalised rows of the matrix and dividing it by the number of criteria used.

$$W_i = \frac{\sum_{j=1}^{n} C_{ij}}{n}, \begin{pmatrix} W_1 \\ \vdots \\ W_n \end{pmatrix}, i = 1, 2...n$$

Step 6: Calculating the Consistency index.

The consistency index is a built-in tool in AHP that allows to check the consistency of the pairwise comparisons of the decision-maker. In the case of three alternatives, let's call them A,B, and C, usually only two comparisons are needed to establish a ranking between them. For example, A can be evaluated as more important than B, and B as more important than C. This automatically establishes the ranking A, B, C (in decreasing order of importance), as C must also be less important than A, if it is already less important than B. AHP however, would require three comparisons instead of the minimum two. In addition, C would also have to be compared against A. Should the judgement of the decision-maker then indicate that C is for example more important than A, it would be inconsistent with his prior comparisons, which would raise doubt about the useability of the comparisons. For this,a four step procedure can be used to check the comparisons for consistency. Here, **w** stands for an estimate of the decision makers' weights.

Step 6.1: Computing $A\mathbf{w}^T$

Step 6.2: Compute $\lambda_{max} = \frac{1}{n}\sum_{i=1}^{i=n} \frac{ith\ entry\ in\ A\mathbf{w}^T}{ith\ entry\ in\ \mathbf{w}^T}$

Step 6.3: Compute the consistency index (CI) :

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

Step 6.4: Compute the consistency ratio (CR), using the consistency index and the respective value for the random index as taken from Table 5.3, where n is the matrix size.

$$CR = \frac{CI}{RI}$$

n	2	3	4	5	6	7	8	9	10
RI	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.51

Table 5.3: Random Indexes as taken from (Winston, 2003)

Step 6.5: If the resulting value is smaller than 0.1, the consistency requirement can be seen as fulfilled. If not, then the comparisons that have been conducted can be seen as not sufficiently consistent and thus needs to be repeated. This concludes the basic AHP procedure.

5.3.1 Four-Layer AHP-Model

To reach the goal of selecting the best supplier out of a set of alternatives, the steps 3 to 6.5 outlined in the previous subsection will need to be repeated for the criteria, the attributes, and the alternatives. For all future references in this subsection, see Figure 5.4.

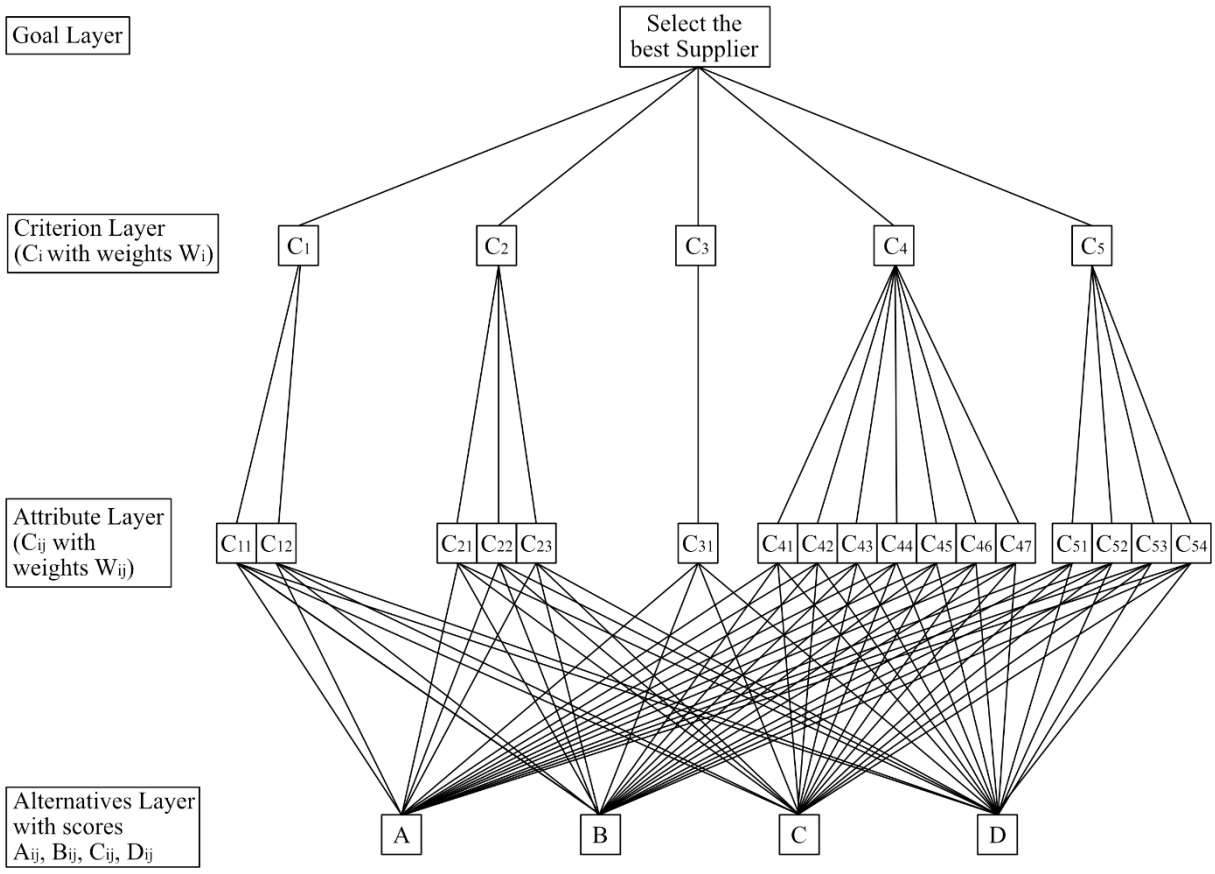

Figure 5.4: Schema of the Four-Layer AHP-Model used

First, the weights of the criteria C_1 to C_5 need to be established. They will be called W_i from now on. Following this, the weights of the corresponding attributes C_{ij} are determined, whereas each cluster, i.e., the attributes C_{ij} that are connected to the same criterion C_i, form their own group where they get compared against each other and whose summed-up weight adds up to 100%. These weights will be called W_{ij}, where *i* refers to the criterion the attributes belong to and where *j* specifies the attribute. Finally, the available alternatives, four in this case, are evaluated against the attributes C_{ij}, leading to the scores A_{ij}, B_{ij}, C_{ij}, and D_{ij}, where the first capital letter refers to the alternative, and *i* and *j* to the respective attribute the alternative has been evaluated against. For example, A_{11} would be the score alternative A received on the attribute C_{11}, which in turn belongs to criterion C_1.

After performing the necessary comparisons, all scores A_{ij}, B_{ij}, C_{ij}, and D_{ij} are multiplicated with the respective weights of the attributes W_{ij} and the weights of the criteria W_i. The resulting number is summed for each alternative separately, leading to the final score, where the highest one is the most preferable supplier. The sum of the final scores must add up to one.

Summarizing, the final scores for this model can be calculated as:

$$FSA = \sum_{i=1}^{5}\sum_{j=1}^{17} A_{ij}W_{ij}W_i \text{ , where } FSA \text{ is the Final Score of Supplier } A$$

$$FSB = \sum_{i=1}^{5}\sum_{j=1}^{17} B_{ij}W_{ij}W_i \text{ , where } FSB \text{ is the Final Score of Supplier } B$$

$$FSC = \sum_{i=1}^{5}\sum_{j=1}^{17} C_{ij}W_{ij}W_i \text{ , where } FSC \text{ is the Final Score of Supplier } C$$

$$FSD = \sum_{i=1}^{5}\sum_{j=1}^{17} D_{ij}W_{ij}W_i \text{ , where } FSD \text{ is the Final Score of Supplier } D$$

To check for correctness, the following must hold:

$$FSA + FSB + FSC + FSD = 1$$

For example, we take the following data for Criterion 1, its two corresponding attributes, and the scores of Supplier A on it, as shown in Table 5.5.

W_1	W_{11}	W_{12}	A_{11}	A_{12}
0.2	0.3	0.7	0.25	0.4

Table 5.5: Exemplary Data of Supplier A on Criterion 1

The overall score for Supplier A on Criterion 1 is then:

$$0.25 * 0.3 * 0.2 + 0.4 * 0.7 * 0.2 = 0.071 = 7.1\%$$

This process is repeated for the rest of the criteria and attributes. Say, the calculations yielded the following overall scores for the other criteria as seen in Table 5.6. The final score of Supplier A would then be:

C_1	0.071
C_2	0.033
C_3	0..007
C_4	0.14
C_5	0.02

Table 5.6: Exemplary Data

$$0.071 + 0.033 + 0.007 + 0.14 + 0.02 = 0.271 = 27.1\%$$

The process is then repeated for the other alternatives.

5.4 Weighting the Supplier Selection Criteria and Scoring the Suppliers

In this section, AHP will be applied to determine the weighting of the supplier selection criteria chosen in Chapter 4, together with their corresponding attributes. Additionally, the scoring of the suppliers for glass parts and for body parts will be conducted. All the steps necessary, together with their calculations, will be shown exemplary for the weighting of the criteria. The evaluation was performed by a single decision-maker and led to the following pairwise comparison matrix, as seen in Table 5.7:

	Quality	Price	Financial Position	Service	Sustainability
Quality	1	3	9	1/2	5
Price	1/3	1	8	1/6	3
Financial Position	1/9	1/8	1	1/9	1/6
Service	2	6	9	1	5
Sustainability	1/5	1/3	6	1/5	1
SUM	3.64	10.45	33	1.97	14.16

Table 5.7: Pairwise Comparison Matrix

Next, each cell has been divided by the respective column total. The results are shown in Table 5.8.

	Quality	Price	Financial Position	Service	Sustainability
Quality	0.27	0.28	0.27	0.25	0.35
Price	0.09	0.09	0.24	0.08	0.21
Financial Position	0.03	0.01	0.03	0.05	0.01
Service	0.55	0.57	0.27	0.50	0.35
Sustainability	0.05	0.03	0.18	0.10	0.07

Table 5.8: Normalized Results

Taking the average of each row yields the preference vector, and thus the weightings. They are shown in Table 5.9 and have been judged as correctly reflecting the intuition of the decision-maker according to him.

	Preference Vector	Resulting Weights
Quality	0.29	29%
Price	0.14	14%
Financial Position	0.026	2.6%
Service	0.464	46.4%
Sustainability	0.08	8%

Table 5.9: Preference Vector and resulting Weights

For further validation and to check for consistency, the consistency ration will be calculated, for which the respective rows of the pairwise comparison matrix are multiplied with the preference vector. The results can be seen in Table 6.

Quality	1.64
Price	0.80
Financial Position	0.14
Service	2.59
Sustainability	0.45

Table 6: Results after Multiplication of the Rows of the Pairwise Comparison Matrix with the Preference Vector

Next, each value found in the previous step gets divided by the corresponding value from the preference vector. The average is taken from the results, which yields λ_{max} (see Table 6.1).

Quality	5.70
Price	5.55
Financial Position	5.08
Service	5.75
Sustainability	5.14
Λ_{max}	5.45

Table 6.1: Calculating λ_{max}

The consistency index is computed through subtracting n, the number of criteria used (in this case 5), from λ_{max}, and then dividing the results by n-1, which yields 0.11. The consistency ration is then calculated by taking the consistency index and dividing it by the respective random index, which in our case is 1.12. This results in a consistency ratio of 9.5%, which is lower than 10%. Thus, the consistency ratio shows that the comparison was sufficiently consistent.

This process was repeated in the same manner for the attributes and the suppliers. The raw data of the suppliers on the attributes is listed in Table 6.2 and the outcome in Table 6.3.

Attributes	Attribute Weight	Supplier A (Spain)	Supplier B (Finland)	Supplier C (Finland)	Supplier D (Finland)
Percentage Rejections	10%	5%	7%	2%	1%
Product Performance	90%	Product fully fulfils its goal	Product fully fulfils its goal	Product fully fulfils its goal	Product fully fulfils its goal
Quantity Discount[1]	28.6%	7.38%	-	6.24%	33.33%
Cost	57.1%	230.39€	119.03€	125.58€	116.38€
Transport Cost[2]	14.3%	Equal	Equal	Equal	Equal
Credit Rating Policy	100%	Green light	Green light	Green light	Green light
Delivery Speed	18.9%	3 Weeks	12-14 Weeks	10-12 Weeks	6-7 Weeks
Dependence	4.1%	Low	Low	Low	Low
Flexibility Delivery Schedule	15.5%	Average	Low	Low	High
Flexibility Production Volume	22.2%	Average	Low	Low	High
Ability for Modifications	9.8%	High	Low	Low	Average
After-Sales Service	9.9%	No data	No data	No data	No data
Availability Spare Parts	19.6%	Low	Average	Low-Average	High
Environmental Competencies	38.6%	No data	No data	No data	No data
Green R&D	11.3%	No data	No data	No data	No data
Green Manufacturing	27.4%	No data	No data	No data	No data
Green Packing and Labelling	22.7%	No data	No data	No data	No data

Table 6.2: Background Data on the Glass Parts Suppliers A – D

[1] Supplier B does offer quantity discount, however, not for order sizes that are applicable in this case
[2] The transport cost for all suppliers equals out as their distance to the Netherlands is almost the same and they are able to service different countries better, as for example with Supplier A which is situated in Spain, who can service the Western European Market better, whereas the other Suppliers are closer to the Nordic region.

Criteria	Attributes	Attribute Weight	Supplier A (Spain)	Supplier B (Finland)	Supplier C (Finland)	Supplier D (Finland)
Quality 29%	**Percentage Rejections**	10%	20.4%	16.8%	24.2%	38.6%
	Product Performance	90%	25%	25%	25%	25%
Price 14%	**Quantity Discount**	28.6%	19%	5.7%	12.8%	62.5%
	Cost	57.1%	9.8%	29.5%	25.1%	35.6%
	Transport Cost	14.3%	25%	25%	25%	25%
Financial Position 2.6%	**Credit Rating Policy**	100%	25%	25%	25%	25%
Service 46.4%	**Delivery Speed**	18.9%	44.8%	10.6%	16.4%	28.3%
	Dependence	4.1%	25%	25%	25%	25%
	Flexibility Delivery Schedule	15.5%	30.5%	9.3%	14.3%	45.9%
	Flexibility Production Volume	22.2%	30.5%	9.3%	14.3%	45.9%
	Ability for Modifications	9.8%	45.5%	14.1%	14.1%	26.3%
	After-Sales Service	9.9%	25%	25%	25%	25%
	Availability Spare Parts	19.6%	16.8%	23.9%	19.8%	39.5%
Sustainability 8%	**Environmental Competencies**	38.6%	25%	25%	25%	25%
	Green R&D	11.3%	25%	25%	25%	25%
	Green Manufacturing	27.4%	25%	25%	25%	25%
	Green Packing and Labelling	22.7%	25%	25%	25%	25%

Table 6.3: Weight of the Supplier Selection Criteria, Attributes, and Supplier Scores

The sometimes-occurring rows of equal comparisons (all 25%) can stem from two reasons: Either there is no data available yet and thus no comparison can be made, such as in the case of the sustainability attributes, or the suppliers are truly equal in that regard, such as in the case of transport cost. They do not influence the final result. If new data, for example on the sustainability, would appear, the preference of the decision-maker would change, and so would the outcome of the model. This will be discussed in more depth in Chapter 7.

This leads to the following weighted scores of the suppliers of the glass parts on the criteria, shown in Table 6.4. The country the supplier is located in is written next to the name.

Criteria / Supplier	Supplier A (Spain)	Supplier B (Finland)	Supplier C (Finland)	Supplier D (Finland)
Quality (29%)	7.1%	7%	7.2%	7.6%
Price (14%)	2%	3.1%	3%	5.8%
Financial Position (2.6%)	0.7%	0.7%	0.7%	0.7%
Service (46.4%)	14.5%	7%	8%	16.9%
Sustainability (8%)	2%	2%	2%	2%
SUM	26.3%	19.7%	20.9%	33.1%

Table 6.4: Weighted Scores of the Glass Parts Suppliers on the Criteria

Thus, according to AHP, Supplier D should be chosen as the next supplier for glass parts.

Additionally, to show the useability of the model also for other parts and categories without changing the weightings of the criteria and attributes, the process gets repeated with the suppliers for body parts without showing all the steps in between. The result can be seen in Table 6.5.

Criteria / Supplier	Supplier E (Sweden)	Supplier F (Spain)	Supplier G (Spain)
Quality (29%)	11.4%	11.4%	6.2%
Price (14%)	2.5%	7.2%	4.3%
Financial Position (2.6%)	0.9%	0.9%	0.9%
Service (46.4%)	21.2%	13.6%	11.6%
Sustainability (8%)	2.7%	2.7%	2.7%
SUM	38.6%	35.8%	25.6%

Table 6.5: Weighted Scores of the Body Parts Suppliers on the Criteria

The evaluation of the suppliers for the body parts thus concludes that Supplier E should be chosen.

After determining the weightings of the criteria, the attributes, and the scores of the suppliers, the decision-maker was asked whether the results were in accordance with his intuition, which has always been the case. This proves that the model can capture the decision maker's intuition and translate it into tangible numbers. Furthermore, by applying the model to a completely unrelated product category, it has been shown that it is also generalizable to a broader range of parts, without the need to adjust the weightings of the criteria and attributes.

5.5 Sensitivity Analysis of the Results

This subsection performs a sensitivity analysis on the results obtained from AHP. The reasons why this is conducted are manifold. Firstly, it is done to judge the accuracy of the model. Should the result of the analysis be that even a small change in the weight of a criterion or attribute could lead to vastly different outcomes, it would raise the question whether the assessment by the decision maker is indeed precise enough, or whether perhaps a re-evaluation should be conducted for the respective criteria or attributes to better capture the decision-makers intuition. Furthermore, as the usage of AHP allows to quantify qualitative statements which are based on the decision makers subjective perception which can change over time, it is important to evaluate how likely it is that such a change would lead to different results. Positive results on that, meaning an analysis that showed that the involved criteria and attributes are not sensitive, can then raise the confidence in the model.

In general, a sensitivity analysis on a multi- criteria decision-making problem is concerned with questions such as what would happen if the weights of the criteria or attributes would change, and, following this, how sensitive the results are based on this shift. For this, the software "SuperDecision" will be used to simulate a change in the weight of the criteria and the attributes. It simulates all possible values for the weight of the criteria and their attributes and calculates what the corresponding outcome in such a case would be. Special attention is paid to rank reversal points, meaning points that would change the ranking of the results.

All relevant findings are summarized in Table 6.6. Attributes or criteria that are not listed did not have a meaningful influence on the outcome, i.e. they either did not change the ranking at all independent of the simulated weight, or it is negligible, such as in the case for Financial Position, which would only change the outcome if its weight is increased from 2.6% to 100%, which in turn would rank all suppliers as equal, as their scores on the respective attribute are also equal. A change to the final outcome is defined as a change that leads to a different supplier being the highest ranked one in comparison to current outcome, i.e., all changes that lead to Supplier D dropping its rank.

Attributes / Criteria	Rank Reversal Point	Current Weight	Description	Change to Final Outcome?
Quality	95.7%	29%	Supplier C becomes second rank	No
Price	55%	14%	Supplier A drops to the fourth rank	No
Service	9.5%	46.4%	Suppler A drops to the fourth rank	No
Delivery Speed	74.2%	18.9%	Supplier A becomes first rank	Yes
Dependence	88.9%	4.1%	Supplier A drops to the fourth rank	No
Ability for Modifications in Designs	63.9%	9.8%	Supplier A becomes first rank	Yes
After-Sales Service	89.9%	9.9%	Supplier A drops to the fourth rank	No
Availability of Spare Parts	75.7%	19.6%	Supplier A drops to the fourth rank	No

Table 6.6: Sensitivity Analysis of the Attributes

5.5.7 Conclusion Sensitivity Analysis

As only the highest-ranking supplier is selected, special attention is paid towards criteria or attributes that change the ranking in such a way, that Supplier D does not rank first anymore. For this, only two instances have been found. An increase of the weighting of the delivery speed attribute from 18.9% to 74.2%, which corresponds to a percentage increase of 293%, leads to Supplier A being the most favoured one. This makes sense as the delivery time for Supplier A is the lowest with about three weeks. Next, an increase of the weight for the ability to accommodate design modifications from 9.8% to 63.9%, a percentage increase of 552%, would lead once again to Supplier A becoming first rank.

Both of these results are negligible as it is highly unlikely that a change of circumstances would lead to such a massive shift in the preferences of the decision maker. Besides this, no especially critical criterion or attribute could be identified. It is thus reasonable to assume that the weightings of the models are equitable and that no special attention will need to be paid in the near future for possible adjustments of them, as it has been proven that minor changes in them do not lead to different results.

With this in place and in addition to the confirmation of the decision-maker that the results of the AHP model correctly reflected his intuition, it is concluded that the use of AHP is applicable to this case.

Chapter 6 Implementation Plan and Recommendations

This chapter covers the fourth and final research question, "*How can the changes efficiently be implemented and what further steps need to be taken*?". After conducting the previous steps, the gained knowledge and models need to be incorporated in an implementation plan that shows the company what the road ahead is to reach the goal of implementing a nearshoring sourcing strategy. For this, the implementation plan will be structured into four smaller steps (see Section 6.1-6.4) that each build up on each other and help the company achieve an improved service level. It is structured in the order in which the steps should be conducted. Finally, all tasks involved in them are summarized in a time plan in Section 6.5.

6.1 Implement a Categorization and the new Ordering Program

For this, it is proposed that the company first implements a proper categorisation in their ERP system. The current state involves inconsistent naming and a lack of overview. For example, two very similar parts that could be grouped, such as a blinker on the left side and a blinker on the right side, do not necessarily share similar names, nor does the current system recognise their similarity. In addition to this comes the difficulty of multiple existing IDs that all refer to the in principle same part, which was introduced in Section 1.3.1 ("Improvable Documentation"). Both of these issues lead to massive difficulties in adequately assessing important supply chain metrics for the respective parts. For example, there is no difference in the purchasing process between the two blinkers, as the same supplier can be used for both of them. Nevertheless, in the current state, the system does not recognise that they are essentially the same. If now the database is scanned for parts that, for example, have low availability, the system might show one but not the other. The same goes for the evaluation of supply chain metrics. When deciding for which parts the supplier should be changed next, essential metrics such as the number of orders or the currently achieved service level must be kept in mind. Also, a supplier change would be done for the collective group and not just for a single part. For example, when thinking about changing the supplier for glass, all glass parts would then be sourced from the new supplier, not just single ones. However, the current system does not allow for an evaluation of supply chain metrics from a higher level, it only shows these for the single parts. A categorisation of the parts would be necessary to establish a high-level view. A proper naming convention of the parts is needed to achieve such a categorisation. It is proposed to adopt a similar system as other major vehicle manufacturers, such as Volkswagen. It is shown exemplarily in Figure 6.7.

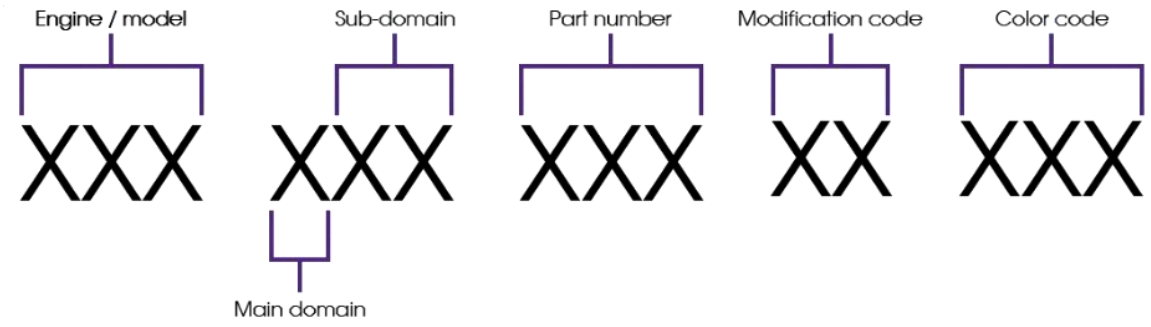

Figure 6.7: VAG-OEM Numbers as shown by (Actronics, 2022)

The first three digits would, in this specific case, contain the respective model numbers. As the model numbers already are three digits long, no change would be necessary. The second group indicates the component group. For the main domain of it, the following structure would be advisable. It is for the most part taken from the example of VW from (Actronics, 2022), although two small changes have been made for a better fit., namely replacing "Fuel, exhaust and air conditioning" and "Electricity and electrical systems" by "High-Voltage Electronics" and "Low-Voltage Electronics" respectively.

1. Engine
2. High-Voltage Electronics
3. Gearbox and Transmission
4. Steering, Front Axle, and Differential
5. Rear Axle
6. Brakes and Wheels
7. Hand and Foot Levers, Pedals
8. Bodywork and Interior
9. Low-Voltage Electronics
10. Accessories

The third group indicates the part numbers, the fourth the modification code (in case there are any modifications), and the fourth the colour code. The concrete implementation of this system, though, especially for the latter groups of digits, is out of the scope of this research and remains with the company.

This system's main advantage is that parts can be identified by the sequence alone, which allows searching for specific elements or groups of parts. It could be, for example decided to look for supply chain metrics for a whole model or only selected parts of it. It is advisable to add multiple columns to the current ERP system, each one containing a different block of the sequence and the final one containing the whole, as this would allow an easier search for a specific group of parts. For example, the final one contains the whole sequence (e.g. 001 345 87R 00 386) and five more columns each contain one block of the sequence (e.g. the first one contains the first three digits, which specify the model number, the second one the next three digits which specify the domain etc.).

Additionally, the new, improved ordering process (the issue has been discussed in Section 1.3.2 ("Inefficient Ordering Process") needs to be implemented to avoid further unnecessary long shipments. For this, a column titled "Supplier Identification Number" needs to be added to the current ERP system, containing unique supplier IDs that can be looked up by every employee, leading to a description of the supplier, which contains the necessary information about a supplier such as the country the manufacturing site is based in. This, in turn, allows for a grounded judgement on the locality of the supplier, thus avoiding unnecessary shipments. Furthermore, the usage of the same ERP systems throughout the branches is essential to avoid combability errors. Both the solution to the ordering program and process is also outlined in Appendix A.

6.2 Determine Parts and Categories with Biggest Impact

The shift of the supplier base cannot happen all at once. Thus, it is necessary to carefully evaluate the possible positive impact the new sourcing strategy could have on a part or a category. As the company aims to increase their service level and customer satisfaction, an essential metric to consider here is the number of customer complaints received for a part. This makes it necessary to add a further column to the ERP system that acts as a ticker, counting up by one every time a customer complaint is received for a particular part. With this in place, we can introduce another metric, the impact factor. It is calculated by taking the number of orders, dividing it by the number of customer complaints received, and raising the result to the power of minus one.

$$Impact\ Factor = \left(\frac{Number\ of\ Orders}{Number\ of\ Customer\ Complaints}\right)^{-1}$$

The higher, i.e., the more complaints in relation to the orders, the resulting number, the more critical a change in the sourcing strategy is to avoid further issues with the delivery. Additionally, a minimum number of orders can be established to avoid small deficiencies, such as if one order were placed for a part and one complaint about it was received. The impact factor can be calculated and displayed in a column of the ERP system, which then allows sorting from the highest to lowest factor, which is the order in which the sourcing strategy should be changed.

6.3 Determine Nearshoring Suitability

After determining the parts and categories that could potentially have the biggest impact, it is necessary to evaluate their suitability for a nearshoring sourcing strategy. For this, the established factors from Section 3.4 should be used. They are:

- Confidentiality / Sensitive Information
- Complexity / Price vs MOQ
- Value
- Volume
- Weight

To shortly recap, a feasible part or category does not involve sharing confidential data of manufacturing processes or technology to the new supplier. The part should be rather simple to produce, or, if it is more complex, the price of setting up the production should be in a reasonable relation to the quantity that is needed. Furthermore, the lower the value and the higher the volume and the weight, the more attractive changing the sourcing strategy would be. Implementing a "Feasibility Factor" in another ERP column will allow to quickly assess the useability of a part or category for the new sourcing strategy. It is calculated as follows:

$$Feasibility\ Factor = \big((1 - NV_a) + NV_o + NW\big) * C_1 * C_2\ , where$$

$NV_a = Normalized\ Value\ of\ the\ part$

$NV_0 = Normalized\ Volume\ of\ the\ part$

$NW = Normalized\ Weight\ of\ the\ part$

$C_1 = Confidentiality, can\ be\ either\ 1\ (if\ non - confidential), or\ 0\ (if\ confidential)$

$C_2 = Complexity, can\ be\ either\ 1\ (if\ non - complex), or\ 0\ (if\ too\ complex)$

The normalization of the values is conducted by applying the following formula:

$$X_{norm} = \frac{x - \min(x)}{\max(x) - \min(x)}\ , where\ x\ are\ the\ respective\ values$$

Complexity and confidentiality have been modelled this way, as they are hard criteria. If parts are either too complex to produce or entail sharing confidential information, shifting their sourcing strategy becomes out of question. Normalizing the value, volume and weight allows for comparison of these metrics and a holistic view. The resulting feasibility factor is then either zero or a decimal number higher than zero. Additionally, weights can be added to Value, Volume, and Weight should the need arise. The higher the number, the more feasible a part or category is for nearshoring. All parts with a zero-feasibility factor are excluded from the shift.

6.4 Determine, Evaluate, and Change Suppliers

Following the core thought of a nearshoring sourcing strategy, the next step entails determining suitable suppliers that are fairly close to the main markets the company operates in. Based on that, it would mainly restrict the area in which to look at to the European continent. For example, the highest-ranking supplier for the glass parts is based in Finland, and the counterpart for body parts in Sweden. An immediate shift to using them as the new supplier is advisable. The prior steps laid out the foundation for the change, whereas here the actual change is conducted. As switching the suppliers is not an act that can be performed from one moment to the other, but instead requires time, it is a continuous process. After ranking the most promising parts and categories with the help of the impact factor and evaluating their nearshoring useability with the feasibility factor, the highest ranking one should then be chosen to change the suppliers. As determining what suppliers are available and how they can be found has not been in the scope of this research, this part remains at the discretion of the relevant employees. At this stage, it is essential to gather all the data necessary for the model that will be used to evaluate the suppliers.

- Percentage Rejections
- Product Performance
- Quantity Discount
- Cost
- Transport Cost
- Credit Rating Policy
- Delivery Speed
- Dependence
- Flexibility in the Delivery Schedule
- Flexibility in the Production Volume
- Ability to Accommodate Modifications in Design
- After-Sales Service
- Availability of Spare Parts
- Environmental Competencies
- Green R&D Innovation
- Green Manufacturing
- Green Packing and Labelling

A definition of each of each of them can be found in Section 4.2.2.

This should then be used to determine the scores of the respective suppliers on the relevant attributes using AHP, which can be done by more than one person. The supplier with the highest final score should be chosen. The process then repeats with the second highest ranking part or category. If, after some time, the results of the model should not properly reflect the intuition of the decision maker, it would be advisable to re-evaluate the weightings of the criteria and their respective attributes. A sensitivity analysis has shown that no criteria or attributes are sensible, making this case rather unlikely. Alternatively, it should be evaluated whether the chosen criteria and attributes still reflect all the considerations done by the decision-maker or whether certain aspects are not captured. Finally, after a year or two of working together with the new suppliers, it would be advisable to perform the scoring of the supplier and possible competitors once again, as further experience has been gained and the suppliers' performance can be rated better than previously.

6.5 Time Plan

In addition to the previous subsections, which outlined and described the current underlying issues and the measurements that need to be taken to tackle them and shift to a nearshoring sourcing strategy, this subsection aims to translate all steps into a concrete plan.

Although the previous steps are already listed in chronological order, it is possible and advisable to move up and bundle specific tasks to save time. For example, adding the columns "Complexity" and "Confidentiality", or assigning the parts a value for it, is of little use without the naming convention in place. However, as establishing the naming convention takes the most time (about three months), moving these tasks up ensures that everything is prepared to properly use the newly introduced impact and feasibility factor once it is in place.

The tasks are sorted in chronological order in Table 6.8. The first capital letter indicates the responsible person or department for the task,

- A stands for tasks related to the ERP system, which would be done primarily by the IT – Developer at the company
- B indicates tasks performed by the Team – Leader of the department and the Purchaser, as their knowledge and responsibilities overlap
- C relates to the Spare Parts Engineering Team in China

The letter is followed by a number, showing which tasks need to be completed before it, independent of the assigned responsibility. For example, task B.2 is completed by the Team Leader and the Purchaser and requires tasks B.0, A.0 and A.1 to be finished beforehand. The assigned person does not necessarily conduct the tasks. They are only responsible for them and could decide to delegate the work to other employees at their own discretion.

The new naming convention must be in place first to fully benefit from the added impact and feasibility factor. As establishing this is the most time-expensive process, taking about three months, it is advisable to determine already promising parts and suppliers for the nearshoring sourcing strategy and perform the shift before they are in place. Even though the circumstances without the categorization are only suboptimal, the responsible employees in the procurement department possess a vast amount of experience and knowledge about the parts, their supply chain metrics, and their impact and feasibility. Starting the shift to nearshoring on Day 18 allows one to fully capitalize on that experience and already perform about three months of work before, around Day 108, the new system is fully established. From this point onward, it is supposed to provide valuable assistance and the necessary data to make well-grounded decisions.

In conclusion, it can be said that the estimates point to an implementation time of around 110 working days until the suggested changes' benefits can be fully reaped.

Order	Tasks	Expected Starting Time	Expected Finishing Time	Responsible Person/Department
A.0	• Adapt ERP system by adding a column containing the supplier ID • Add the columns “Customer Complaints”, “Feasibility Factor” and “Impact Factor” to the ERP system together with their calculations in the background • Add the columns “Confidentiality” and “Complexity”, to the ERP system together with their calculations in the background	Day 1	Day 3	IT-Developer
B.0	Decide on the format of the proposed naming convention and adapt it to the companies needs	Day 1	Day 14	Team Lead Procurement
A.1	Adapt ERP system by adding columns for the sequences of the new naming convention	Day 15	Day 16	IT - Developer
B.2	Assign parts a value (either 0 or 1) for confidentiality and complexity	Day 17	Day 31	Team Leader Procurement / Purchaser
C.2	Assign each part a sequence	Day 17	~Day 107	Spare Parts Engineering Team China
B.2	• Change suppliers for glass parts to Supplier D and for body parts to Supplier E • Determine promising parts by experience and possible suppliers • Evaluate them using AHP • Change the Supplier	Day 17	~Day 107	Team Leader Procurement / Purchaser
B.3	• Determine parts and categories with biggest impact using the impact factor • Evaluate nearshoring feasibility by sorting for the highest resulting feasibility factor	Day 108	Day 109	Team Leader Procurement
B.4	• Determine possible new suppliers on the most promising parts from Step B.4 and gather data on them • Evaluate them using the proposed AHP model • Change the Supplier	Day 110	Continuous	Team Leader Procurement / Purchaser

Table 6.8: Suggested Time Plan

Chapter 7 Conclusion and Discussion

In this chapter, we look back at the findings of this research by restating the research questions and the answers given. In doing so, the most important results are summarized, the limitations discussed, and additional room for contribution to this research is outlined. Section 7.1 provides a conclusion, and Section 7.2 further discusses the findings and limitations of the study.

7.1 Conclusion

The initial analysis of the circumstances showed that the mainly Chinese supplier base of the company was the leading cause for the improvable service level, together with other factors such as an inefficient ordering process, which stems from the inability of the employees to correctly judge the location of the supplier due to a lack of data, leading to shipments being delivered to the wrong location, and insufficient documentation, which led to multiple IDs existing for the same SKUs, causing difficulties in demand planning. As the long lead times stem from the mainly Chinese supplier base, introducing nearshoring was a reasonable choice to shorten these and guarantee higher parts availability for the customers. Next to the core problem, it was also decided to investigate a solution for the inefficient ordering process due to its impact on the service level and anticipated ease of implementation. However, the documentation issue was deemed out of reach for this research as it is a management issue, requiring pressure from higher up to implement an already known solution. Thus, the main research question, "*How can a Nearshoring Sourcing Strategy improve the Service Level of the After Sales Department?*" was formulated. Several sub-questions were investigated first to answer the main research question, which will be repeated now, together with their answer and main findings.

1. *What factors determine whether a nearshoring sourcing strategy is advantageous?*

An extensive literature review provided a list of the most common factors or attributes a part should entail that support a nearshoring sourcing strategy. While all are sensible, a selection had to be made to fit better the availability of data at the company, which limits the generalizability of the final result. The final selection was:

- Value
- Volume
- Weight
- Confidentiality
- Complexity

The lower the value and the higher the volume and weight, the more attractive switching from offshoring to nearshoring becomes. Other readers should evaluate the factors listed in Chapter 3 themselves to make a selection that is better suited for their circumstances. In addition to the in the literature review determined factors, further consultation with the company showed that confidentiality and complexity need to be considered too. Confidential parts and products are less suited for nearshoring as they entail sharing sensitive data with a supplier. Similar holds for parts that have a complex production process. The more complex it is, the less suitable it is for nearshoring, as it comes to a trade-off between the minimum order quantity and the price. Thus, it would be only advisable if the number of needed parts justifies the production set-up's initial costs. In the case of the aftersales department and spare parts more specifically, the order size is usually too low to justify a change.

2. *What are the supplier selection criteria that should be considered?*

In contrast to the previous research question, which investigated factors on which parts should be evaluated on their nearshoring feasibility, the second research question aimed to identify supplier selection criteria that should be used in the supplier evaluation. It was split into two further sub-questions, one investigating what the literature deems as considerable and one about what criteria the

company should use. The literature review yielded a variety of criteria to choose from, with traditional ones such as Quality and Price still ranking high when it comes to supplier evaluation in the industry.

Following this, a decision-maker at the company selected the criteria that work the best for them:

- Quality
- Price
- Financial Position
- Service
- Sustainability

Even though sustainability was not part of any of the by the literature identified criteria, it has been added at the company's request as it reflects their goal to create a better environment. All criteria have been made measurable through seventeen attributes, which will not be listed here due to their amount but can be found, for example, in Section 4.2.2. Again, it is essential to note that these findings do not claim to be universally valid and applicable, and an outside reader should consider making his own choices. The supplier selection criteria are being established as they are needed for a later part, where suppliers are evaluated against each other using an MCDA model. While this "customization" does limit generalizability, it allows to strengthen the model on its primary task, namely, to capture the intuition of the decision-maker in the supplier evaluation process, which has been determined to be an important factor to consider.

3. *How can Multi-Criteria Decision Analysis be applied to make a well-grounded decision in selecting a supplier?*

This research question has been split into three further parts, investigating what MCDA method should be chosen for the supplier evaluation and then determining the decision-maker's preferences towards the criteria, their attributes, and the chosen suppliers for two different parts. A literature review unveiled several different MCDA methods, their properties, and distinguished them between the different kinds of problems they are most suited for. The findings showed that AHP is the most appropriate method for context at hand due to its compensatory properties and ability to quantify qualitative. It was first applied to determine the weights of the criteria and attributes, as seen in Section 5.4. Following this, the first four suppliers for glass parts have been evaluated against the attributes, yielding Supplier D as the highest-ranked one. Next, the process was repeated with three suppliers for body parts, resulting in the selection of Supplier E. After each step, the decision-maker was asked whether the outcomes reflected his intuition, which was always the case, thus, validating that the model is an accurate reflection of it. To further increase confidence in the model, a sensitivity analysis was performed on it, showing that no significant changes in the outcome can be expected for reasonable changes in the weight of the criteria and attributes.

4. *How can the changes efficiently be implemented and what further steps need to be taken?*

The final research question translated the research findings into precise recommendations for the company in the form of an implementation – and time plan that will help the company to perform the shift to a nearshoring sourcing strategy. The main suggestion at this point was the establishment of a proper categorization through implementing a naming convention for the parts, which would allow getting a high-level overview of relevant supply chain metrics, which are not available at the moment.

Furthermore, the implementation of two new metrics, the impact factor and the feasibility factor, is proposed. The former rates the possible impact switching to nearshoring for a certain part can have by comparing the number of customer complaints received for a part (which would be, in this case, the number of times a customer did not receive their part in time, leading to a low service level), against the total number of orders for the respective part. It is calculated as follows:

$$Impact\ Factor = \frac{Number\ of\ Orders}{Number\ of\ Customer\ Complaints}^{-1}$$

The latter evaluates the extent to which a part is suitable for nearshoring, by calculating a score based on the in Chapter 3 / Research Question 1 determined factors. The higher the score, the more feasible a part is for nearshoring. Scores of zero automatically exclude a part from the shift.

$$Feasibility\ Factor = \big((1 - NV_a) + NV_o + NW\big) * C_1 * C_2\ , where$$

$NV_a = Normalized\ Value\ of\ the\ part$

$NV_0 = Normalized\ Volume\ of\ the\ part$

$NW = Normalized\ Weight\ of\ the\ part$

$C_1 = Confidentiality, can\ be\ either\ 1\ (if\ non - confidential), or\ 0\ (if\ confidential)$

$C_2 = Complexity, can\ be\ either\ 1\ (if\ non - complex), or\ 0\ (if\ too\ complex)$

The normalization of the values is conducted by applying the following formula:

$$X_{norm} = \frac{x - \min(x)}{\max(x) - \min(x)}\ , where\ x\ are\ the\ respective\ values$$

Overall, it is anticipated that the complete shift will take about 110 working days, with the application of the new naming convention taking up the bulk of the time. Nevertheless, the company can already start at around Day 18 to change their suppliers, as the experience and knowledge of the respective employees is sufficient to come to a well-grounded conclusion on what the most promising parts are for this. For a complete overview of the timeline and involved tasks, see Section 6.5.

Finally, a solution was brought forward to solve the improvable ordering program, which caused shipments to get delivered to the HQ in China instead of the warehouse where it was needed. For this, implementing a column containing the supplier identification number in the company's ERP system will allow the proper identification of the supplier's location.

All the steps conducted established a framework the company and future readers can use when thinking about establishing a nearshoring or related sourcing strategy—from selecting factors on which to evaluate parts and products on, over supplier selection criteria, to choosing an MCDA method to score suppliers. Next to this, the implementation plan can provide further insights into what the application of it could look like, even though it is highly tailored to the company's needs. It is not possible to stress enough that throughout all steps, it is highly advisable to not rely on the final selection made in this report but rather to use the preliminary findings and conclusions of the literature reviews and adapt them to one's own needs.

This allows us to revisit the main research question. It can be concluded that a nearshoring sourcing strategy can improve the service level of the aftersales department by significantly reducing the lead times and the inherent risk of supply chain disruptions, making the company more flexible and reactive to the requests of their customers. The increase of the purchasing price is expected to be offset by the lower stock needed and the reduced transport costs, which, however, all only play a side role as the primary goal was the increase of the service level and the with it involved customer satisfaction. The answers to all the involved sub-questions allowed to pave the way towards it.

7.2 Limitations and Discussion

The study proved highly useful for the company it was conducted for, delivering insights into the advantages of a nearshoring sourcing strategy and its expected positive influence on the underlying issue of the low service level, as well as majorly improving the way their suppliers are evaluated. For the latter, a simple Excel file with criteria on which the suppliers were scored has been replaced by a sophisticated AHP model that can adequately capture the decision-maker's intuition. For the first, insights were given into the steps that are now necessary to do next to perform the shift. After doing the groundwork, it is now up to the company to implement the changes according to the implementation plan or a variation of it and evaluate the results, as the time scope of this assignment, unfortunately, did not permit to do the observation. This also opens up room for further studies.

A perk and limitation of the model simultaneously is the number of attributes it uses to evaluate suppliers. It was designed this way to distinguish between different aspects properly, such as, for example, the division of price into the three attributes quantity discount, transport cost, and cost. However, as in the case of the service criterion, the seven attributes and the thus involved high number of paired comparisons are on the edge of a decision-maker's capability to distinguish between them and weight them properly. Several tries were needed till a satisfactory result was achieved for this. The use of AHP is highly advantageous here due to the built-in consistency check it offers, which other methods not always provide. When adapting the model, it is advisable to not further increase the number of attributes used for service. On a side note, it should be noted that the compensatory properties of AHP are seen as a perk and a reason to choose this method. In supplier evaluation, however, hard criteria are often set, e.g., the price cannot exceed a certain amount. AHP would, in this case, fail to encompass this unless the respective alternatives have been sorted out beforehand.

Furthermore, it was a conscious decision to define the attributes but not operationalize them to the greatest extent possible using methods such as scales or grading rubrics. This was done to accommodate the unique, fast-moving nature of the spare parts department. Decisions need to be made quickly to ensure the availability of spare parts to the customer. As there is no way to use scales or grading rubrics in a way that can be applied to every supplier or every situation, they have to be adapted frequently, it was decided to entirely rely on the comparisons performed in AHP, even though it offers the possibility to use quantitative data as an input. Being aware that aftersales is only a tiny part of the industry where suppliers need to be evaluated, the model would fall short for other areas where more time is available for supplier selection, for example in Research and Development.

Next, the decision to only use one decision-maker to determine the weights for the criteria and attributes made the process easier. However, it is expected that more than one person will use the model to evaluate suppliers. It has been assumed that the chosen decision-maker, which is the team leader of the procurement department, has a clear and thorough understanding of the importance of the criteria and attributes for the company and the view of the other relevant employees involved in the supplier evaluation, and thus can adequately represent them. Poor communication would, in this case, be of course detrimental.

Due to the lack of data on sustainability attributes, it was impossible to perform a proper sensitivity analysis on it, as all suppliers have been rated equal. Thus, it remains outstanding what possible impact different weights for it could have on the outcome. However, this is only an issue in this specific case, as using the same weights is not recommended for any outside reader of this report.

Although the literature review yielded an extensive list of supporting factors and properties a part should encompass to be advantageous for nearshoring, a selection had to be made to accommodate the company's available data, which limits generalizability. Although factors such as demand uncertainty are valuable to consider, implementing them was unfortunately impossible. Still, the research stays

relevant as it demonstrates the application of theoretical findings in a practical environment, demonstrating that only a selection is sufficient.

The naming convention proposed in Chapter 6 can be classified as intelligent and numeric, meaning that the naming follows a certain logic. This is not the only option; in general, two other possibilities exist. A generic descriptive one, where the names of the parts and products are a combination of attributes that describe them, and a generic numeric one, where every part or product gets assigned a number more or less randomly (without the possibility of doubles, of course). Each one has its advantages and disadvantages, which should be carefully evaluated when deciding on one. Implementing a new naming convention is an extensive amount of work, especially if an old one already exists.

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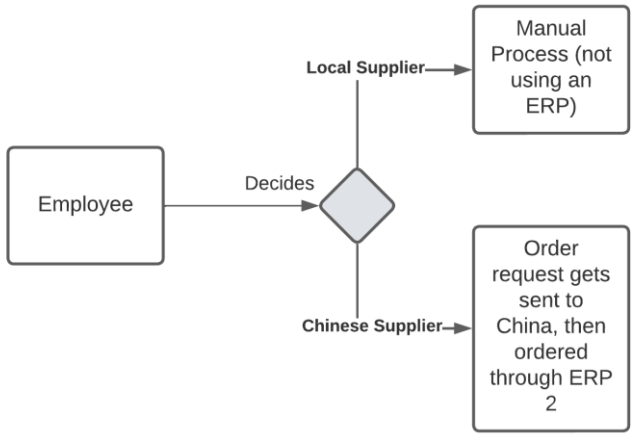
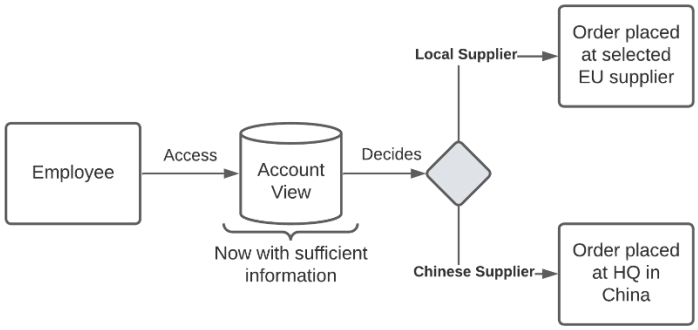
Appendix A Ordering Process

Appendix A.1 Current Ordering Process



Appendix A.2 New Ordering Process



The new ordering process enables the employee to access a database with sufficient information to properly judge about the locality of a supplier, after which the order is placed automatically at either the supplier in the case of the EU (in contrast to a manual process as it is now), or at the HQ in China, where the same ERP system should be used.