Multi-Criteria Supplier Selection in the Edible Oil Industry

The Case of a New Oils & Fats Plant in China

Master Thesis

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Preface

In front of you lies the final deliverable of my Master education in Transport, Infrastructure and Logistics. It provides a method for a multi-product company to extract the criteria from its organization and use this to assess and select an optimal supply base. Completing this thesis for a case company, allowed me to exercise the skills and knowledge gained during my years of study on a problem situation of a large production company, something which I enjoyed to the fullest.

This would not have been possible without the help of the case company and some of its employees. First of all I would like to thank Person A for his help with creating this project, integrating the thesis with the company and finally the trust he placed upon me to produce a desirable output. Person B owes my gratitude for his supervision during the project, his help with gathering the required data and managing the project. Besides his professional help, I especially appreciate his concerns and effort to make my stay in Asia both memorable and enjoyable. Person D proved to be an invaluable asset to this thesis as she assisted in very practical matters like understanding the market and the communication with local parties. I would like to thank her for all her efforts. My gratitude also goes out to Person C for taking on the supervision of the project from Europe. Also I would like to thank all other employees of the case company both in Asia and Europe involved with this thesis project for their help, feedback and support.

Special thanks also goes out to Jafar Rezaei for his feedback and flexibility to remotely supervise the project. His experience in supplier selection and guidance during our fortnightly feedback sessions often provided me with the confidence and new perspective to further complete the thesis project. Prof. dr.ir. Lóránt Tavasszy made sure I kept achieving the right goals and didn't become bogged down in all the wrong details. Furthermore I would like to thank Karimah Wan Ahmad, for her help with the thesis report and input on sustainable aspects of the project and Yusong Pang for his perspective and feedback from a more technical viewpoint.

Lastly I thank my greatest support, not only during this project but even more during my years of study. My sister Marieke Nispeling, for always looking out for me and motivating me to pursue whatever goal I have in mind. My mother Aadje Petrie, for placing an unmeasurable trust upon me even when things turn out not to be in my favor. My father Tom Nispeling, for creating the opportunity to do whatever I think is best and supporting me in the decisions I make. My girlfriend Bente de Kok, for supporting me all the way in my wish to complete my master thesis abroad. Finally a great appreciation goes out to my friends who encouraged and supported me and who made my student career exceptional.

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Thomas Nispeling

Summary

The process of supplier selection is regarded as a critical step in the development of a competitive supply chain. The share of raw material purchasing in the total turnover of industrial companies can range between 50 to 90%, which underlines the importance of selecting the right suppliers for a company. This thesis aims to create a framework for the selection of suppliers. A ranking will serve as the basis for advice on the optimal supply base. Multiple criteria are extracted from the organization and integrated in a framework that ranks the suppliers based on their performance. This is subsequently implemented in a problem situation in order to reflect on the value of the framework for with respect to the supplier selection process. The realization of a new oils and fats plant in China provides the problem situation and it is used as a case for this thesis. Currently the company is not aware of the availability of suppliers and the method of selection. Implementing a framework within a case company will be beneficial in two ways. On the one hand this thesis will allow a scientific theory to be implemented in the structure of a commercial corporation so its actual use can be determined, a step that in literature is often recommended but not taken. On the other hand the company will be provided with an insight in value of academic knowledge and how it can contribute to the development of a supply chain strategy. In order to reap these benefits a literature research is conducted on supplier selection and the related topics like sourcing, selection criteria and sustainability. This will provide a knowledgebase to work from. Subsequently the methodology describes the specific method used to create the framework, which is called the Best-Worst Method. This method is chosen because of its ability to produce reliable results with a low amount of comparison data. An extensive data collection has a twofold approach. Data is required for the design of the selection method. This involves obtaining industry specific criteria and their weights in order to make a distinction on their importance. A more practical approach is required for the rest of the data collection. This is on the available suppliers, located not only in China, but also in Asia and beyond. Once identified, contact with the suppliers is required to determine their abilities and characteristics. Substantial effort is made on the exploration of the transportation market in Asia, as different products with different modes will be transported to the new plant. The analysis of this data will be conducted according to the steps of the Best-Worst Method. The obtained data is used to determine the scores of the suppliers on the different criteria. Together with the weights of the criteria a final score can be calculated, which is the basis for the supplier ranking. To come to a meaningful advise that aligns with the operations of the case company, optimizations are performed on product importance and the transportation mode. This outcome is complemented with a presentation of the practical implications encountered during the research. These regard the transportation, the storage of raw materials, the certification and qualification in the Chinese market and on the management and organization of the new plant. The conclusion provides an answer on how a multi-product company can execute its supplier selection process. Finally the discussion reflects on the method, which is perceived to be a valuable and easy to use tool. A fragility of the method is the possibility for validation as no robust options for this are available. The framework is perceived to be valuable, because it allows the company and its employees a better insight on the selection problem, by which the complexity is reduced. Its ability to deal with extreme values however, is limited and must be kept in mind. A note on the dynamics of the problem situation concludes the thesis. It is incorporated in the thesis, to increase the usability and value of the framework over time. It provides an overview of the most important and likely factors that will affect the problem context in the near future.

Index

List of Figures

List of Tables

List of Equations

Glossary

Commodity	A basic good used in commerce that is interchangeable with other commodities of the same type.
Flexibag	Hermetic sealed, collapsible and flexible bag/bladder which is stuffed in a 20ft container.
ISO Tank or Container	A steel standardized box used for transporting (liquid) goods.
Liquid Bulk	A wet commodity which is shipped in large unpackaged amounts.
Modality	Mode of transport.
Non-palm raw materials	Raw materials extracted from other crops than palm.
Olein	Fats occurring naturally in liquid form.
Palm raw materials	Raw materials extracted from the palm mesocarp or kernel.
Shelf life	The length of time a product may be stored without becoming unsuitable for use or consumption.
Soft oils	Raw materials of the soft oil group.
Sourcing	To obtain materials or parts from another business or country for manufacturing.
Stearin	Fats occurring naturally in solid form.
Supply Base	Selection of preferred supplier forming a group that will supply a buyer.

List of Abbreviations

Item	Description	Item	Description
AHP	Analytic Hierarchy Process	***JIT***	Just in Time
ANP	Analytic Network Process	***LT***	Lead Time
AVL	Approved Vendor List	***MCDM***	Multi-Criteria Decision-Making
BO	Best-to-Others	***MFN***	Most Favored Nation
BWM	Best-Worst Method	***MNC***	Multinational Corporation
CI	Consistency indicator	***MODM***	Multi-Objective Decision-Making
CIF	Cost, Insurance and Freight	***MOQ***	Minimum Order Quantity
COD	Cost of Delivery	***MT***	Metric Tonne
DEA	Data Envelopment Analysis	***NOBL***	Not On Blacklist
FB	Flexibag	***OTIF***	On Time in Full
FFB	Fresh Fruit Bunch	***OW***	Others-to-Worst
FOB	Free On Board	***QA***	Quality Assurance
FOSFA	Federation of Oils, Seeds and Fats Associations	***QC***	Quality Control
FSSC	Food Safety System Certification	***RM***	Raw Material
GMO	Genetically Modified Organism	***RSPO***	Roundtable on Sustainable Palm Oil
GMP	Good Manufacturing Practice	***RT***	Road Tanker
HACCP	Hazard Analysis and Critical Control Points	***SS***	Supplier Selection
ISO	International Organization for Standardization	***USDA***	United Stated Department of Agriculture
		WWF	World Wildlife Fund

Table 1: Overview of abbreviations

1 Introduction

The first use of the term Logistics dates back to the early 19th century and was used for military journals (Lummus, Krumwiede, & Vokurka, 2001). In this particular field of research the term Supply Chain was also introduced. This subject has been of keen interest by scholars, governments and companies and its application has certainly surpassed the military topic ever since. A fundamental element of supply chain management is the subject of supplier selection. Interest in this topic took off after the influential work on criteria for supplier selection was carried out by Dickson (1966). This thesis will contribute to the supplier selection paradigm by applying a multi-criteria decision method in order to select a supply base. For the implementation of the multi-criteria decision method, the commissioning of a new edible oils and fats plant in China of a case company is used. This implementation will provide the case company a method to select an optimal supply base for their new plant. The first chapter will start off by introducing the field of research, the case company and the edible oil industry. Subsequently the research questions and scope will be presented.

1.1 Supplier Selection

The notion that supplier selection is a critical step in developing a competitive supply chain has been around since the early days of the supply chain thinking (Lewis & Irwin, 1943). This importance is rooted in the critical nature of purchasing decisions. In industrial companies, the share of raw material purchasing in the total turnover typically ranges between 50 and 90% (Telgen, 1994). Selecting the right suppliers to form a supply base that allows a company to purchase their raw materials effectively and efficient, is something that will directly support the business continuity. The use of multiple criteria to assess the performance of available suppliers needs to be applied in order to obtain a well-structured approach. Using these criteria can minimize the uncertainty and inaccuracy of selection by experience or gut feeling. The number of criteria available has increased in the last decades. This has widened the focus from obvious business principles that relate directly to the product, quality or price, to more intangible and soft matters like relationships, attitude and commitment (Chai, Liu, & Ngai, 2013) The days of simply using competitive bidding are long gone and the use of multiple criteria with increasing focal areas, complicate the decision-making process. The incorporation of softer criteria into the process is something that should be guided by a supporting method that is able to cope with the complexity. With a successful implementation of a method for supplier selection that incorporates the aforementioned elements, a company is enabled to reap the benefits of an efficient supply chain.

Focusing on the supplier selection as a separate business process however, is like looking at a wagon without noticing the train. As it holds so many ties to the performance of a company and even being a way of outcompeting rivalling companies, the process has become a strategic part of business operation. Using it in ways to increase the performance of a company requires a great deal of alignment with other business processes. The make-or-buy decision for instance should be a preparatory consideration. Furthermore is the sourcing strategy closely related to the supplier selection. Besides these strategic considerations the outcome of the supplier selection process is also of influence at an operational level. The inventory strategy for instance, is closely linked to the supplier selection process. This great deal of relationships complicate the selection process and a sound research with the right scope is needed in order to successfully complete this process.

1.2 The Case of a New Oils and Fats Plant

The development and implementation of the supplier selection framework is executed for a case company, active in the edible oil industry. This section will introduce the industry, the company and its endeavor in the Chinese market. The company operates at a global level. It develops oils and fats primarily for the food manufacturing industry. Their operations in the Asia division will be extended with a new Oils & Fats Plant in China. In the following section an introduction to the project and the problem statement is provided.

1.2.1 The China project

The case company is expanding their production with a new plant in China. With this addition it can reap the benefits from the expanding Chinese market. The current state of the project is in the early construction phase. The design of the plant and the required supporting facilities have been tendered to external parties. Currently the first construction work on the plant itself is carried out. The planning for the commission of the plant is within the next 5 years.

1.2.2 Supplying the China plant

The China plant will have a considerable influence on the performance of the Asian division. The facility is different from other refineries in a way that the inbound logistics are of a greater importance and they are yet to be defined. The existing plants are located in proximity of the plantations that deliver the required raw materials. This allows for a simple inbound logistics strategy, since the distances are small and the options for transport are numerous. Keeping the geographical configuration in mind, it is easy to comprehend that the addition of the new plant will have substantial influence on the operations in the region. The location of the new plant can be seen in Figure 2 at the end of this section. The inbound logistics of the new Chinese plant are far more complex.

The raw materials for the plant can be sourced from known suppliers and the existing facilities in Malaysia and Indonesia. This however will go hand in hand with considerable transportation costs as the distances are substantial. Given this construct, the inbound logistics are thus of a greater importance since higher lead times and cost are involved. This results in a larger share in the overall costs affecting the competitiveness of the company in the market. An alternative is to identify and select local suppliers in China or in neighboring countries in order to reduce the transportation costs, lead time and achieve a more cost effective supply chain operation. The problem with this is that the existence and characteristics of the local suppliers are unknown to the case company. Also some of the raw materials are of a very generic nature and some are more complex, affecting issues like the availability, quality requirements and considerations on competition. Finally an important issue is the effect on the current company supply chain. The company is not active in merely one stage of the edible oil supply chain, but it is vertically integrated in the value chain. The company owns plantations and mills that provide the case company with the raw materials for their products. Sourcing from within company will thus further reinforce the value chain, but as explained previously this will come at a certain price. In order to comprehend the considerations on the supply chain, the situation is visualized in Figure 1.

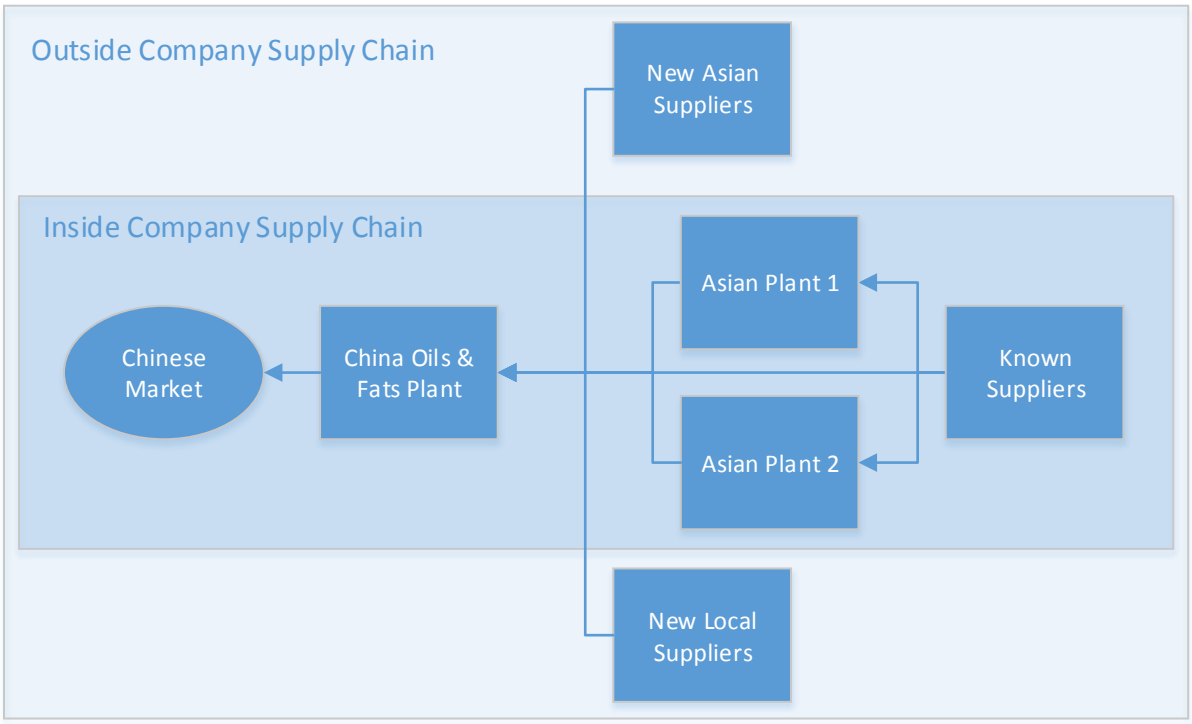

Figure 1: Supply Chain considerations

For matters of simplicity only the last section of the supply chain is visualized. It can be seen that the current operations in Asia receive their raw material from known suppliers. The two Asia locations produce both goods for industrial consumers as well as the needed raw materials for the oils and fats plant in China. These are thus able to fulfil the supply to China, increasing the company value chain. Because the known suppliers are also producers of the needed raw materials in China, another option is to surpass the two plants and directly supply to the plant. The final option is to source outside the company supply chain and find new suppliers. These can be located in China, or in neighboring Asian countries. This option could enable a savings in transportation costs and a reduction in lead time, but this is accompanied with lower internal revenue of the company group which could affect the company's profitability.

1.2.3 The China plant problem statement

Whether to use existing suppliers, company owned production locations or to attract new local suppliers, is something that requires careful consideration. Therefore a raw material strategy with respect to competitive and effective sourcing needs to be developed. An important element of this strategy is the supplier selection. This process needs to be able to carefully assess the issues regarding sourcing from known suppliers, company owned productions sites and new suppliers which are currently not identified. Dependent of this selection the organization of the inbound logistics and the effects on the plant operation and management can be indicated.

The selection of suppliers is thus a crucial step in developing a supply chain and it is needed to serve as input for a number of other strategic and operational considerations. It is therefore selected as the subject of thesis research. The supplier selection process is dependent on a number of decision variables for the new Chinese plant like production volume and product mix. These need to be determined by the company in order to set the constraints for the supplier selection. Subsequently the criteria for supplier selection are to be identified. These come both from literature and from

experts within the case company. Next, the available suppliers need to be known. This will require an explorative analysis of the region and a market analysis. By using Multi-Criteria Decision Analysis (MCDA), a framework can be constructed that assesses the performance of each supplier, based on the selected criteria. Different weights can be assigned to the criteria in order to create a dimension of importance between them. Methods for the determination of weights are widely available and the preferred method will be selected from a literature research. The supplier selection framework should be constructed in such manner that new (local) suppliers, existing suppliers and supply from the own supply chain can be considered. In order to realize this, key characteristics like transport distances, import duties and the effect of buying from competitors need to be taken into account. When the this has been determined, differences in product importance need to be incorporated in order to focus the purchasing task on the most prominent materials. These steps will lead up to the selection of a supply base and the effects of this base on the organization can be determined. With this focus the thesis research takes on a more operational perspective, where the selection of supplier can be seen as strategic. A supplier might for instance deliver their materials only with a specific transport mode. This has consequences for the operation of the plant.

Using experts within the case company in order to determine the weights of the criteria and finally select the preferred alternative is something that could allow for inaccuracy. When individuals are asked to state their preference, their ability to be rational is bounded. Making consistent comparisons between the suppliers is therefore a challenge, which will need to be addressed by a suiting method. Using this method to create a framework for the selection of suppliers and implementing this at the case company will be beneficial in two ways. On the one hand this thesis will allow a scientific theory to be implemented in the structure of a commercial corporation so its actual use is realized, a step that in literature is often recommended but not taken. On the other hand the company will be provided with an insight in academic knowledge and how it can contribute to the development of new business strategies. This can provide their employees with a new perspective on how to deal with complex situations.

Also the first period of operation of the plant needs to be considered. The start-up of such a large production facility is not a matter of flipping the switch. During the first operational period several teething problems that limit productivity will have to be overcome. The sales will need a ramp up period in order to reach the target market share. New customers aren’t just lined up from day one. Therefore a transition period, in which the Chinese plant will gradually become operational, is desired. The relevance of this to the thesis project is the effects of this volume growth on the transportation and plant facilities need to be taken into account

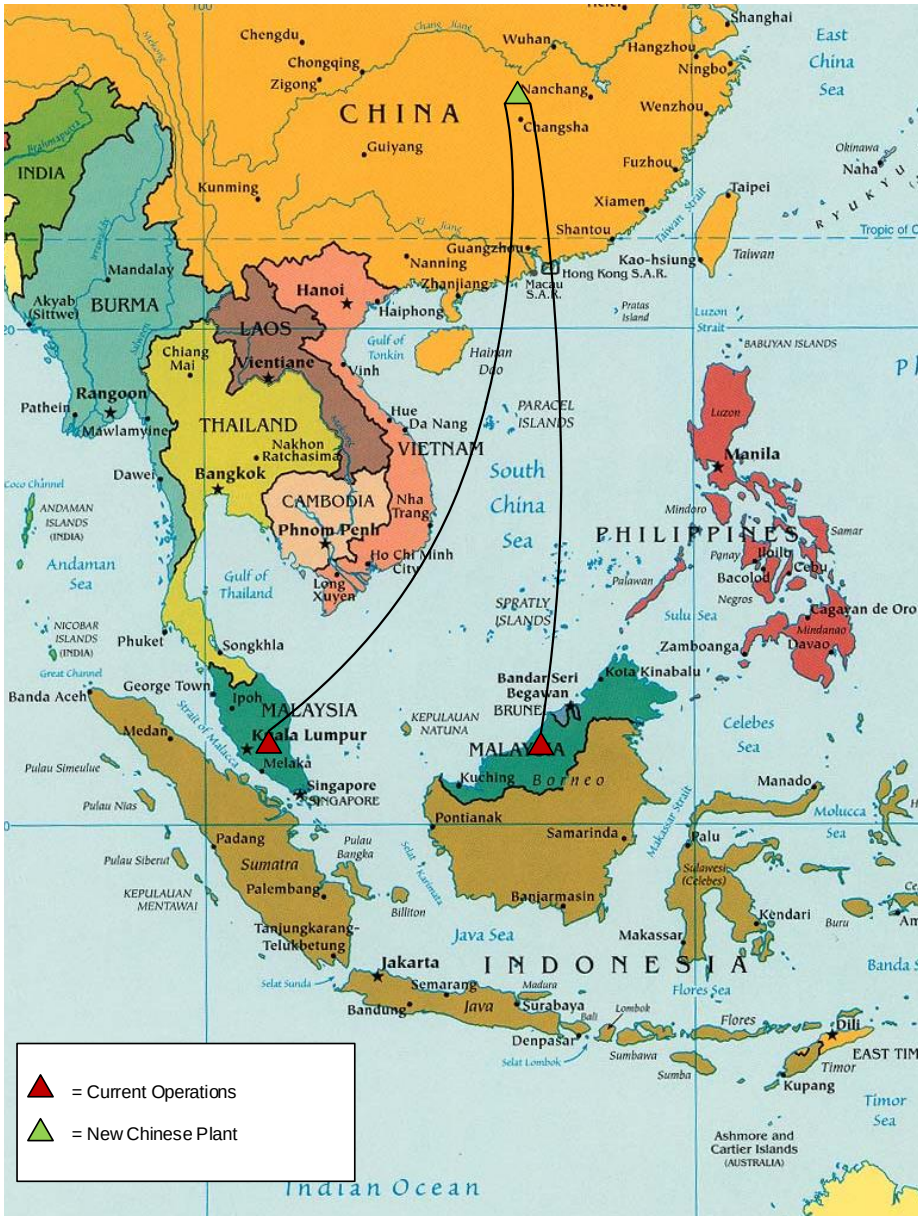

Figure 2: A map of the Asian operations

1.3 Thesis Aim and Research Question

This thesis aims to develop a framework for the supplier selection with the use of a MCDM method. This framework will then provide the case company with an indication on the optimal supply base in order to produce the selected product mix and deliver this to the market. A case is used for the implementation of the framework. It is provided by the case company and it contains the commission of a new oils and fats plant in China. The use of the framework will enable the company to select the suppliers on basis of well-defined criteria and in a structured manner so that the new plant will operate efficiently in the Asia region. Currently the company is unaware of the available suppliers in the region and the selection process is something that is often executed by gut feeling or on the basis of highly subjective factors. The documentation of this process is desired in order to improve similar activities in the future and to evaluate the selection process over time. Once the framework has delivered a supply base, advice can be delivered on the consequences and

requirements for the plant facilities and organization. In order to complete this objective, the following research question is posed:

How should the supplier selection decision-making process be executed in order to obtain an optimal supply base for a multi-product company?

The sub questions that will support this research question are stated below. These questions will aid in answering the research question.

- Which suppliers are available to the new Chinese plant of the case company?
- Which criteria can be developed both from literature and experts within the case company?
- How do the suppliers perform on these criteria?
- What is the optimal supply base for the selected product mix?
- What are the consequences of the obtained supply base on the case company's facilities and organization?

1.4 Research Scope and Assumptions

As indicated in the previous sections of this chapter, the supplier selection process holds many ties to other subjects of supply chain management. Therefore a balance is required on the elements that need to be incorporated in order to achieve a meaningful and accurate outcome. A balance by definition implies that a number of elements also need to be excluded in order to reduce the complexity and increase the feasibility of this thesis within the given timeframe. The scope of this project is therefore placed upon the inbound logistics of the new plant. The outbound logistics and the way the market is served, is not considered. A target market share, established by the company is used as an input for the raw material volume demand. The case company also determined a product mix for the first period of operation. This is used as an input for the type of raw material needed. The identification of suppliers is also bound to a certain extent. Limitations exist in terms of available time and research capacity. After a market research and explorative analysis the identified suppliers serve as a selection pool for further analysis. In a later stage, with more available knowledge on the local market and active players, the company can rerun the analysis with a larger pool of possible suppliers, in order to update the supply base. Regarding the outcome of this research an optimal supply base is retrieved. Optimal is to be defined by the criteria that are drawn from literature, from consulting company experts and decision makers and by the importance of the required raw materials. The implications of this supply base will be structured into advice on the further implementation. This advice on both technical and managerial aspects is only provided with regard to the effects caused by the obtained supply base.

Now that research has been introduced and framed, the following chapter will go into detail on the available literature.

2 Literature Research

In this chapter the scientific relevance and available literature will be discussed. It will provide a solid base of knowledge on supplier selection and the topics related to this. Prior to the selection process, the question whether to make or buy is of importance. This will provide input for different sourcing strategies. Then the actual supplier selection should be addressed. A critical element of this process is the use of multiple criteria for the selection. This has even become a field of study on its own. Next is the selection of a method. This is preceded by the discussion of the paradigm in which it takes place, the Multi-Criteria Decision Method. As the research and the industry of the case company is associated to sustainability issues, the topic is discussed in the second to last section. The final section will look into the cultural aspects of the Chinese business environment. As local suppliers are an important element in this research, knowledge on some basic differences or beliefs could be beneficial when contacting these suppliers.

2.1 The Make-or-Buy Decision

This section will go into detail on the make-or-buy decision. In order to provide a sound understanding of this problem, first the theoretical background is discussed. This is followed by the implementation of this theory in practice and it is concluded with some final remarks.

2.1.1 Theoretical background

Looking back at the history of this subject in literature, traditional approaches to the make-or-buy problem considered only financial or economic criteria to support the decision-making. Can another company provide a good or service for a lower price than the costs for doing this in-house (Platts, Probert, & Cáñez, 2002)? But it was stated by Coase (1937) that not simply the price in the market should be considered, but also all the costs of acquiring the commodity or good. These costs are recognized as transactional costs and formed the basis for transaction cost economics. This concept was further developed by Commons (1970) who considered the transaction as the basic unit in organizational theory. Williamson (1975) elaborated on this and explored the complexity of transaction costs. Their work laid a basis for many other scholars who provided a wide range of analytical tools for answering the make-or-buy question on an economical level (Platts et al., 2002).

But focusing solely on costs can be regarded as somewhat myopic. There are other factors that play a significant role and therefore need to be taken into account. This awareness is something that has been around for quite a while. Culliton (1942) already found quality and quantity issues to be important in the make-or-buy decision and that these were dependent of the current economic, social and political climate. Later on the strategic importance of the make-or-buy decision became apparent. Something that was underlined with a number of valuable scientific contributions (Ford & Farmer, 1986; Welch & Nayak, 1992). Empirical studies examined which factors could be considered as determinants for the make-or-buy decision (Poppo & Zenger, 1998; Walker & Weber, 1984). Asset specificity introduced by Williamson (1981) is found to be an important factor in the make-or-buy decision. It is regarded as the extent to which the investments made to support a particular transaction, have a higher value to that transaction than they would have if they were redeployed for any other purpose (McGuinness, 1994). Finally other academics concur on the belief that besides costs issues, outsourcing should also be based on other decisive factors like, quality, time, reliability or technical capability (McIvor, 2000; McIvor & Humphreys, 2000; Platts et al., 2002; Probert, 1996, 1997). It must be considered that the terms of make-or-buy and outsourcing are used in literature

interchangeably as the type of decision that outsourcing represent is similar to the classic make-or-buy decision (Russell & Taylor, 2003).

The question whether to make or to buy has been focused on choosing either the one or the other option. However as pointed out by Sousa (2014) no firm is a business island, but a three governance structure exist in the business world: hierarchies, markets, and inter-firm cooperative arrangements. To think of the outsourcing problem as a twofold and discrete choice would be delusive. Companies can consider between three options or a combination of these: they can internally develop the needed resources or capabilities, they can internalize the valuable resources and capabilities or they can access and explore those resources or capabilities by developing and sustaining cooperative arrangements with competent counterparts (Sousa, 2014). So outsourcing can be a combination of make, buy or a cooperation. This indicates that a degree of outsourcing exists and this is indeed indicated by several scholars. Willcocks and Lacity (1998) identified four different types. Although these were based on the sourcing question for IT services, the categories can be used in a broader view. The types are: Total Insourcing, Selective Outsourcing, De Facto Outsourcing and Total Outsourcing. This typology refers to the degree of outsourcing and ranges from small to large. Ho, Atkins and Eardly (2004) extended this typology by also including the distinction between services and process. This resulted in the additional categories of 'Offshore Outsourcing', which entails the transfer of the provision and management of services and 'Business Process Outsourcing' which refers to outsourcing of parts of core or noncore business processes.

2.1.2 Make-or-buy decision in practice

The decision whether to make or to buy has been a predicament for many companies (Barthélemy, 2003). It has been identified by multiple scholars that traditionally companies preferred the make option by means of backward or forward vertical integration, while later on this trend moved to outsourcing combined with the creation of supply chain relationships (Baxter, Ritchie, & Seeto, 1996; Wisner, Tan, & Leong, 2015). Outsourcing in the early stages focused on activities that were regarded secondary like cleaning, IT or catering but this has shifted to more primary activities like design, manufacturing or marketing. This opened almost the entire value chain to an outside supply (Jennings, 1997). Generally companies tend to outsource the noncore activities to enable a greater focus on the core competencies.

So outsourcing can provided a competitive advantage and it enables companies to focus on their core competencies, making it a major determinant of profitability (Yoon & Naadimuthu, 1994). The question whether to make or buy should be one of the cornerstones of a company's business strategy. Surveys conducted on this believe show that senior managers in manufacturing industry are unanimous in this believe. But when outsourcing decisions are evaluated, the outcome is surprising. In a study by Lacity and Willcocks (1995) they indicate that out of 61 sourcing decisions an unsatisfactory outcome was reported in 53 cases. The PA Consulting Group conducted a survey in 1996 which concluded that only five percent of the companies outsourcing actually reap the benefits they desired (McIvor & Humphreys, 2000). Also Barthélemy (2003) refers to a survey by the American Management Association in which three quarters of the US managers reported that outsourcing failed to meet their expectations.

McIvor, Humphreys and McAleer (1997) looked in the motivation for outsourcing as literature showed that it is an important strategic business element and it should be used accordingly. It

showed that this is rarely the case and short-term cost advantages are the main reason for outsourcing. Furthermore did Blaxhill and Hout (1991) found out that many companies make the outsourcing decision on the basis of overhead costs and which elements will provide the largest (short-term) cost saving.

2.1.3 Concluding on make-or-buy decision

On the one hand it is recognized both in literature and by managers in the industry that outsourcing should be an integral part of the business strategy of a company and it can provide a considerable contribution to the profitability. On the other hand however, when it comes to the execution, managers solely consider short-term benefits and economic factors like overhead cost reduction. Clearly the is a gap between practice and research. To close this gap, other factors like quality and reliability should be taken into account. Also the make-or-buy question is not a matter of selecting one or the other, partial outsourcing is possible of both services and business processes. It can be concluded that the make-or-buy decision is a complex one, it requires multiple inputs and it calls for a structured strategic approach.

2.2 Sourcing Strategies

The problem of selecting a supplier has a close relation to another field of study, which is the number of suppliers used by a company to enable their production or business operation. This section will first provide a theoretical background and will then look into different sourcing strategies.

2.2.1 Theoretical background of the sourcing strategy

In the late 1980's the trend in supplier relationships moved from the traditional arms' length relationships to a closer, more cooperative relationship. In order to realize this, companies reduced their supply base and treated the remaining suppliers as allies. This reduction has led to some companies even relying on a single supplier (Swift, 1995). A description of the types of sourcing is provided by Xia and Wu (2007) who incorporate the number of suppliers into the selection problem and make a distinction between two available options.

Multiple sourcing

Limitations such as a supplier's capacity, quality and delivery are considered in the supplier selection process. No one supplier can thus satisfy the buyer's total demand and requirements. The buyer needs to purchase some part of demand from one supplier and the other part from another supplier to compensate for the shortage of capacity or low quality of the first supplier. The buyer needs to make two decisions in these circumstances: which suppliers are the best, and how much should be purchased from each selected supplier? It must be noted that this definition disregards the fact the some buyers are able to source from multiple suppliers that meet the demand and requirements. In this way a buyer may maximize bargaining leverage by spreading the sourcing of product among multiple suppliers (Xia & Wu, 2007).

Single sourcing

There are no constraints considered in the supplier selection process. All suppliers can satisfy the buyer's requirements of demand, quality, delivery and so on. Only one decision has to be made by the buyer, namely which supplier is best (Xia & Wu, 2007).

This distinction does not take into account a third type of sourcing that is described by Newman (1988) and Wisner et al. (2015). It has been used interchangeably with single sourcing, but is actually different.

Sole sourcing
There is no need for a supplier selection process since there are no multiple supplier to choose from. This type of sourcing refers to the situation when the supplier is the only available source for the product or service and the buyer has no other option than to purchase from this party (Newman, 1988; Wisner et al., 2015).

Now that the different sourcing strategies are indicated, the next section will look into the characteristics and the most important differences of single and multiple sourcing.

2.2.2 Comparing single and multiple sourcing

Selecting the best strategy is not a straightforward task. Different beliefs stated in literature are contradicting. This dichotomy is also reflected in the contrasting beliefs of the well-known management authorities Deming and Porter. In Demining's fourth point of his quality/productivity improvement approach, he suggests: "End the practice of awarding business on the basis of price tag. Instead, minimize total cost. Move toward a single supplier for any one item, on a long-term relationship of loyalty and trust" (Deming, p. 23). This indicates that Deming believes that a lower price and higher quality can be obtained by applying single sourcing. Porter however, warns that "purchasing everything from one supplier may yield that supplier too much of an opportunity to exercise power". With this power Porter suggests that a supplier might "raise prices or reduce the quality of purchased goods and services" (Porter, p. 124). This indicates that Porter believes that single sourcing generates a lack of competition among suppliers which will lead to lower quality products and higher costs. This shows that there is no strategy is better or worse in all situations. Different aspects need to be considered and each strategy thus has its advantages and disadvantages.

When a company depends on single sourcing, it can improve its relationship with the supplier and come to a valuable cooperation. In this way a higher quality of product at lower total cost can be delivered to the buyer, which supports the beliefs of Deming. This was also indicated in a survey conducted by Larson and Kulchitsky (1998) among 1.000 purchasing professionals. Other benefits of single-sourcing are quantity discounts from order consolidation, reduced order lead times and logistical cost reductions as a result of a scaled down supply base (Mohr & Spekman, 1994). Drawbacks of the strategy are that the buyer may expose itself to a greater risk of supply interruption or hold-up from unforeseen events at the supplier or the transport (Costantino & Pellegrino, 2010; Smeltzer & Siferd, 1998).

Ramasesh (1991) puts forth that multiple-sourcing can provide a greater assurance of timely delivery and greater upside volume flexibility due to the diversification of the company's total requirements. On a strategic level the power of a supplier can be weakened with multiple sourcing, when the total requirement is split among multiple sources. In this way the strategy hedges the risks of creating a monopolistic (sole source) supply base and supplier forward integration (Newman, 1989). The most recognized effect of multiple sourcing is that it increases the competition among suppliers. This can lead to several benefits for the buyer like lower pricing, lower shipping costs and higher service (Render & Heizer, 1997; Segal, 1989). However, the quantity purchased with each supplier does need

to substantial enough to provoke the suppliers concern over losing the contract with the buyer while limiting the reliance on this supplier. Actually, when too many suppliers are used a buyer does not bear the advantage of his structural bargaining position (Porter, 1980). Also managing multiple suppliers can lead to higher managerial costs, something that can undo the benefits of bargaining a lower product price (Costantino & Pellegrino, 2010).

As can be seen, both strategies have beneficial effects, but also have drawbacks. Some effects can even occur with both strategies. To end this section an overview is provided in Table 2, containing the most recognized and likely effects of single and multiple sourcing, based on the work of Wisner et al. (2015).

Reasons favoring a Single Supplier	Reasons favoring Multiple Suppliers
Establishing a mutually beneficial strategic relationship	Lower risk of supply interruption
Less quality variability	Impose lower pricing through competition
Lower purchase cost due to order consolidation	Impose higher quality through competition
Lower costs due to avoiding duplicate fixed costs	Increasing market information from multiple sources
Transportation economies because of simpler routing	High volume that exceeds supplier capacity
Low volume that is too small to split	

Table 2: Sourcing strategy motivations, adapted from (Wisner et al., 2015)

Currently the buyer-supplier relationship, particularly in integrated supply chain settings, have grown into trusting, cooperative and mutually beneficial long term relationships. This allows successful companies to reap the benefits provided by multiple sourcing, while reducing the supply base, sometimes even leading to single sourcing (Berger, Gerstenfeld, & Zeng, 2004; Wisner et al., 2015).

2.2.3 Considerations on selecting a sourcing strategy

Some considerations in order to achieve a successful sourcing strategy need to be stated. First, single sourcing will only work when a supplier's capacities are relatively large compared to the product demand. In this case the least cost supplier might be selected. This also implies that with capacitated suppliers, multiple sourcing is favorable (Burke, Carrillo, & Vakharia, 2007). Second, single and multiple sourcing should not be assessed using the same weight for the criteria. Differences are found between the importance of price, reliability of the product, the availability of technical support and the total cost of the product. Determining the importance of these criteria on forehand will allow a company to make a better decision on its sourcing strategy (Swift, 1995). Third, the effects of a sourcing strategy are highly dependent on the type of product that is sourced. For products with a high degree of standardization and low products differentiation like commodities, the most important purchasing criteria are price and service. In this case the market characteristics allow for low switching costs and high competition making multiple sourcing a favorable strategy (Bensaou, 1999). In contrast to this, more complex products might enable a supplier to progress on a learning curve, lowering the production costs during the contracting period. This however, also increases the supplier's relative bargaining position. A tradeoff thus exists between the bargaining position and the rate by which learning effects at the supplier will decrease production costs (Heese, 2015). Finally, a sourcing strategy can also be influenced by cultural preferences. For instance in the Japanese manufacturing industry long-term relationships, partner specific investments and buyer-supplier cooperation are highly valued and more common than in other countries like the US (Richardson, 1993; Sako & Helper, 1998).

2.3 Supplier Selection

Literature on the topics of supplier selection and evaluation is extensive and a lot of research has been done. This is due to the fact that in literature, supplier selection is identified as a critical process in the operation of a firm (Chai & Ngai, 2014; Dulmin & Mininno, 2003; Weber, Current, & Benton, 1991). This awareness is not new as shown by the emphasis placed upon this issue in one of the early purchasing texts of Howard Lewis (1943): "It is probable that of all the responsibilities which may be said to belong to the purchasing officers, there is none more important than the selection of a proper source. Indeed, it is in some respects the most important single factor in purchasing" (Lewis p.249). The main underlying principle of this awareness is that supplier selection process is one of the most significant variables, which has a direct impact on the performance of an organization. As the organization becomes more and more dependent on their suppliers, the direct and indirect consequences of poor decision-making will become more critical (Chan & Kumar, 2007). Furthermore, small improvements in the practice of supplier selection can have a knock-on effect on the efficiency in downstream areas (Scott, Ho, Dey, & Talluri, 2014). This is also reflected in the fact that in industrial companies, the purchasing share in the total turnover typically ranges between 50 and 90 percent (Telgen, 1994). In addition to this critical property of supplier selection, the topic itself is also becoming increasingly complicated and important. The choice set of a purchaser is enlarged by the globalization of trade and use of internet. Customers preferences are changing and this requires a broader and faster supply base. Also do public procurement regulations demand more transparency in the decision-making and finally new organizational forms entail the involvement of more decision makers (de Boer, Labro, & Morlacchi, 2001). These developments are visualized in Figure 3 and it depicts how impact the importance and complexity of purchasing decisions.

2.3.1 Supplier selection classification

A classification of supplier selection situations is made by Faris et al. (1967). The most complicated situation would be a *new task* in a purchasing situation, in the sense that the level of uncertainty is the highest. A *modified rebuy* entails a new purchase from a known supplier and is less complex. The simplest task is a *straight rebuy* in the way that all information is known and it involves placing an order according to existing contracts and agreements. The complete classification is shown in Table 3.

Besides the Faris model, others are available in order to cover the dimensions of complexity of purchasing situations. Kraljic's (1983) portfolio approach combines the complexity with the importance of purchasing situations and they are identified in terms of two factors: *profit impact* and *supply risk*. The profit impact includes elements like the monetary volume involved with the goods or services to be purchased, and the impact on the product quality. The supply risk may be indicated with the availability of the goods or services and the number of potential suppliers. Kraljic grouped the purchasing decisions into a matrix, dependent of the value of these factors into strategic, bottleneck, leverage and routine purchases. The portfolio matrix can be seen in Table 4.

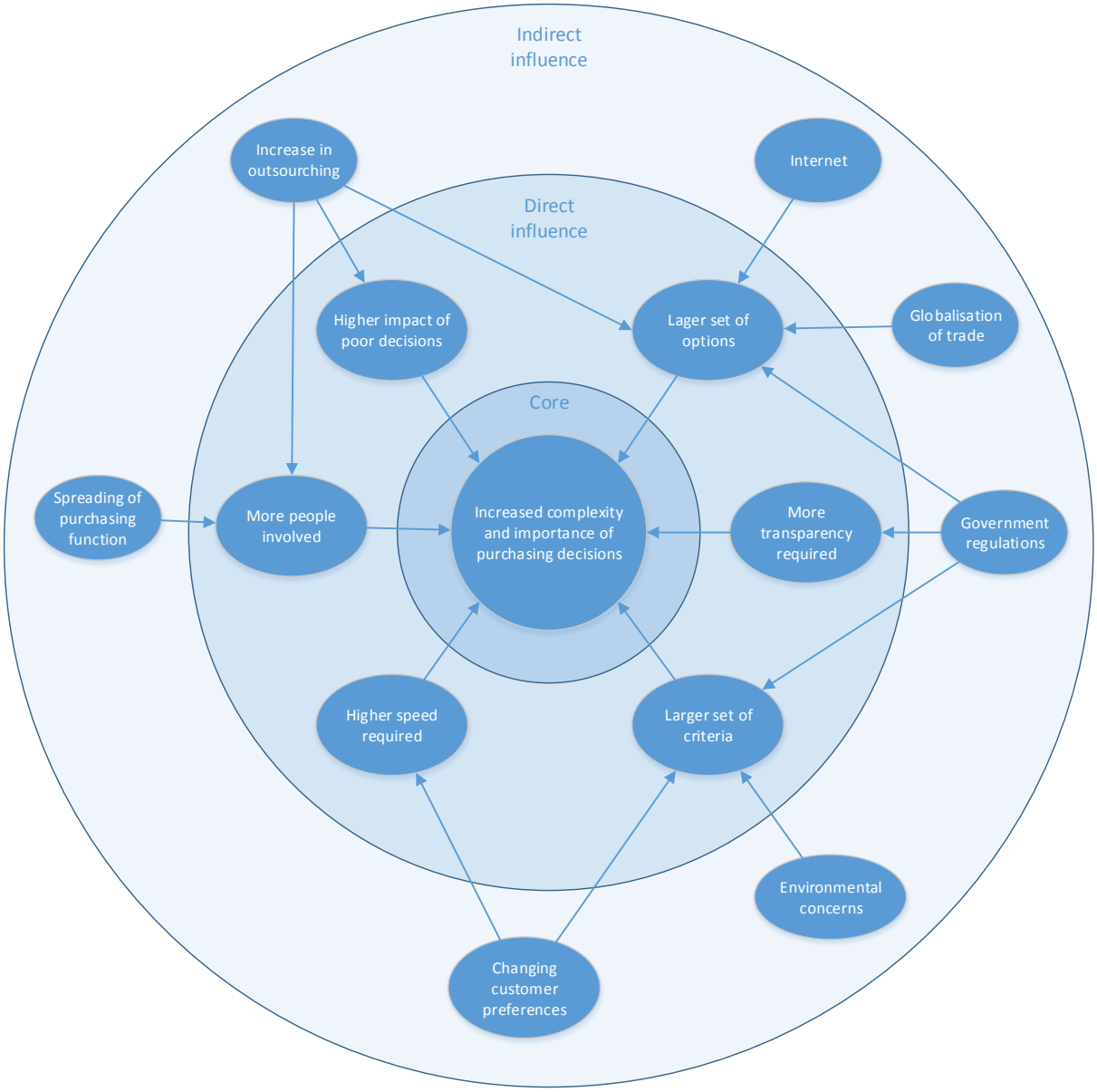

Figure 3: The increase in complexity and importance of buying decisions, adapted from de Boer et al. (2001)

New task situation	Entirely new product/service; no previous experience
	No (known) suppliers
	High level of uncertainty with respect to the specification
	Extensive problem solving; group decision making
Modified rebuy	New product/service to be purchased from known suppliers
	Existing (modified) products to be purchased from new suppliers
	Moderate level of uncertainty with respect to specification
	Less extensive problem solving
Straight rebuy	Perfect information concerning specification and supplier
	Involves placing an order within existing contracts and agreements

Table 3: Classification of purchasing situations (Faris et al., 1967)

	Low-supply risk	**High-supply risk**
Low-profit impact	*Routine items*	*Bottleneck items*
	Many suppliers	Monopolistic supply market
	Rationalize purchasing procedures	Long-term contracts
	Systems contracting	Develop alternatives (internally)
	Automate/delegate	Contingency planning
High-profit impact	*Leverage items*	*Strategic items*
	Many suppliers available	Few (difficult to switch) suppliers
	Competitive bidding	Medium/long-term contracts
	Short-term contracts	Supplier development/partnership (develop alternatives 'externally')
	Active sourcing	Continuous review

Table 4: Purchasing portfolio matrix (Kraljic, 1983)

In the work of de Boer, Labro and Morlacchi (2001) the two classification models of Faris and Kraljic and the distinction between single versus multiple sourcing, which has been described in the previous section, are nicely combined into a prescriptive framework of supplier selection situations. The purpose of the framework is to provide an overview of a manageable number of typical supplier selection situations with associated ways of carrying out and organizing the supplier selection process. It can be seen in Table 5 that in order to do so, de Boer et al. divided the straight rebuy situations in two categories dependent of their importance. As for the situation that relate to the case of the new oils and fats plant in China, the new task situations, de Boer et al. indicates that these decisions can have a varying importance. But irrespective of this, the basic sequencing, preparations and execution of the steps in the supplier selection process will be the same. The authors state that because of the unique character of the situation, the process can hardly be prepared.

	New task	Modified rebuy (*leverage items*)	Straight rebuy (*routine items*)	Straight rebuy (*strategic/bottleneck*)
Problem definition	Use a supplier or not?	Use more, fewer or other suppliers?	Replacing the current supplier?	How to deal with the supplier?
	Varying importance	Moderate/high importance	Low/moderate importance	High importance
	One-off decision	Repeating decision	Repeating decision	Repeating evaluation
Formulation of criteria	No historical data on suppliers available	Historical data on suppliers available	Historical data on suppliers available	Historical data on suppliers available, yet very few actual selections
	No previously used criteria available	Previously used criteria available	Previously used criteria available	Previously used criteria available
	Varying importance			
Qualification	Small initial set of suppliers	Large set of initial suppliers	Large set of initial suppliers	Very small set of suppliers
	Sorting rather than ranking	Sorting as well as ranking	Sorting rather than ranking	Sorting rather than ranking
	No historical records available	Historical data available	Historical data available	Historical data available
Choice	Small initial set of suppliers	Small to moderate set of initial suppliers	Small to moderate set of initial suppliers	Very small set of suppliers (often only one)
	Ranking rather than sorting	Ranking rather than sorting	Ranking rather than sorting	Historical data available
	Many criteria	Also: how to allocate volume?	Fewer criteria	Evaluation rather selection
	Much interaction	Fewer criteria	Less interaction	Sole sourcing
	No historical records available	Less interaction	Historical data available	
	Varying importance	Historical data available	Model used again	
	Model used once	Model used again	Single sourcing rather than multiple sourcing	

Table 5: The supplier selection framework (de Boer et al., 2001)

A final note on the supplier selection process relates to the perception of the decision makers. When they are asked on their opinion on what is the most important attribute when selecting supplier they will state a different attribute from the one they actually use when they are involved in the selection process. This effect is addressed by Verma and Pullman (1998) who state that managers perceive quality to be the most important attribute when selecting a supplier. When this is checked with the actual choice made by the suppliers it appears that even though managers understand and perceive quality to be more important than cost, in practice they do not choose suppliers based on quality. More detail on the use of criteria is provided in section 2.5.

A gap thus exists between the perception and actual practice. Their choice of suppliers is not the same as the perceived importance of the attributes (Verma & Pullman, 1998). This is very complex to deal with and it should be kept in mind in the case of the new plant.

2.4 Multi-Criteria Decision-Making

Supplier selection is regarded as a typical multi-criteria decision problem (Liao & Rittscher, 2007). The theory to address this problem is called Multi-Criteria Decision-Making (MCDM) and was developed by Keeney and Raiffa (1976). Ever since then it is widely accepted by academic and industrial communities (Chai & Ngai, 2014). MCDM problems are generally divided into two classes based upon the solution space of the problem. For continuous problems with an infinite or non-countable set of alternatives, Multi-Objective Decision-Making (MODM) methods are used. For discrete problems with a finite number of alternatives, Multi-Attribute Decision-Making (MODM) methods are used. However in existing literature MCDM is commonly used to describe the latter of the two categories (Rezaei, 2015a). The goal of decision-making is to find the best option from all feasible alternatives. In almost all of such problems the multiplicity of criteria for evaluating the alternatives is pervasive. In that case the decision-maker wants to solve a MCDM problem C. T. Chen (2000). These can problems can concisely be expressed in matrix form as can be seen in equation 1.

$$D = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \end{array} \\ \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \end{array},$$

$$W = [w_1\ w_2\ \cdots\ w_n],$$

(1)

Where $A_1, A_2, \ldots A_m$ are possible alternatives among which decision makers have to choose, $C_1, C_2, \ldots C_n$ are criteria with which the performance of an alternative are measured, x_{ij} is the rating of Alternative A_i with respect to criterion C_j and w_j is the weight of criterion C_j. In order to reach the goal of finding the best option among the alternatives the overall value of the alternatives needs to be obtained. This can be acquired according to various methods, but in general form if weight w_j ($w_j \geq 0$, $\sum w_j = 1$) is assigned to criterion j, the value of alternative i, V_i can be obtained using a simple additive weighted value function, which is the underlying model of most MCDM methods (Rezaei, 2015a) and can be seen in equation 2.

$$V_i = \sum_{j=1}^{n} w_j\, x_{ij}$$

(2)

There are numerous ways in which the weights can be obtained and this has been the catalyst for many different MCDM methods that have been developed during the last decades.

Regarding these methods, in recent history there are at least three academic surveys on methods and criteria for supplier selection. De Boer et al. (2001) reviewed MCDA approaches for supplier selection and suggested four problem solving stages: problem definition, criteria formulation,

supplier qualification and ranking and selection. Also the research concluded that the focal point of most research is placed upon the choice phase in the supplier selection process. The phases prior to this, namely problem definition, criteria formulation and qualification, have received far less attention from researchers in operations research or purchasing and supply. It stands to reason that this is because the choice phase is often the most visible phase. However, the quality of the choice phase is largely dependent on the quality of the steps prior to that phase and thus the determination of the criteria should receive adequate attention. Finally it concludes that the existing articles on methods for supplier selection do not sufficiently address the context of the issue at hands. Often they assume, explicitly or implicitly, that their method is applicable in all purchasing contexts. The study categorizes the available literature per supplier selection situation as used in Table 5. It is striking that for the new task situations there is very little research available, even none for the events of problem definition and criteria formulation. For the complete overview please see de Boer et al. (2001).

Ho, Xu and Dey (2010) primarily summarized the literature between 2000 and 2008. The most prevalent individual approach is Data Envelopment Analysis (DEA), a nonparametric mathematical programming technique for evaluating the relative efficiency of comparable entities in terms of decision-making units (Chai et al., 2013). The most popular integrated approach is Analytic Hierarchy Process with Goal Programming (AHP-GP). With AHP the relative importance of a set of activities in a multi-criteria decision problem is determined. The process makes it possible to both incorporate judgments on intangible qualitative criteria as well as tangible quantitative criteria. In the combined model, the objective function also includes deviation variables associated with the quality measure goals. It will seek to minimize such deviations from desired levels (Badri, 2001). It is noteworthy to mention that AHP is a technique that has been around for a while, it was developed by Saaty (1977) in the seventies. Besides this, Ho et al. (2010) also observed that the most widely adopted criterion used for evaluating the performance of suppliers is nor price or cost, but quality, followed by delivery and then price or cost. This shows that the traditional single criterion approach based on lowest cost is not valid anymore for contemporary supply chain management. This traditional approach cannot guarantee that the selected supplier is global optimal because the customer-oriented criteria were not considered Ho et al. (2010). A more elaborate research on the criteria for supplier selection will be provided in the next section.

The third survey was conducted by Chai et al. (2013) and reviewed 123 international journal articles published from 2008 to 2012. It identified AHP still to be the most popular decision-making technique, followed by mathematical programming. Most recent literature seems to incorporate more real-world uncertainties and human effects into decision-making techniques (Chai & Ngai, 2014). The preference of the decision maker and the effect of this on the criteria analysis and supplier selection is an example of this latter effect.

Many methods are available in order to apply the MCDM paradigm to the selection of suppliers and it seems that AHP is a highly used approach. These models do have their limitations, they often focus solely on the choice phase and their applicability in the purchasing context can be troublesome.

2.5 Criteria for Suppliers Selection

The subject of supplier selection is something that has been researched extensively as described in the first section of this chapter. In the previous section the focal point of most research was addressed, this not being equally divided over the different phases as indicated by de Boer (2001), but focusing on the choice phase. However, the quality of the choice phase is largely dependent on the quality of the steps prior to that phase. This section will therefore go into detail on the criteria for supplier selection.

The available criteria that can be used for supplier selection are numerous and before looking into this, it is wise to create a broader understanding of the differences between these criteria. Traditionally suppliers are focused on the evaluation of a mostly quantitative technical output in terms of quality, delivery, speed and price (Weber et al., 1991). However, when relationships are of importance, the number of criteria increase and the distinction and definition of the criteria can become vaguer. In the latter case, more intangible and qualitative criteria like supplier involvement, company image and continuous improvement capabilities become of greater importance (Dulmin & Mininno, 2003). This construct is also coupled with the distinction between the manufacturing and the services industry (Feng, Fan, & Li, 2011). The focus of this research will be on the manufacturing industry since this is the industry in which the case company is active.

Techniques on the formulation of criteria are limited and this subject has not received much attention in the purchasing literature. Two techniques for the formulation of criteria are identified by de Boer et al. (2001). These are Interpretive Structural Modelling (ISM) by Mandal and Deshmuk (1994) and an expert system developed by Vokurka, Choobineh and Vadi (1996). However these techniques are used for a straight rebuy task. For a new task there no techniques available (de Boer et al., 2001).Therefore the following sections will present an overview of the criteria found in literature on supplier selection.

2.5.1 Literature on management criteria for supplier selection

Important work on supplier selection criteria has been carried out by Dickson (1966). In his seminal work, a questioner was sent to 273 purchasing agents and managers in Canada and the United States. With 170 responses Dickson was able to summarize in his study the importance of 23 criteria for supplier selection. The criteria and their rank, rating and importance can be seen in Table 6.

Rank	Factor	Mean rating	Evaluation
1	Quality	3,508	Extreme importance
2	Delivery	3,417	
3	Performance history	2,998	
4	Warranties and claim policies	2,849	
5	Production facilities and capacity	2,775	Considerable importance
6	Price	2,758	
7	Technical capability	2,545	
8	Financial position	2,514	
9	Procedural compliance	2,488	
10	Communication system	2,426	
11	Reputation and position in industry	2,412	
12	Desire for business	2,256	

13	Management and organization	2,216	
14	Operation controls	2,211	
15	Repair service	2,187	Average importance
16	Attitude	2,120	
17	Impression	2,054	
18	Packaging ability	2,009	
19	Labor relations record	2,003	
20	Geographical location	1,872	
21	Amount of past business	1,597	
22	Training aids	1,537	
23	Reciprocal arrangements	0,610	Slight importance

Table 6: Dickson's vendor selection criteria (Dickson, 1966)

Based upon this work, Weber, Current and Benton (1991) reviewed the research conducted since the study of Dickson in 1966. The primary purpose of their paper is to review the literature published since the Dickson study in order to provide a comprehensive view of the criteria that academicians and purchase practitioners feel are important in the supplier selection process (Weber et al., 1991). In total 74 articles were reviewed, annotated and classified. An overview of appearance in the literature used by Weber and their rank in Dickson's study is provided in Table 7. It must be noted that while the Dickson study is based upon information from the industry, the work of Weber et al. is primarily based only upon academic literature. Hence any comparisons should be done with the notice of the difference in 'populations' (Weber et al., 1991).

Rank	Rating	Factor	Number of articles	%
6	1	Net price	61	80
2	1	Delivery	44	58
1	1A	Quality	40	53
5	1	Production facilities and capacity	23	30
20	2	Geographical location	16	21
7	1	Technical capability	15	20
13	2	Management and organization	10	13
11	2	Reputation and position in industry	8	11
8	1	Financial position	7	9
3	1	Performance history	7	9
15	2	Repair service	7	9
16	2	Attitude	6	8
18	2	Packaging ability	3	4
14	2	Operational controls	3	4
22	2	Training aids	2	3
9	2	Bidding procedural compliance	2	3
19	2	Labor relations record	2	3
10	2	Communications system	2	3
23	3	Reciprocal arrangements	2	3
17	2	Impression	2	3
12	2	Desire for business	1	1
21	2	Amount of past business	1	1

4	1	Warranties and claims	0	0
	Ratings:	1A = Extreme importance		
		1 = Considerable importance		
		2 = Average importance		
		3 = Slight importance		

Table 7: Criteria found in literature by Weber et al. and their Dickson rank (Weber et al., 1991)

In the academic literature, Weber found that in 47 cases one or more criteria presented in the Dickson study were discussed. Furthermore, the net price, delivery and quality were discussed in respectively 80, 59 and 54% of the articles. This underlines the multi-attribute nature of supplier selection and it indicates that many of the criteria remained important in the field of supplier selection and that the Dickson study can still provide valuable information although it is conducted in the sixties. The developments in the field of supplier selection criteria can be seen with the increase of importance of the geographical location that is found in 21% of the literature, while it received an average importance (ranked 20th) in the Dickson study. A trend in manufacturing strategy at that time was the Just-in-Time (JIT) philosophy and this brought increased concern over the geographical location of suppliers. Warranties and claims were of considerable importance (ranked 4th) in the Dickson study but it was not specifically discussed in any of the literature review by Weber. It is likely that this criterion has been included as component of other criteria or that this criterion is discussed in publications, for instance legal publications, that are not considered in this study (Weber et al., 1991).

The work of Dickson and Weber has been used to build upon in numerous other academic literature (Cheraghi, Dadashzadeh, & Subramanian, 2004; Kar, 2014; Ng, 2008; Parthiban, Zubar, & Katakar, 2012; Roodhooft & Konings, 1997; Thiruchelvam & Tookey, 2011; Xia & Wu, 2007). This indicates the value of the work. A further extension of the overview of criteria used in supplier selection literature in the period after the Weber study is provided by Cheraghi (2004). In an update on the topic, Cheranghi reviewed 113 scientific papers in the post-Weber period until 2001. This work is summarized in Table 8, and it provides a comparison of the criteria used in the period of 1966 until 1990 (Dickson and Weber) and the following period of 1991 until 2001.

Factor	1966 - 1990		1990 - 2001		Overall	
	Papers	%	Papers	%	Paper	%
Quality	40	54	31	79	71	63
Delivery	45	61	30	77	75	66
Performance History	7	9	4	10	11	10
Warranties & Claim Policies	1	1	0	0	1	1
Production Facilities and Capacity	25	34	10	26	35	31
Price	55	74	26	67	81	72
Technical Capability	19	26	11	28	30	27
Financial Position	8	11	7	18	15	13
Procedural Compliance	2	3	2	5	4	4
Communication System	3	4	4	10	7	6
Reputation and Position in Industry	9	12	1	3	10	9
Desire for Business	2	3	0	0	2	2

Management and Organization	10	14	7	18	17	15
Operating Controls	5	7	0	0	5	4
Repair Service	7	9	11	28	18	16
Attitude	9	12	5	13	14	12
Impression	4	5	2	5	6	5
Packaging Ability	5	7	0	0	5	4
Labor Relations Record	3	4	1	3	4	4
Geographical Location	15	20	2	5	17	15
Amount of Past Business	1	1	0	0	1	1
Training Aids	3	4	0	0	3	3
Reciprocal Arrangements	3	4	2	5	5	4

Table 8: Comparison of criteria between the periods of 1996 – 1990 and 1990 – 2001 (Cheraghi et al., 2004)

A better insight on the significant changes in the use of criteria is provided in Figure 4. It shows that while the criterion geographical locations gained importance partially due to the JIT philosophy in the period after the Dickson study, it has certainly lost importance based on the reduction of it use in papers from 20 to 5%. The globalization of the world economy has resulted in an increase in the number of firms that have shifted their concentration on domestic sourcing to development of supplier bases around the world (Min, 1994). This construct no longer favors supplier in the proximity of a buyer and therefore the geographical location is of less importance. Furthermore it is remarkable that the criterion repair service has gained in attention. Customer are becoming more knowledgeable in terms of defining their requirements in combination with an increase in competition, customers have begun to dictate the terms of purchasing. Old company values like mass production, stability, and growth are no longer a guarantee for success. A shift has occurred towards customer satisfaction, which places the criterion repair service within the new values of many companies (Cheraghi et al., 2004). This is also concluded in the work of Kannan, Khodaverdi, Olifat, Jafarian and Diabat (2013) which states that in the early 1990s cycle time and customer responsiveness were considered, and finally in the late 1990s, the focus shifted to flexibility. Also the usual suspects of quality, delivery and price have remained the most important criteria, although their ranking has changed. Especially quality, but also delivery has received more attention, while price has received less. The latter is a function of cost, profit margin, and market forces, and delivery is a function of the organization's efficiency and effectiveness. However, quality is determined by the extent to which a product or service successfully serves the purpose of the user during usage and not just at the point of sale. Price and delivery are transient features whereas the impact of quality is sustained long after the effects of price and delivery have receded. (Cheraghi et al., 2004). This perspective can explain the increase in importance of quality. However, please bear in mind the gap between stated preference and actual choice by decision makers as indicated by Verma and Pullman (1998), described in section 2.3.1.

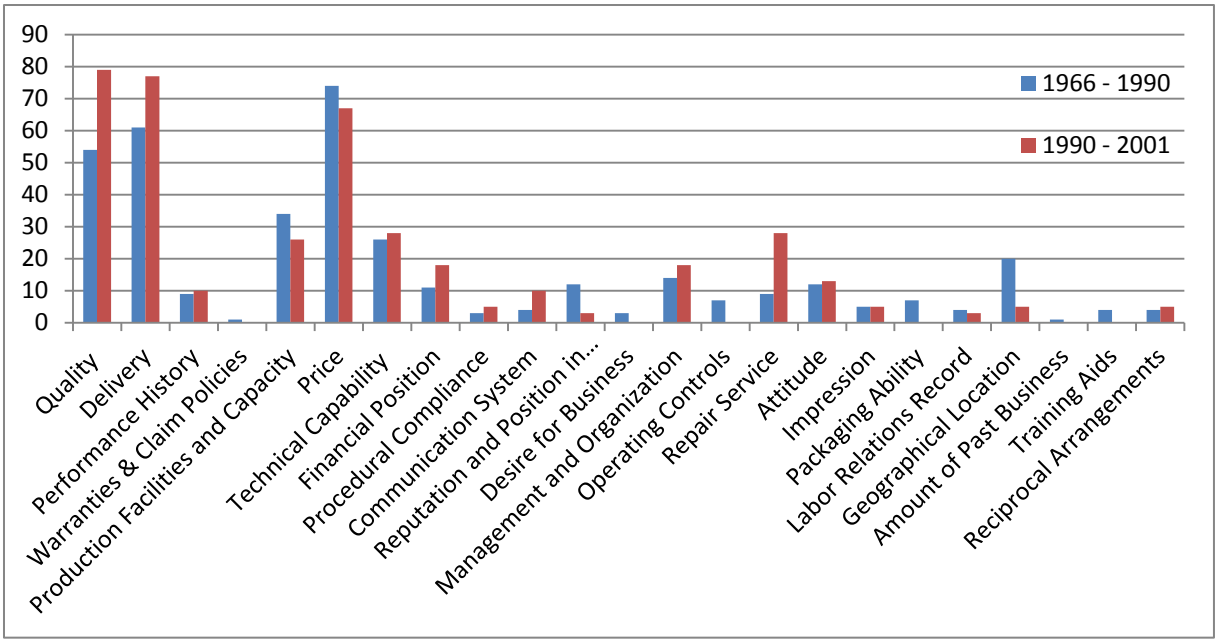

Figure 4: Comparison of criteria between the periods of 1996 – 1990 and 1990 – 2001 (Cheraghi et al., 2004)

When more recent work is considered the three criteria of price, quality and delivery remain the most important. Other criteria of importance are of a less tangible character. In the study of Shyur and Shih (2006) on the development of a model for supplier selection process in new task situations, several criteria per line of business are selected from the literature of Weber (1991), Muralidharan et al. (2002), Petroni and Braglia (2000) and Karpak et al. (1999). The criteria relevant for the same line of business as the case company is in, are shown in Table 9.

Factor	Proposed by
Price	Weber (1991), Muralidharan et al. (2002), Petroni and Braglia (2000) and Karpak et al. (1999)
Quality	Weber (1991), Muralidharan et al. (2002), Petroni and Braglia (2000) and Karpak et al. (1999)
Delivery	Weber (1991), Muralidharan et al. (2002), Petroni and Braglia (2000) and Karpak et al. (1999)
Technical capability	Muralidharan et al. (2002)
Financial position	Muralidharan et al. (2002)
Past performance attitude	Muralidharan et al. (2002)
Flexibility	Muralidharan et al. (2002)
Service	Muralidharan et al. (2002)

Table 9: Selected criteria for supplier selection (Shyur & Shih, 2006)

It can be noted that for all, except flexibility the criteria have already been mentioned by Weber, though not by the exact same definition. This again underlines the value of the study.

In the extensive research of Ho et al. (2010) the most popular criterion in the reviewed literature of the period 2000 to 2008 is determined. It was revealed that the shift of focus from price towards quality that started off in the 1990s, continued in the successive decade as the most popular criterion remains quality. The second most popular criterion is delivery and third is price. These three dominant criteria are followed by manufacturing capability, service, management, technology,

research and development, finance, flexibility, reputation, relationship, risk and safety and environment.

The study of Chang, Chang and Wu (2011) takes a step away from the three most used criteria of price quality and delivery. This study pioneers in using the fuzzy decision-making trial and evaluation laboratory (DEMATEL) method to find influential factors in selecting suppliers. The method evaluates supplier performance to find the key factor criteria to improve the decision-making information in supplier selection. The study finds that technology ability, stable delivery of goods, lead time, and production capability criteria are more influential than other evaluation criteria. It must be noted that these criteria are based upon a survey of 17 businesses in the electronics industry and that use existing supplier in the situation of a straight or modified rebuy. The applicability of these criteria in the case of a new task is not stated.

A recent study by Pal (2013) reviewed the available literature on supplier selection. A total of 34 articles were used to determine the current research status of supplier selection criteria and methods. In literature many of the criteria from the study of Weber were found. Pal selected the criteria in Table 10 to be the most important in the supplier selection process. It must be noted that although many studies reviewed are of the period after 2000, some older studies were also considered. This overview is thus not characterized with such a clear distinction in time as the previous literature reviews.

Factors	
Price	Reputation and Position in Industry
Quality	Desire for Business
Delivery	Repair Service
Performance History	Attitude
Warranty and Claim Policies	Packaging Ability
Production Facilities and Capacity	Labor Relations record
Technical Capability	Geographical Location
Financial Position	Amount of Past Business
Procedural Compliance	Reciprocal Arrangement

Table 10: Important criteria found in literature by Pal (2013)

Pal (2013) stated that from the literature used in his study it can be concluded that price, delivery and quality, continue to be the most dominant criteria. Further information on the ranking or importance is not provided. It is striking that little attention is paid on environmental factors. This latter issue is addressed by Kannan et al. (2013) who does state that environmental factors are becoming a key issue which will give rise to the new paradigm green supply chains.

2.5.2 Literature on environmental criteria for supplier selection

When the focused is placed upon the use of environmental criteria it seems that while there is a large amount of research done on the traditional criteria for supplier selection, the literature regarding green supplier evaluation or work that considers environmental criteria is less extensive (Amindoust, Ahmed, Saghafinia, & Bahreininejad, 2012; Handfield, Walton, Sroufe, & Melnyk, 2002; Lee, Kang, Hsu, & Hung, 2009). Also the work that has been done on environmental criteria for supplier selection can be focused solely on the sustainability topic itself. When this needs to be combined with traditional supplier selection criteria the applicability of the combined becomes a

challenge. The compatibility of environmental supplier criteria with management criteria is far from seamless and a possible trade-off arises when both criteria are considered (Dobos & Vörösmarty, 2014). It seems that green supplier selection is often far from straightforward. The criteria are less specific and can be ambiguous. Therefore the operationalization of these criteria into meaningful, practical and measurable variables often poses challenges, both for purchasers and suppliers (Igarashi, de Boer, & Fet, 2013). This must be kept in mind when environmental criteria are selected. A structuring manner introduced by Lloyd (1994), is by categorization of two main criteria groups. Environmental criteria related to the supplier and criteria related to the product. Literature addressing environmental criteria for supplier selection is available and it has received more attention in recent years (Humphreys, Wong, & Chan, 2003; Lee et al., 2009). The work of several researchers who summarize the available literature is used to construct the overview of Table 11 (Amindoust et al., 2012; Hashemi, Karimi, & Tavana, 2015; Kuo, Wang, & Tien, 2010).

Factor	Proposed by
Pollution production	(Amin & Zhang, 2012; Govindan, Khodaverdi, & Jafarian, 2013; Humphreys et al., 2003)
Pollution control	(Awasthi, Chauhan, & Goyal, 2010; Bai & Sarkis, 2010; Lee et al., 2009; Qinghua, Yijie, & Joseph, 2010)
Resource consumption	(Amin & Zhang, 2012; Bai & Sarkis, 2010; Govindan et al., 2013; Qinghua et al., 2010)
Environmental costs	(Humphreys et al., 2003; Mafakheri, Breton, & Ghoniem, 2011; Noci, 1997; Yeh & Chuang, 2011)
Environmental management system	(Amin & Zhang, 2012; Awasthi et al., 2010; Bai & Sarkis, 2010; Govindan et al., 2013; Handfield et al., 2002; Hsu & Hu, 2009; Humphreys et al., 2003; Kuo et al., 2010; Lee et al., 2009; Mafakheri et al., 2011; Qinghua et al., 2010; Tseng & Chiu, 2013; Yeh & Chuang, 2011)
Green image	(Mafakheri et al., 2011; Noci, 1997)
Green/environmental competencies	(Handfield et al., 2002; Hsu & Hu, 2009; Humphreys et al., 2003; Lee et al., 2009; Mafakheri et al., 2011; Noci, 1997)
Procurement management	(Hsu & Hu, 2009)
Incoming quality control	(Hsu & Hu, 2009)
Green R&D	(Awasthi et al., 2010; Hsu & Hu, 2009; Tseng & Chiu, 2013)
Green supply chain management	(Tseng & Chiu, 2013; Yeh & Chuang, 2011)
Innovation	(Amin & Zhang, 2012; Tseng & Chiu, 2013)
Product	
Green product	(Handfield et al., 2002; Qinghua et al., 2010; Tseng & Chiu, 2013) (Amin & Zhang, 2012; Lee et al., 2009; Qinghua et al., 2010)
Green/Eco-design	(Awasthi et al., 2010; Govindan et al., 2013; Humphreys et al., 2003; Kuo et al., 2010; Mafakheri et al., 2011; Tseng & Chiu, 2013; Yeh & Chuang, 2011)
Recycling	(Amin & Zhang, 2012; Yeh & Chuang, 2011)

Table 11: Environmental criteria found in literature

2.5.3 Classification of the criteria for supplier selection

Clearly there is a wide variety of criteria for supplier selection. In order to create a better overview, categories can be used as a way of grouping the criteria. In literature different ways of categorization have been applied. Rezaei and Ortt (2011) for instance state that in general there are three categories. These are 'Element of exchange', 'Supplier' and 'Relationship'. The first category relates to the good or service that is being exchanged from the supplier to the buyer. The second category relates to the characteristics of the supplier and the third category relates to the relationship between the buyer and supplier. A categorization of four is provided by Kahraman and Kaya (2010) who define 'Supplier criteria', 'Product performance criteria', 'Service performance criteria' and 'Cost criteria'. Other categorizations are available (Huang & Keskar, 2007; Luo, Wu, Rosenberg, & Barnes, 2009) but the separation of criteria relating directly to the product and the supplier are the most prevalent. Some other might take financial elements as a separate category, this will be motivated by the topic of the research paper in which the categories are used. As for supplier selection in the case of this research, more primary and easy assessable criteria are important. This is because the buying task which is a new task situation as indicated by the classification of Faris et al. discussed in section 2.3.1. Therefore more detailed classification on financial elements or innovation are not desired. The classification in this research will therefore consider the three categories of 'Goods', 'Supplier' and 'Relationship'.

2.5.4 Conclusions on supplier selection criteria in literature

To conclude on the literature review of supplier selection criteria it can be stated that it has been the topic of interest in academic literature as early as the 1960s. Several periods with different criteria of emphasis have gone by. At first little or even a single criterion was used for supplier selection and the focus was placed upon cost. In the 1970s and early 1980s the number of criteria grew and delivery and quality gained importance. This eventually led to a change in focus in the 1990s when the quality became the dominant criterion and also delivery was considered more important than cost. Several criteria became outdated or redundant due to their incorporation in other criteria or fields of research. The increase in popular production strategies, for instance JIT, favored the use of certain criteria like geographical location. This eventually changed due to globalization and an emphasis on more intangible and service related criteria. Customer satisfaction, cycle time, responsiveness and later on flexibility become important criteria around the year 2000. The changes in the new millennium seem less volatile as quality, delivery and price remain the most important criteria. Also it appears that literature on other criteria is not congenial on the importance. There is a diversity of criteria that are considered to be important in different studies. Examples of these are: service, management, technology ability, lead time, research and development, finance, flexibility, reputation, relationship, risk and safety and environment. Although the literature might not be unanimous on the important criteria, consensus is found in the fact that criteria become more intangible and possibly harder to measure. Finally the use of environmental supplier selection criteria that previously were hardly mentioned in literature seems to take off. However the compatibility with the traditional criteria is limited and a trade-off can arise between these categories. In order to use a well-founded base of criteria, the findings on supplier selection criteria in this literature research will be checked with experts of the case company. The most prevalent criteria, both traditional and environmental will be used to complement the criteria indicated by the experts. This construct will be further discussed in the next chapter.

2.6 Sustainability

The topic of sustainability is highly linked to the industry of edible oils as many issues have been indicated in the past. For this to be reflected in the thesis, the following section will discuss the topic in relation to supply chain management and the industry.

2.6.1 Sustainability background and concepts

A growing number of companies have realized that environmental management is a key strategic issue with the potential for a lasting impact on organizational performance (Zhu & Sarkis, 2006). This gives way to the expectation that all companies will need to implement strategies to reduce the environmental impacts of their products and services (Lewis & Gretsakis, 2001). The concept of sustainability has first been described by the Brundtland Commission in 1987 as: ”development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (WCED, 1987). Since then numerous definitions of sustainability haven been introduced, but most of these are based upon the three perspectives of environment, society and economy. A well-known concept that uses these perspectives is the ‘triple bottom line’ concept which has received great attention after Elkington (1998) published his work on this topic (Krajnc & Glavič, 2005). The idea behind this concept is that a company’s health or performance should not just be measured by the traditional financial bottom line, but also by its social and environmental achievements. This however is a very difficult task and the measurement of the three aspects is still very skewed (Norman & MacDonald, 2004). Other concepts strongly linked to these three dimensions are ‘people, planet, profit’ and the ‘three pillars of sustainability’ (Kleindorfer, Singhal, & Van Wassenhove, 2005; Pope, Annandale, & Morrison-Saunders, 2004).

2.6.2 Sustainability in supply chain management

Because the term is widely used, it is wise to discuss how it is applied in supply chains and supply chain management. Within this field of research, the increase of attention for sustainability has paved the way for a new cross-disciplinary, namely green supply chain management (GSCM) and it has received growing attention within both academia and the industry in recent years (Sarkis, Zhu, & Lai, 2011). Again as with the interpretation of sustainability itself, there is no single clear definition, but useful literature for this provided by Pagell and Wu (2009). They state that a truly sustainable supply chain would at worst do no net harm to natural or social systems while still producing a profit over an extended period of time. However, until now no such supply chain exists. Therefore this objective must be seen as a scale that companies live up to in different extents. With respect to suppliers, traditional purchasing strategy suggests that when buying a commodity, leverage should be used over the suppliers because they are easily replaced. But sustainable organizations have shown to turn that notion on its head and instead de-commoditized not only their own business, but also their suppliers’ businesses. Supply management at these organizations also has a deep social dimension. Supply base continuity, material traceability and price transparency demonstrate a concern for the long-term well-being and social equity of every member of the supply chain (Pagell & Wu, 2009). A pitfall in reaching this is indicated by Seuring & Müller (2008) and arises when sustainability is treated as a subset of logistics management. This is a limitation that many companies encounter and therefore they are not able to become truly sustainable.

With regard to supplier selection, the field of research also has given way to green supplier selection. The criteria used for green supplier selection are growing. This is also reflected in the analysis of section 2.5.2 of this literature research, which identifies environmental criteria for supplier selection.

The compatibility and integration with the traditional management criteria remains a challenge, but the number of researchers proposing methods for specific or combined green supplier selection is increasing (Büyüközkan & Ifi, 2012; Hsu & Hu, 2009; Kuo et al., 2010; Lee et al., 2009; Tsai & Hung, 2009).

2.6.3 Sustainability in the edible oil industry

Demand for edible oil is growing on a global level, fueled by an increase in applications in biofuels, food ingredients, soap and other chemicals. As a result palm oil production increased which has led to economic growth in producing countries, but also to environmental and social problems such as destruction of tropical forests, climate change and a decrease in biodiversity. For these reasons, the use of palm oil and its production have become controversial. Because of the global character of production and consumption and the many actors involved and its multiple use, the task of creating a sustainable palm oil industry is highly complex (Oosterveer, 2014). Individual national governments can no longer oversee and control the global flow of palm oil and an overarching body is needed to shoulder the responsibility of a sustainable palm oil industry. In the late 1990s, the WWF brought the connection of rapid rainforest destruction and the use of everyday consumer products like margarine and fats under public attention by starting a case study on its correlation. This was followed by a mobilization of the industry actors to form the Roundtable on Sustainable Palm Oil (RSPO). The WWF brought together palm oil processing and trade companies, financial players, NGOs, retailers and food manufacturers as well as consultants, like Aarhus, Migros, the MPOA, Sainsbury's and Unilever. Other active agents serving on the RSPO's Executive Board were Pacific Rim Palm Oil and The Body Shop. On the 8th of April 2004, the RSPO, was formally established as a non-profit organization (Midttun, Nikoloyuk, Burns, & de Man, 2010). It aims to transform markets to make sustainable certified palm oil the norm and unite stakeholders from the palm oil industry to develop and implement global standards for sustainable palm oil. The RSPO currently has 2166 members and 18% of the global palm oil is RSPO certified (RSPO, 2015).

Although this success, there is some criticism on this form of sustainability. There an insufficient consideration for the increased market demand for palm oil, something that limits the ability of the RSPO to steer value chains towards sustainability (Schouten & Glasbergen, 2011). Subsequently, the membership to RSPO seems to be used as a badge for corporate responsibility at company level, which could give off a false image of sustainability (McCarthy, Gillespie, & Zen, 2012). Also there is a concern on the integration of small-scale farmers as they struggle in the power structure of the industry (von Geibler, 2013). This structure has shifted dramatically and it is result of the increasing demand from emerging economies like China, increasing oil prices and the introduction of biofuel policies in countries in the EU (Midttun et al., 2010). According to McCarthy (2012), this unequal distribution of power in the global supply chain is real cause for uncontrolled oil palm expansion. This criticism shows that major challenges still exist and the and the industry is still far from being truly sustainable. However, with the introduction of certified palm oil by the RSPO a change has been made and the increase in its use is promising.

2.7 Differences and Considerations in the Chinese Business Culture

As the research on the supplier selection will also include Chinese suppliers this section will briefly discuss cultural differences and considerations that might play a role in the supplier selection process. Besides the selection of suppliers this section will also hold ties with the sourcing strategy as this can be influenced by cultural beliefs. When depending on a single supplier for instance, one should be aware of effects of cultural differences that can affect the relationship between a buyer and a supplier.

2.7.1 Literature on Chinese business culture

Academic researchers have a keen interest in the cultural differences between Western and Asian countries since the position of the local markets have radically changed in the past few decades, with China now being the biggest economy according to the IMF (Carter, 2014). However the research conducted on purchasing in China is nowhere near proportional to the current position of the country's economy. Relatively little is known on the development and content of the relations of Western companies with their Chinese suppliers (Davies, Leung, Luk, & Wong, 1995; Wang, 2007). More general literature on business in China reports that there are substantial differences between Chinese and Western companies. It is reported that companies entering the Chinese market encounter more difficulties than they anticipated (Ambler, Witzel, & Xi, 2008). A common understanding in literature on Chinese business culture is that personal relationships or connections have a high importance. This concept known as *Guanxi* is based on factors that provide a shared social experience between and among individuals in traditional Chinese society (Chiao, 1982; King, 1991). The importance of Guanxi in business relationships is stated by Wang (2007):

> It *is composed of two Chinese characters,* guan *(gate) and* xi *(connection). One must pass the gate to get connected to networks. As such,* Guanxi *generally refers to relationships or social connections based on mutual interests and benefits (Yang, 1994). It is a special type of relationship that bonds the exchange partners through reciprocal obligations to obtain resources through a continual cooperation and exchange of favors (M. Chen, 2004; Davies et al., 1995).*

This concept is important to understand and adhere to for a Western company, trying to enter the Chinese market.

2.7.2 Differences and considerations

When it comes to sourcing, it is important that China is not perceived as a coherent nation or a homogenous market. Large differences exists between regions in terms of salary or economic development, which might pose a barriers (Fang, Olsson, & Sporrong, 2004). On an individual level, one must contemplate personal relations as they can expose valuable information in the search for suppliers. Once a supplier is contacted, face-to-face contacts are important for business negotiations (Millington, Eberhardt, & Wilkinson, 2006). Furthermore, the concept of 'face' refers to the way an individual is viewed by others close to him or her. Interaction in a pleasant and comfortable way is important. One must maintain its own composure and at all times and avoid causing embarrassment to one itself or another. Another cultural aspect that is to be kept in mind is that the Chinese find it difficult to disclose bad news. This relates to the previous issue, since losing face would be the consequence of this. As a relationship develops, problems can be discussed more openly (Salmi, 2006). Finally a much heard Western complaint that the real decision maker in Chinese corporate

culture cannot be identified, must be seen in the perspective of a collectivist culture. Within a network that works according the ethics and morals of Guanxi, the network itself may be seen as the decision maker (Davies et al., 1995).

The Chinese culture presents concepts or features that cannot be directly translated in comparable Western business behavior and a recipe for successful business cannot be prescribed. But long-term and personal relationships are appreciated. When a more empathic perspective is maintained and consideration, patience and willingness to invest in such a relationship is displayed, one is more likely to succeed in finding a valuable Chinese supplier.

3 Methodology

With the knowledge from the literature research of Chapter 2 in mind, the following step will focus on the application and extension of this knowledge by means of executing the supplier selection process for a case company. This chapter will provide the required approach in order to achieve the aim of the research. To do so, not only the method for supplier selection will be discussed in this chapter, but all required steps prior and after the application of a supplier selection method. The next section will therefore discuss a multi-stage approach in order to decrease the complexity of the supplier selection process. Finally this chapter is concluded with an overview of all elements of this research combined together in a research approach.

3.1 A Four Stage Approach for Supplier Selection

In order to achieve the goal of this thesis, the supplier selection process is guided by a framework that ensures the overall process is divided in smaller and more comprehensive stages. In this way the complexity of the task at hands can be reduced. Using a framework is something that is also common in the academic work discussed in the literature research chapter. A well-structured framework for suppliers selection in agile supply chains is crafted by Luo, Wu, Rosenberg and Barnes (2009), that could provide a basis to work from. This framework is actually a four stage approach that also considers a preparation phase that requires the determination of industry specific criteria and a fourth phase that allows for feedback on the prior stages. This framework is adapted to the specific situation of the case company and this thesis research. It still contains the four stages, but the input of the stages is added according to the situation of the case company. The framework can be seen in Figure 5.

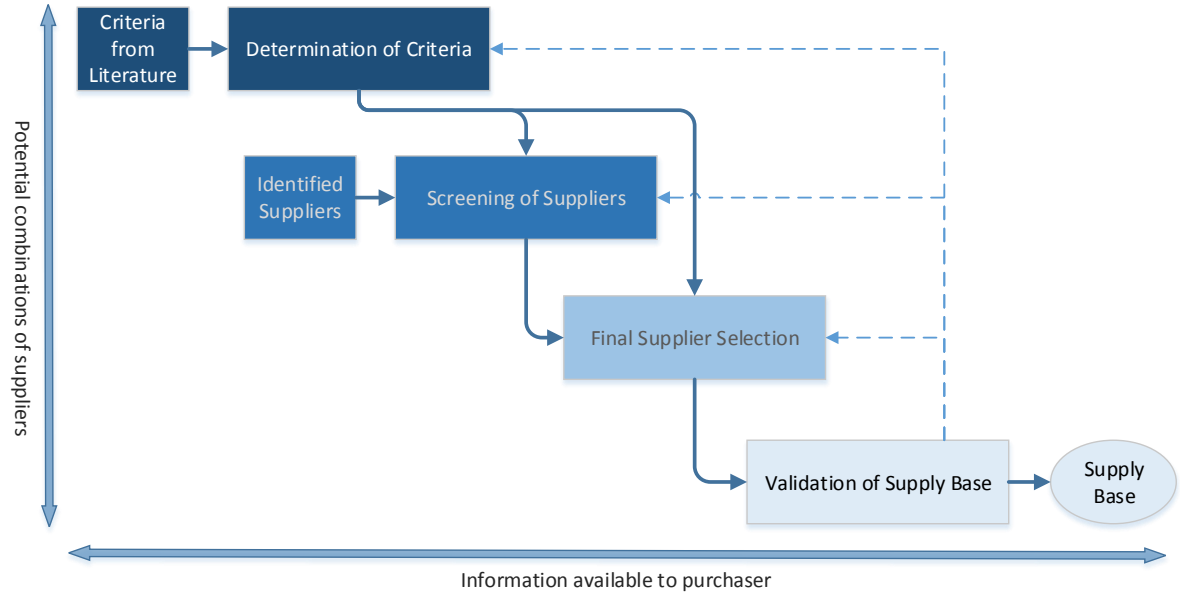

Figure 5: A four stage approach to supplier selection adapted from Luo et al. (2009)

The arrows flowing out of each stage represent the outcome of that stage that is controlling or providing input for the sequential stage. A controlling outcome is represented by flowing into the sequential stage from the top. An input will naturally enter the sequential stage from the left side. The final stage allows for a feedback loop, which is indicated by the dotted lines. This feedback may concern any of the three previous stages. As the process moves across the four stages, the information that becomes available to the purchasing company increases, as indicated on the

horizontal axis. The number of potential combinations of suppliers is decreasing as the process moves along the stages. This is indicated on the vertical axis. The four stages will be discussed in the following sections.

3.2 Supplier Selection Preparation: Determination of Criteria

The preparation for the supplier selection process is carried out in the first stage. In this stage all the criteria that could be needed in the selection process are gathered. This is done according to three steps, starting from a very generic point of view and narrowing it down to the situation of the purchaser (Luo et al., 2009). First a generic list of criteria is drawn from the available literature. This step is carried out in section 2.5 of the literature research. The result is an extensive list of criteria which is backed by the literature. This list is then prioritized into a list of industry specific criteria. The final step is to run these criteria by the company decision makers or experts. In this way both criteria from literature that might be overlooked by the experts can be added and vice versa.

3.3 Pre Classification: The Screening of Suppliers

In order to select an optimal supply base not only the final choice phase must be considered, but also the phase prior to this. As indicated in the literature research, this aspect of supplier selection is often overlooked by scholars and it therefore has a limited appearance in literature. The work of de Boer et al. (2001) provides an extensive overview of supplier selection literature and it also identifies whether the screening phase is taken into account or not. The overview shows that especially for new task situation, like the one the case company faces, very little is known on supplier screening. The supplier classification matrix of Kraljic (1983) is often used in order to prequalify the suppliers into different categories (van Weele, 2005). However, in order to apply this method to this research, detailed information on the suppliers is required. This is something that is not at hands in new task situation. The characteristic of this supplier selection problem also rules out other possible screening methods and therefore another solution has to be found.

Basic screening methods are conjunctive, disjunctive or lexicographical screening (Hwang & Yoon, 1981). Conjunctive screening requires a supplier to equal or exceed a minimum score on each criterion, while disjunctive requires them to do this on at least one criterion. Lexicographical screening ranks the criteria on importance and the suppliers that exceed the requirements of the most important criterion move on to the next one (de Boer et al., 2001). Due to the nature of the food industry, some very specific criteria are crucial. On top of this the palm oil industry has set its own standards for certain products. The combination of these elements is important to the case company and with conjunctive screening this can be captured in the screening process as an alternative must meet a performance threshold on *all attributes* (Linkov et al., 2004). It is therefore selected as the method for the screening of the suppliers.

In interviews with experts and decision makers a list of the criteria for conjunctive screening is formulated. In literature these criteria are commonly used and referred to as non-compensatory rules (Lima Junior, Osiro, & Carpinetti, 2013). Compensatory rules are based on the assumption that a poor performance on a certain criterion can be compensated with a high performance on another criterion. In the screening phase however, there should be no compensation for a supplier not meeting a minimum requirement of a criterion. Therefore the use of non-compensatory rules is more appropriate in this phase. When qualified suppliers are compared in the final phase, compensatory

rules should be used as they have all met the minimum requirements (de Boer, van Der Wegen, & Telgen, 1998).

The selection of the screening criteria is based on their indication by at least two respondents from the case company. Using this rule only the screening criteria that are considered by multiple experts or decision makers are taken into account. In this way the inclusion of screening criteria from a respondent misunderstanding the concept of non-compensatory rules or one having a very specific view on the subject is ruled out.

3.4 Final Selection: Supplier Selection Using MCDM

Once the decision space has been reduced by the screening of suppliers, more detailed information and a more elaborate model can be used in order to complete the final selection. The problem of selecting suppliers is a typical multi-criteria decision problem, which has been discussed in the literature research. Within this field of research a method has to be selected in order to carry out the final selection. Regarding the methods discussed in the literature review and their characteristics, a relatively new method is chosen for this task. This method will be discussed in the following sections.

3.4.1 The Best-Worst Method

One of the most recent developments that can improve the MCDM is the Best-Worst Method (BWM). Developed by Rezaei (2015a), it uses two vectors of pairwise comparisons to determine the weights of criteria. The final score of the alternatives is derived by aggregating the weights from the different sets of criteria with the score of the alternatives. A consistency indicator is proposed in order to check the reliability of the comparisons. Compared to the well-known and used AHP method, BWM requires less comparison data and the method leads to more consistent comparisons, which means that it provides more reliable results Rezaei (2015a). This method is tested in a small scale decision-making problem, but the applicability in a large firm is yet to be determined. This research is to provide in this need by implementing the BWM in a supplier selection framework for the case company. The following section will go into detail on the BWM in order to apply the method in this research.

In a multi-criteria decision method two or more criteria are available in order to assess different alternatives. The importance of the criteria can be obtained with a number of pairwise comparisons in which the preference of the criteria are stated. The significant challenge in pairwise comparisons is proposed by the lack of consistency of the comparison which occurs in practice (Herman & Koczkodaj, 1996). The goal of BWM is to reduce this inconsistency and use less data in doing so. When a pairwise comparison is executed, the direction and strength of the preference of *i* over *j* are stated. The direction is simple for the decision maker to determine, the strength however is more difficult and can lead to inconsistency. Pairwise comparisons can be categorized in the following two groups.

Reference comparisons

Comparison a_{ij} is defined as a reference comparison if *i* is the best element and/or *j* is the worst element.

Secondary comparisons

Comparison a_{ij} is defined as a secondary comparison if *i* nor *j* are the best or the worst elements and $a_{ij} \geq 1$.

With the identification of the comparisons it appears that the reference comparisons are less complex to obtain and thus an efficient approach would entail the identification of this category as a first step. Furthermore it can be stated that with the identification of the reference comparisons the secondary comparisons have become obsolete. This is because it is possible to derive the relative importance of the criteria or alternatives even without carrying out the secondary comparisons. Each secondary comparison (a_{ij}) appears in two relation chains, two members of which are reference comparisons. In a general form this is shown by:

$$a_{best,\,i} \times a_{ij} = a_{best,\,j}\ ,\ a_{ij} \times a_{j,\,worst} = a_{i,\,worst}$$

With this construct the reference comparisons that can be seen in Figure 6 become the backbone of the BWM. The next step is to derive weights based on these comparisons, which will be shown as part of the five steps of BWM, discussed in the next section.

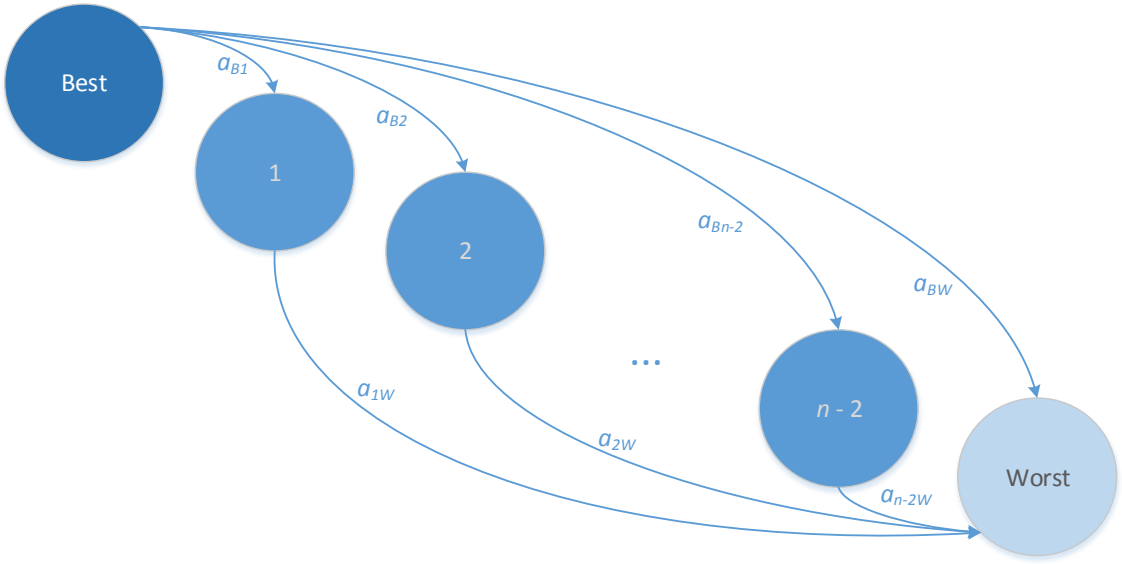

Figure 6. The reference comparisons

3.4.2 The five steps of BWM

Five steps are constructed in order to obtain the weights of the criteria. These steps will be presented in this section.

Step 1. Determine a set of decision criteria.

The criteria (c_1, c_2, …, c_n) are first to be identified in order to arrive at a decision. These criteria will be the factors on which the performance of the alternatives is determined. Examples of these criteria can be (quality (c_1), price (c_2), lead time (c_3)).

Step 2. Determine the best and the worst criteria.

The best criterion can be the most desirable, preferred or important while the worst would be the opposite, the least desirable, preferred or important. The decision maker identifies these in general and no comparison among decision makers is made at this stage.

Step 3. Determine the preference of the best criterion over all the other criteria
A number between 1 and 9 is used to indicate this. The resulting Best-to-Others vector would be:

$A_B = (a_{B1}, a_{B2}, \ldots, a_{Bn})$,

In this, a_{Bj} indicates the preference of the best criterion *B* over criterion *j*. It is clear that $a_{BB} = 1$.

Step 4. Determine the preference of the best criterion over the worst criterion.
A number between 1 and 9 is used for this again. The Other-to-Worst vector would be:

$A_w = (a_{1w}, a_{2w}, \ldots, a_{nw})^T$,

In this, A_{jw} indicates the preference of the criterion *j* over the worst criterion *W*. It is clear that $A_{ww} = 1$.

Step 5. Find the optimal weights.
The final step of the BWM is conducted according to the latest findings in this field, which describes a linear method for obtaining the optimal weights (Rezaei, 2015b). Initially a non-linear method was used, which could result in multiple optimal solutions and the use of interval weights. Since a unique solution is preferred, this linear version is applied.

In order to find the optimal weights ($w^*_1, w^*_2, \ldots, w^*_n$), a solution should be found where the maximum absolute differences for all *j* is minimized of the following set $\{|w_B - a_{Bj}w_j|, |w_j - a_{jW}w_w|\}$. This can be formulated as follows.

$$\min \max_j \{|w_B - a_{Bj}w_j|, |w_j - a_{jW}w_w|\} \quad (3)$$

s.t.

$$\sum_j w_j = 1$$
$$w_j \geq 0, \text{for all } j$$

This can be solved by transferring it to the following lineair programming problem:

$$\min \xi^L$$

s.t.

$$\left|w_B - a_{Bj} w_j\right| \leq \xi^L, \text{for all } j$$

$$\left|w_j - a_{jW} w_w\right| \leq \xi^L, \text{for all } j \qquad (4)$$

$$\sum_j w_j = 1$$

$$w_j \geq 0, \text{for all } j$$

Problem (4) is a linear problem, which has a unique solution. By solving this problem the optimal weights (w^*_1, w^*_2, …, w^*_n) and the optimal value of ξ^L, called ξ^{L^*} are obtained.

3.4.3 Consistency indicator

In this section a consistency indicator will be discussed that is used to check the reliability of the comparisons.

A comparison is fully consistent when $a_{Bj} \times a_{jW} = a_{BW}$, for all j, where a_{Bj}, a_{jW} and a_{BW} are respectively the preference of the best criterion over criterion j, the preference of criterion j over the worst criterion and the preference of the best criterion over the worst criterion. However, it can be that for some j the comparison is not fully consistent. This inconsistency even characterizes the kind of pairwise comparisons in question and it is a common critic on MCDM (Herman & Koczkodaj, 1996). Inconsistencies can emerge because of a preference or lack of concentration with the decision maker or they might struggle with assigning numerical values to the comparisons. Also some criteria are of a qualitative nature which will complicate the attribution of numerical value to the criteria. In order to indicate how consistent a comparison is, an indicator is used. This indicator is the value of ξ^L* which has been obtained in the fifth step of the BWM setup. The closer the value to zero is, the higher the consistency. Values below one are considered to have a sufficient consistency.

3.5 Application of Feedback: Validation

The fourth and final stage of this approach is used for validation of the methods and results. This is done with the help of experts and decision makers of the company. They are able to provide feedback on the first, second and third stage of the supplier selection process. These stages can be considered valid if they agree upon the results and methods used. Something that needs to be noted here is that these experts were also involved in the prior stages. This will result in them reviewing their own work for a certain part, which will limit their objectivity. This could be avoided by using different experts for the validation, however this has a low feasibility because of the limited number of experts and decision makers in the company that weren't involved in the research.

3.6 Research Framework

In the previous sections the four different stages of the supplier selection process are explained. Since this only considered the selection process itself, this final section of the methodology chapter will aim to incorporate this four stage approach into a framework of the complete thesis research. For this the elements prior and after the supplier selection need to be taken into account. Since the selection of suppliers for a company in the food industry is accompanied by a vast selection of matters with a more practical nature, the framework is dived into two separate tracks. The left track follows the guidelines of a classical research approach. The different steps of this approach are then translated into a case specific step that incorporates the elements of a more practical nature which together make up the right track. The complete framework can be seen in Figure 7.

The first phase contains the literature research and the configuration of a methodology. These require an extensive analysis and the outcome is used as input, support or the control of the following processes. Next is the data collection phase for the supplier selection process. This entails gathering large amount of data on the raw material need, available suppliers and the identification of criteria. From the four stage approach presented in section 3.1 the first stage of preparation for the supplier selection is carried out at this moment. The third phase of the research comprises the analysis of the gathered data and the presentation and discussion of the results. The BWM is applied in this phase. With regard to the right track this entails the second, third and fourth stage of supplier screening, selection and validation. The latter is represented by a feedback loop from the results, back to the analysis or selection process. The outcome of the previous phases is the conclusion, which translates to the optimal supply base for the Chinese plant and the discovered implications during the research. This will then be finalized by the last phase of the discussion and recommendation. This is dived in a discussion on the dynamics of the supplier selection problem and a reflection on the outcome of the research and the methods that have been used.

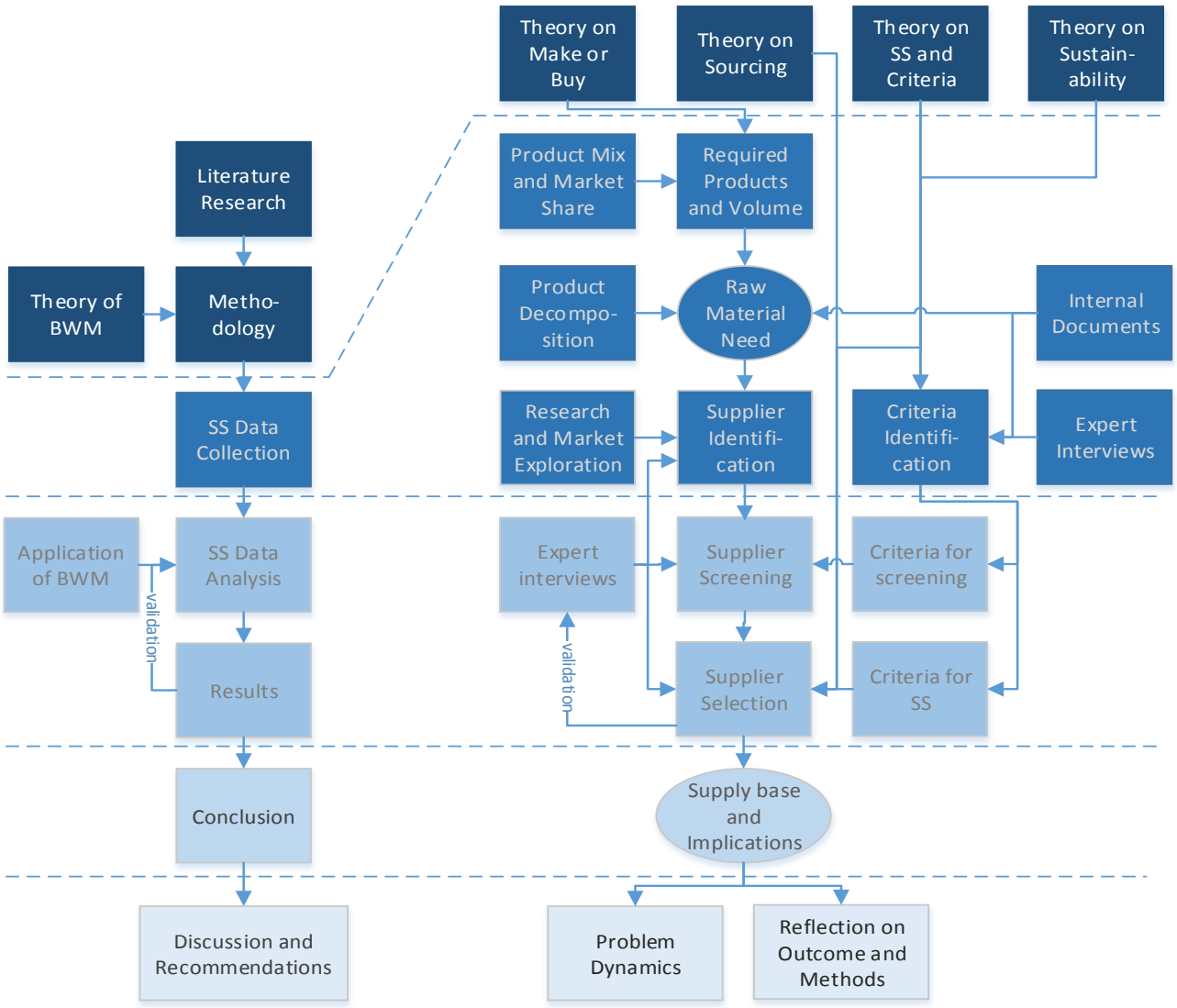

Figure 7: A two-track research framework

4 Data Collection

This chapter will cover the data collection that is required for this research. Following the research approach from section 3.6, it consists of the collection of the required criteria both for screening and selection, the potential suppliers and the required raw materials. These three subjects will be discussed in the following sections.

4.1 The Raw Material Need

The required raw materials for the production of oils and fats are considered in this section. In Figure 8 the items from the research framework regarding the raw material need can be seen. The overview shows that the product mix and market share are used as input for the required products volumes. Together with the product decomposition the raw material need can be determined. Internal documents of the company and interviews are used to support this process.

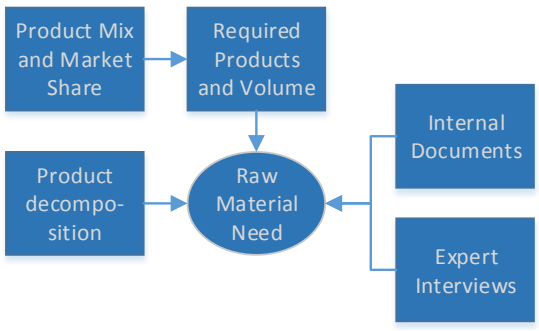

Figure 8: Snapshot from the research framework regarding raw material need

4.1.1 Product mix, target market share and decomposition

The starting point for the raw material determination is the product mix and the market share that is targeted by the company. This is based on the operation of the plant after two years. The sales department of the case company provided their assessment of the Chinese market, the product mix and target market share. After the product determination, the next step is to split this according to the product decomposition into the required raw materials. Internal documents on this decomposition together with interviews with the case company purchasers supported this process. The result from this can be seen in Table 12. More information on the abbreviations used in this chapter can be found in the list of abbreviations in Table 1. The target is included in order to provide an understanding of the importance of the products based on the required volume. The decomposition is used to determine the required raw materials which will be discussed in the next section.

Product	Target (mt/year)	Decomposition
O	X	92% G, 8% D
P	x	40% G, 40% C_1, 20% B_1
Q	x	50% X, 50% Y
R	x	50% B_1, 30% Z, 20% B_2
S	x	90% A, 10% C_2
T	x	20% D, 80% E
U	x	100% H
V	x	100% V
W	x	48% I, 20% L, 10% M, 20% J, 2% N
Total	**x**	

Table 12: Product mix, target sales and decomposition

4.1.2 Required raw materials

The next step is to use the gathered information and determine the raw materials and the required volume. This is done according to the decomposition of the products, presented in the previous section. The demand (Q) is split in different periods to be used as an indication for the restocking rate and to give a better insight in the options for bulk shipping. The complete overview of the raw materials and their split demand volumes can be seen in Table 13.

Raw Material	Q / Year (mt)	Q / Quarter (mt)	Q / 2 months (mt)	Q / Month (mt)
G	X	x/4	x/6	x/12
H	X	x/4	x/6	x/12
A	X	x/4	x/6	x/12
E	X	x/4	x/6	x/12
C_1	X	x/4	x/6	x/12
B_1	X	x/4	x/6	x/12
D	X	x/4	x/6	x/12
V	X	x/4	x/6	x/12
X	X	x/4	x/6	x/12
Y	X	x/4	x/6	x/12
I	X	x/4	x/6	x/12
Z	X	x/4	x/6	x/12
C_2	X	x/4	x/6	x/12
L	X	x/4	x/6	x/12
J	X	x/4	x/6	x/12
B_2	X	x/4	x/6	x/12
M	X	x/4	x/6	x/12
N	X	x/4	x/6	x/12
TOTAL	**x**	x/4	x/6	x/12

Table 13: Raw material overview

4.2 Criteria for Supplier Selection

The criteria are the backbone of this thesis and therefore the identification of these is an important step in the process. The research framework, of which a snapshot can be seen in Figure 9, shows that both literature and data form the case company are used in this process. The following sections will discuss these elements individually.

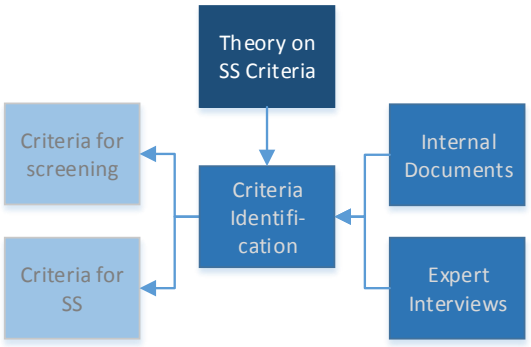

Figure 9: Snapshot from the research framework regarding criteria identification

4.2.1 Criteria provided by literature

Literature is used to obtain the most important and common used criteria by academics. The research on this subject is conducted in Chapter 2. It provides an extensive overview of the most used and important criteria over time. The work covers both traditional as well as environmental criteria. The outcome of this analysis is used to create an overview, which can be seen in Table 14. It shows the most prevailing criteria found selected on the applicability to the situation and industry of the case company.

Criteria from Literature		
Price	Quality	Reputation and Position in Industry
Ordering costs	Service	Delivery
Technological ability	Reciprocal Arrangement	Attitude
Financial Position	Flexibility	Management and Organization
Warranty and Claim Policies	Desire for Business	Trade restrictions
Production Facilities and Capacity	Labor Relations record	Green supply chain management
Geographical Location	Pollution of production	Environmental responsibility of product
Capabilities and standards	Political situation	Green / environmental practice

Table 14: Most prevalent criteria obtained from the literature research

This overview is presented to the company experts and decision makers. This process will be discussed in the following section.

4.2.2 Criteria selection in cooperation with company experts and decision makers

As mentioned in the previous section the experts and decision makers of the company are asked to provide the criteria they use or find important in the supplier selection process. This is done prior to presenting the criteria from the literature in order to ensure that the respondents are not influenced in their answers by this information. Using the combination of both literature and company knowledge works in multiple ways. Company experts and decision makers can indicate which criteria are used in the industry. Very specific criteria may be used, for instance relating to food safety considerations or sustainability issues. Subsequently this can be complemented by criteria from literature. Typically these might not be considered as they can origin from other industries. However this does not imply that they do not hold any value for the supplier selection process and therefore they should be considered. In this way the obtained criteria cover a broad spectrum of considerations. Furthermore does the questionnaire asks the respondents to state their opinion on the criteria that should be used as a minimum requirement. These are used for the conjunctive screening of the suppliers. In this way, the criteria for this process and the final selection can be identified or separated. More details on the identification of criteria and questionnaire can be found in appendix A. The results of the criteria identification will be presented in the following chapter of the data analysis.

4.3 Identification of Suppliers

The identification of suppliers is conducted in order to establish the pool of potential suppliers for screening and final selection. The overview of materials from section 4.1.2 is used as an input for this process. Furthermore, this process is supported by experts and decision makers in the company and by internal documents. Conducting a market research and exploration is an important process in this phase of the thesis, as can be seen in Figure 10. The following sections will go into detail on the structure of the identification process and the results.

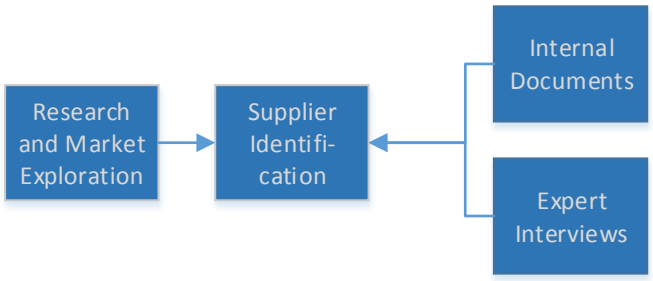

Figure 10: Snapshot from the research framework regarding supplier identification

4.3.1 Structure of identification process

The first step of structuring the identification process is splitting the raw materials into sourcing categories. As explained in the introduction there are four options for material sourcing. The first two can be from the own company or known suppliers. These two options are considered to be in the current supply chain. The remaining two other options are considered to be outside of the supply chain. These are local suppliers, or suppliers from neighboring countries. Please refer to Figure 1 of section 1.2.2 for a visualization of this construct.

Together with the decision makers of the case company the sourcing strategy is defined. The experts select the raw materials that need to be sourced internally based on strategic planning and commercial considerations. These considerations are both on the new Chinese market as well as the

existing Malaysian production and its international market. The higher the number of internally sourced materials, the lower the number of materials for local sourcing. Therefore, the result of the sourcing strategy translates into sourcing locations for the raw materials. The raw materials, demand and possible sourcing locations can be seen in Table 15.

Raw Material	Q / Year (mt)	Possible sourcing location
G	x	Local market / Case Company / known suppliers
H	x	Local market / known suppliers
A	x	Local market / Case Company / known suppliers
E	x	Local market / Case Company / known suppliers
C_1	x	Local market / Case Company / known suppliers
B_1	x	Case Company*
D	x	Local market / Case Company / known suppliers
V	x	Case Company*
X	x	Case Company*
Y	x	Case Company*
I	x	Local market / known suppliers
Z	x	Case Company*
C_2	x	Local market / Case Company / known suppliers
L	x	Europe, Ukraine, Russia / local market / known suppl.
J	x	Europe / local market / known suppliers
B_2	x	Case Company*
M	x	Europe / local market / known suppliers
N	x	Local market / known suppliers
Total	x	* = determined by Company DM's

Table 15: Raw materials and their sourcing locations

This overview and the sourcing locations provide the input for the four options in the supplier identifications process.

1. *Company Sourcing*
   The raw materials indicated by a * are determined to be sourced within the company. This means that they will be produced in Malaysia and subsequently transported to the Chinese plant for further processing.

2. *Known supplier*
   Since the company is active in many positions, both in the up- and downstream of the supply chain, an existing supply base with approved suppliers is available. This is referred to as the Approved Vendor List (AVL) and it contains suppliers for different types of raw materials. These suppliers have passed the QA requirements and audits and they are contacted in order to determine their possibilities to supply to the new plant.

3. *Local suppliers*
   Local suppliers are regarded as suppliers in the Chinese market. These are unknown to the company and need to be identified through market exploration and research, something that is a time consuming process. Multiple ways of searching for these suppliers and subsequently contacting them have been used. For instance, using company contacts in the Chinese

market, using contacts of the other global divisions of the company that are familiar with the market, using partners or even competitors in the industry. Also professional network websites like Linkedin and meetings at the Malaysian plant with customers or organizations from the industry are used. This resulted in a vast amount of unstructured information with varying value. Only by following up on all these leads and contacts, this information can be structured and it becomes apparent if they hold any value.

4. *Asian suppliers*
   This group is also unknown to the company and are located in Asia except for China. The differentiation between this and the previous category is made because not all raw materials are produced and available in China. In order to get a better understanding of the production, import and export of the raw materials the database of the USDA's Global Agriculture Information Network (USDA, 2015) is used. In order to get into contact with these suppliers, contacts of the company experts, professional network websites and contact information available on the internet is used.

4.3.2 Suppliers identified from desk research and market analysis

With the structure of the supplier identification clarified, this section will present the result from the determination of the sourcing location and the market research and exploration.

Company Sourcing

The products that are required to be sourced from the company all come from Malaysia. The company group has multiple plants that delivery of six specific products, which can be seen in Table 16.

Supplier	Item	Country
Plant 1	C1, X, SHs, Z, B2	Malaysia
Plant 2	V	Malaysia

Table 16: Suppliers from the category Company Sourcing

Known suppliers

The known suppliers are selected from the AVL and contacted in order to determine their capabilities in delivering to the Chinese plant. As can be seen in Table 17 these are located in Asia, Europe and Oceania.

Supplier	Item	Status	Country
16	J	Appr.	Australia
18	N	Appr.	China
21	G	Appr.	Malaysia
22	M	Appr.	Spain
2	L	Appr.	Spain
25	J	Appr.	Australia
15	I	Appr.	China
28	N	Appr.	China

Table 17: Known suppliers obtained from the AVL

Local suppliers

All suppliers the suppliers of this category are located within China. Table 18 will present the identified local suppliers that confirmed their supplying abilities to the new plant.

Supplier	Item
4	All
5	All
9	A, B, C
10	I, J, L, M, H
11	A, B
12	B
13	A, B, C, D, E, G, H
29	J, M, E, G
31	B
33	A
34	A, B, C, I, L, D, H

Table 18: Possible suppliers from China

Asian suppliers

The Asian suppliers are all located in the Philippines and Indonesia. Five suppliers are able to supply to the new plant and they can be seen in Table 19.

Supplier	Item	Country
2	G	Indonesia
6	H	Singapore
7	H	Philippines
17	H	Philippines
26	H	Philippines
30	H	Philippines

Table 19: Possible suppliers from Asia

With the identification of these suppliers the data analysis is completed. The obtained data will be used in the following chapter in which it will be used and analyzed in order to determine the optimal supply base for the case company.

5 Data Analysis

In this chapter the gathered data of the previous sections will be analyzed in order to arrive at a ranking of the suppliers as part of the selection process. Following the research approach from section 3.6, a two stage approach is applied. First a screening will be executed to select a subset of suppliers who will be assessed in the second stage which consists of the actual supplier selection. This can also be seen in the snapshot of Figure 11.

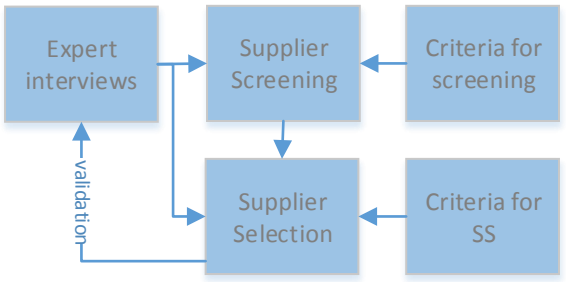

Figure 11: Snapshot of the supplier screening and selection from the research framework

5.1 Conjunctive Supplier Screening

Conjunctive supplier screening is applied to select a subset of suppliers from the initial pool identified in the previous chapter. Please refer to section 3.3 for more details on conjunctive screening. The screening process requires specific criteria which will be discussed in the following section. After the selection of the criteria, the screening will be executed in the second section of this paragraph.

5.1.1 Screening Criteria

The screening criteria are obtained from the case company by interviewing company experts and decision makers. More details on the interviews can be seen in appendix A. As stated in the methodology of section 3.3, a screening criterion needs to be indicated by at least two respondents in order to be incorporated in this research. As the requirements are and separated per product group. The selected criteria for palm products can be seen in Table 20, while the non-palm criteria are displayed in Table 21. The number of times the criteria are indicated by the respondents is displayed in the right column.

Screening criteria	Indications
Cultural Compliance	5
Food Safety Standard (GB/FSSC)	2
Quality within spec	5

Table 20: Minimum requirements for palm and palm kernel suppliers

The non-palm products are among others, used in high quality food products and therefore have an additional requirement on the origin. Non-GMO is added to the criteria in order to take this into account.

Screening criteria	Indications
Cultural Compliance	5
Food Safety Standard (GB/FSSC)	2
Quality within spec	5
Non-GMO	3

Table 21: Minimum requirements for non-palm suppliers

The criteria used in the screening stage of the supplier selection will be discussed below.

Cultural Compliance
This criterion entails halal and kosher considerations. Dependent on the requirements of the customer, the end product of the company may need to comply to a kosher or halal certification. The production process needs to be certified by an external control body and the raw materials used for these products also need to be certified. For this reason the suppliers must be able to deliver certified raw materials in order to ensure the ability to produce halal and kosher certified products. As the requirements and familiarity with these certifications can differ, the criterion is split into kosher and halal compliance. Currently the halal certification is a must and a non-complying supplier will not be selected into the subset for the next stage. On the kosher requirement the case company is not certain if this will be necessary for the Chinese market. Therefore this criterion is not incorporated in the supplier screening process.

Food Safety Standard
The company is unsure on the delivered quality by new suppliers. In order to decrease the risk of purchasing low quality or contaminated products, the criterion of Food Safety Standard is included. This standard ensures that a number of measurements on product quality and safety are implemented by the supplier. Different standards are available, examples of these are ISO, GB Standard, GMP, FSCC or HACCP. Multiple standards are therefore accepted in order to comply to this requirement.

Quality
The quality criterion does not refer to the best possible quality, but to a minimal required quality. This is taken into account in order to ensure only suppliers with usable raw materials are taken into the subset for final selection. The minimum quality is determined in country standards, for China this is the GB standard.

Non-GMO
This selection criterion only applied to products I, J and M. Non-GMO means non-genetically modified. GMOs (genetically modified organisms), are novel organisms which have been created in a laboratory using genetic modification and engineering techniques. Scientists and environmental groups have related health and environmental risks with foods containing GMO's (Roseboro, 2013). As a result of the risks, both the case company and their customers want to make sure that the products do not contain these genetically modified raw materials. When a supplier cannot comply to this requirements, it is excluded from the delivery of soft oils to the new plant, however this does not mean that the supplier is also excluded from delivering palm raw materials as this has no influence.

A final criterion is added to this four criteria which has not been indicated. This is *Willingness to Cooperate* (WtC). As some suppliers might find the new plant a threat, they are not willing to cooperate. Some other suppliers do not have this hostile attitude, but simply do not provide the requested information or communicate very poorly. These suppliers are also considered to have an unacceptable score on this criterion. Needless to say, an unacceptable score on this criterion entails exclusion from the selection process.

With these criteria, the screening of the suppliers can be conducted. This will be discussed in the following section.

5.1.2 Screening of the suppliers

The suppliers are screened on the five criteria obtained from the previous section. As these are minimum requirements, a supplier can either have an acceptable score indicated by *A*, or an unacceptable score which is indicated by *U* in Table 22. The Non-GMO criterion does not apply to suppliers that only deliver palm products and this will be indicated by a dash.

Supplier	CC Halal	FFS	Quality	Non-GMO	WtC
1	A	A	A	U	U
2	A	A	A	-	A
3	A	A	A	A	U
4	A	A	A	A	A
5	A	A	A	A	A
6	A	A	A	A	U
7	A	A	A	A	A
8	A	A	A	U	A
9	A	A	A	-	A
10	A	A	A	A	A
11	A	A	A	-	A
12	A	A	A	-	A
13	A	A	A	-	A
14	U	A	A	U	U
15	A	A	A	A	A
16	A	A	A	A	A
17	A	A	A	-	A
18	A	A	A	-	A
19	A	A	A	-	A
20	A	A	A	-	A
21	A	A	A	-	A
22	A	A	A	A	U
23	A	A	A	-	U
24	A	A	A	-	A
25	A	A	A	A	U
26	A	A	A	-	A
27	A	A	A	-	A
28	A	A	A	-	A
29	A	A	A	A	A
30	A	A	A	-	A
31	U	A	U	-	A
32	U	A	U	-	U
33	A	U	A	-	A
34	A	A	A	A	A

Table 22: Supplier screening scoring

The result of the screening process is that from the pool of 34 suppliers 23 exceed the minimum requirements and are taken into the subset of suppliers for the final phase. This will be executed in the third section of this chapter, but first the setup of the selection method is discussed.

5.2 Setup of the BWM

This section will discuss the setup of the BWM, which consists of five steps. Please refer to section 3.4.2 of the methodology for the theoretical background of these steps.

5.2.1 Determination of the criteria set

The setup of the BWM starts off with the determination of the criteria set. It is obtained from both the case company as well as from the analysis conducted in the literature research of Chapter 2. The input from the company experts and decision makers is retrieved from a number of interviews which have taken place at the offices of the case company. Please refer to appendix A for more details on these interviews. The scores of the criteria represent the number of times the criteria have been indicated by the respondents to be important to the selection process of suppliers in the edible oil industry. The respondents have been asked to first provide their own criteria. Subsequently the criteria obtained through the literature research have been presented to the respondents. They could complement their criteria with additional criteria from literature if they found them to have an additional value. The final score (indications) of criteria indicated by the respondents themselves plus those from the literature review can be seen in Table 23.

Stated + Literature Criteria (Scoring >2)	Score
Quality (in spec)	7
Price	5
Total costs of delivery	4
Lead Time	4
Location	5
OTIF (delivery)	6
Cultural Compliance	6
Service	3
Flexibility (in supply)	4
Reliability	4
Reputation	3
Financial Status	4
Non-Competitor on Specialties	6
Capabilities and standards (FSSC)	5
Labor Relations Record	3
Warranty and Claim Policies	4
Production Facilities and Capacity	4
Specific for Soft Oils (Scoring > 1)	
Non-GMO	3
Specific for Sustainability (Scoring >1)	
RSPO Certified	3
Traceability	4

Table 23: Highest scoring criteria obtained from interviews

Not all criteria can simply be used in the research, a selection needs to take place in order to obtain a useable set. Furthermore does a review on the applicability need to take place in order to correct for the buying situation of the case company. As the interviews retrieved criteria for supplier selection in the industry, these cannot all be applied to the case of the new plant in China. This is a new buying task in which a prior history or relationship with all the suppliers is not existent. As indicated in the literature research, this buying situation is has a higher complexity and preparation is difficult. Please refer to section 2.3.1 for more information on the different buying tasks. Also some criteria might be too complex to use in this research as the time to determine the performance and the information on the suppliers is limited. Another possibility is that the respondents identify separate criteria, but they are in fact overlapping or describing the same element. This is for instance the case with the criteria *Location* and *Lead Time*. Although *Location* actually indicates the local circumstances of a supplier like number of access roads or area type, the respondents often consider the distance to the new plant. Finally some criteria are non-compensatory and binary, these have been used in the screening of the suppliers and not in the final choice phase.

Coherent to the screening process, the criteria for the final choice are also separated per product group. For this process additional differences need to be taken into account. For some edible oils, the *RSPO Certificate* and *Traceability* should be incorporated in the selection process. However, this does not apply to all raw materials. The second reason to separate the two product groups is because of their use in different applications, each with its unique values. The selected criteria per products group can be seen in Table 24 and the following section will discuss each criterion individually.

Criteria for palm suppliers	Symbol	Criteria for non-palm suppliers	Symbol
Cost of Delivery	C^p_1	Cost of Delivery	C^n_1
Lead Time	C^p_2	Lead Time	C^n_2
Non-Competitor on Specialties	C^p_3	Non-Competitor on Specialties	C^n_3
Price	C^p_4	Price	C^n_4
Production Facilities and Capacity	C^p_5	Production Facilities and Capacity	C^n_5
Quality	C^p_6	Quality	C^n_6
RSPO Certification	C^p_7		
Traceability	C^p_8		

Table 24: Criteria used for the final choice phase

Cost of Delivery

The criterion *Cost of Delivery* contains all costs that are incurred by the buyer in order to receive the raw materials at their location. These costs are dominated by the transportation costs which can be originate from the access and egress or the main haul. Other costs that make up the cost of delivery are import duties, customs costs, handling costs, ordering costs or administration costs. Often these costs are considered together with the purchasing price of the product in order to determine the total cost of delivered product. In order to be able to substantiate between these costs, they are separated and all taken into account. The criterion is expressed in $/metric ton.

Lead Time

Lead Time is referred to as the time between the moment of ordering and the moment of delivery of a product, also known as Total Lead Time. It includes the Order Processing Time, Production Lead Time and the Delivery Lead Time of the supplier. The lead times are indicated by the suppliers and can be dependent on the distance of the supplier to the new plant, the transportation mode, the supplier's production planning, the number of outstanding order and stock levels. The criterion is expressed in days.

Non-Competitor on specialties

This criterion considered whether or not the supplying party is also active in the oils and fats market and is competing with the case company. This is important because with the order of a raw material the case company will increase the business continuity of a supplier. If this supplier is competing with the same end products on the same market, placing an order with will indirect increase the competition. This criterion is expressed on a 1 to 9 scale in which a score of 1 means the supplier is extremely competitive and the score of 9 means the supplier is not competing.

Price

This criterion considers the purchasing price of a unit of raw material. As earlier mentioned, the purchasing price is often considered in combination with the costs of delivery in order to obtain the total cost of delivered product. Because most raw materials are commodities, the price will balance around the market price of the commodity. Alterations on the market price can be made by the supplier dependent of the order volume, product stock, production schedule and competing abilities. This criterion is expressed in $/metric ton.

Production facilities and capacity

The production facilities and capacities of a supplier indicate the abilities and flexibility of a supplier. Different facilities are used in order to produce multiple products at different volumes. The capacity of a supplier influences its ability to handle an increase in order size or to alter its production schedule. If a supplier has limited facilities and thus a low capacity, there is a higher chance of forced supplier switching, when disruptions or alterations in the demand or order occur. Clearly this will pose certain switching costs and delays to the buyer. The refining capacity is used as a measure for this criterion and this differs per product. The criterion is expressed in metric tons/day.

Quality

The quality criterion is based on the declared product specifications of the supplier. This will be checked after the raw materials are received by the buyer. Because this physical check is not possible in this phase of the project and indication of the quality will be used based on the national standards and the suppliers reputation and experience from the case company. In the previous stage of supplier screening, the quality was also considered, but this is with regard to the minimum requirements of the products in order to determine its usability. In this phase a higher quality can be preferred for certain applications like infant nutrition. Considering this, it can be expected that the criterion will be valued differently among the two product groups. This criterion is expressed on a 1 to 9 scale in which a higher quality is indicated with a higher score.

RSPO Certification

The criterion *RSPO Certification* relates to the sustainable practice of the supplier. The RSPO is a global, multi-stakeholder initiative on sustainable palm oil that aims to transform markets to make

sustainable palm oil the norm. Please refer to section 2.6.3 of the literature research for more details on the RSPO. This criterion will considers different levels that are associated with the types of supply chain used by the suppliers. There are five different options:

- No membership: this is the lowest level and it indicates that the supplier is not using a supply chain certified by the RSPO.
- Green Palm / Book and Claim: This is the second lowest level and it indicates that the supply chain is not monitored for the presence of sustainable palm oil. Manufacturers and retailers can buy a Green Palm certificate from a RSPO-certified grower.
- Mass Balance: A higher level is called Mass Balance and indicates that sustainable palm oil from certified sources is mixed with ordinary palm oil throughout supply chain.
- Segregated: The second highest level is where the sustainable palm oil from different certified sources is kept separate from ordinary palm oil throughout supply chain.
- Identity Preserved: This is the highest possible level and it indicates that the sustainable palm oil from a single identifiable certified source is kept separately from ordinary palm oil throughout supply chain.

A score of 1 to 9 is used in order to indicate if a supplier is a non-member (low score) or can supply with a high level of certification (high score).

Traceability
Whereas the previous criterion considers the physical separation of types of edible oil, this criterion is solely based on the documentation of the origin or source of the products. When a supplier is able to trace the origin of the oil it has a higher performance on this criterion. Different degrees of traceability define the height of the score. The oil can be traceable up to the manufacturer, the mill or the plantation. A scale of 1 to 9 is used to indicate the performance on this criterion.

This definition of the criteria completes the first step of the BWM setup, the following step will be discussed next.

5.2.2 Determination of the best and worst criteria

The second step in the setup of the BWM is the determination of the best and the worst criterion. This information is obtained through a questionnaire. Six experts and decision makers of the case company are asked to state their preference. The complete questionnaire and more information on the respondents can be found in appendix B. In Table 25 and Table 26 the indicated best and worst criteria of each of the six respondents can be seen. As the criteria are valued different between the palm and non-palm products the selection of the best and worst criterion is separated between the two product groups.

Criterion	Best	Worst
Cost of delivery	2	
Lead time	4	
Non-Competitor on specialties		5, 6
Price	1, 3, 5, 6	
Production facilities and capacity		4

Quality		
RSPO certification		1, 2, 3
Traceability		

Table 25: Best and Worst criteria for palm products, indicated by respondents 1 to 6

Criterion	Best	Worst
Cost of delivery		
Lead time	4, 6	
Non-Competitor on specialties		1, 2, 3, 5, 6
Price	5	
Production facilities and capacity		4
Quality	1, 2, 3	

Table 26: Best and Worst criteria for non-palm products, indicated by respondents 1 to 6

With the best and worst criteria identified, the preference of the respondents needs to be identified in the following steps.

5.2.3 Determination of the preference of the best criterion over all other

The third step consists of identifying the preferences of the best criterion over all other criterion. This is also obtained by the use of the questionnaire. The respondents are asked to compare their selected best criterion to each of the other criteria and state there preference by using a number between 1 and 9. A score of 1 implies an equal importance over the other criterion. A score of 9 implies the most important criterion is extremely more preferred than the other criterion. This results in the best-to-others (BO) vectors which can be seen in Table 27 and Table 28.

BO Vectors Palm							
	Respondent No.	1	2	3	4	5	6
Criterion	A_B^p						
Cost of delivery	A_{B1}^p	3	1	2	2	2	1
Lead time	A_{B2}^p	4	2	2	1	4	2
Non-Competitor on specialties	A_{B3}^p	6	8	3	8	9	9
Price	A_{B4}^p	1	4	1	2	1	1
Production facilities and capacity	A_{B5}^p	5	5	5	9	4	3
Quality	A_{B6}^p	2	3	5	3	3	5
RSPO certification	A_{B7}^p	9	9	9	8	5	5
Traceability	A_{B8}^p	7	6	8	8	5	4

Table 27: BO Vectors for palm product criteria

BO Vectors Non-Palm							
	Respondent No.	1	2	3	4	5	6
Criterion	A_b^n						
Cost of delivery	A_{B1}^n	2	3	3	2	3	3
Lead time	A_{B2}^n	3	2	2	1	2	1
Non-Competitor on specialties	A_{B3}^n	9	9	9	8	9	9
Price	A_{B4}^n	2	4	3	2	1	3

Production facilities and capacity	A_{B5}^{n}	4	5	5	9	3	8
Quality	A_{B6}^{n}	1	1	1	2	4	2

Table 28: BO Vectors for non-palm product criteria

5.2.4 Determination of the preference of all criteria over the worst criterion

The fourth step of the BWM is similar to the third step, only this time the respondents are asked to state their preferences of all other criteria over the least important criterion. Again a number between 1 and 9 is used in which a score of 1 implies an equal preference over the least important criterion. A score of 9 implies an extreme preference of the other criterion over the least important criterion. This results in the others-to-worst (OW) vectors which can be seen in Table 29 and Table 30

OW Vectors Palm							
Respondent No.		1	2	3	4	5	6
Criteria	A_W^p						
Cost of delivery	A_{1W}^{p}	7	9	8	8	8	9
Lead time	A_{2W}^{p}	6	8	8	9	6	8
Non-Competitor on specialties	A_{3W}^{p}	4	2	5	2	1	1
Price	A_{4W}^{p}	9	5	9	8	9	9
Production facilities and capacity	A_{5W}^{p}	5	4	5	1	6	7
Quality	A_{6W}^{p}	8	5	5	8	7	5
RSPO certification	A_{7W}^{p}	1	1	1	2	4	5
Traceability	A_{8W}^{p}	3	3	2	2	4	6

Table 29: OW Vectors for palm product criteria

OW Vectors Non-Palm							
Respondent No.		1	2	3	4	5	6
Criteria	A_W^n						
Cost of delivery	A_{1W}^{n}	8	5	7	8	6	4
Lead time	A_{2W}^{n}	7	4	8	9	7	9
Non-Competitor on specialties	A_{3W}^{n}	1	1	1	2	1	1
Price	A_{4W}^{n}	8	7	7	8	9	8
Production facilities and capacity	A_{5W}^{n}	6	3	5	1	6	2
Quality	A_{6W}^{n}	9	9	9	8	5	8

Table 30: OW Vectors for non-palm product criteria

With the determination of these vectors, the optimal weights can be obtained, which will be conducted in the fifth and final step.

5.2.5 Determination of the optimal weights

The determination of the optimal weights is executed with a linear model of BWM. This linear model prevents the occurrence of obtaining multiple optimal results, please refer to section 3.4.2 for more details on the theory behind the determination of the weights.

The problem is solved for the six different respondents in order to get a better perception of the overall importance of the criteria. However this does imply that six different weights per criterion are identified. The arithmetic mean is used to arrive at a single weight. This weight can be seen in Table 31 and Table 32. For the individual weights please refer to appendix C.

Criteria Palm	w^{*p}	Average weight
Cost of delivery	w^{*p}_1	0,2162
Lead time	w^{*p}_2	0,1738
Non-Competitor on specialties	w^{*p}_3	0,0559
Price	w^{*p}_4	0,2491
Production facilities and capacity	w^{*p}_5	0,0763
Quality	w^{*p}_6	0,1209
RSPO certification	w^{*p}_7	0,0457
Traceability	w^{*p}_8	0,0620
Check (sum)		1
ξ^{L*}		0,0653

Table 31: Optimal weights for palm product criteria

Criteria Non-Palm	w^{*n}	Average weight
Cost of delivery	w^{*n}_1	0,1664
Lead time	w^{*n}_2	0,2493
Non-Competitor on specialties	w^{*n}_3	0,0342
Price	w^{*n}_4	0,1968
Production facilities and capacity	w^{*n}_5	0,0858
Quality	w^{*n}_6	0,2676
Check (sum)		1
ξ^{L*}		0,0759

Table 32: Optimal weights for non-palm product criteria

The ξ^{L*} is considered as an indicator for the consistency of the comparisons. As shown in the table the comparisons of both the palm and the non-palm criteria show a high consistency as the values are close to zero. With the determination of the optimal weights, the five steps of the BWM are completed. The following section will use these steps to construct the framework for the supplier selection.

5.3 Supplier Selection Using the BWM

This section will discuss the supplier selection by using the BWM. The weights obtained in the previous section are used to differentiate on the importance of the criteria. The performance of the suppliers on each of the criteria and the optimal weights are aggregated in order to arrive at the supplier score. With this score a final ranking can be determined which will indicate the best and worst performing suppliers according to the stated preferences. As different raw materials are considered in this research, the framework is created per individual raw material that is selected to be suitable for external sourcing as defined in Table 15 of section 2.3.1. In order to maintain the readability of this thesis, a numerical example of the steps is shown for Product C at the end of this section, the rest of the scores are available upon request.

The final score of the suppliers is obtained in three different steps. First the supplier performance on the different criteria is gathered from the data collection. Different dimensions are used per criterion here. Some use a score between 1 and 9, for instance to indicate the performance on the RSPO criterion, others use days or $/metric ton in order to indicate the lead time or costs of delivery. The complete overview of scores for Product C can be seen in Table 33.

The second step consist of the normalization of the scores. In this way scores in between 0 and 1 are obtained and the scores are corrected for direction. Different methods for normalization are available. Most obvious would be to use a normalization that for a positive relation the score would be subtracted by the minimum value and dived by the total range of the values. Since there are a number of criteria in which only two different scores are given, the use of this method would lead to a score of 0 and 1, independent of the value of the two different scores. Since this is a misrepresentation of the original values a more simple method is chosen, which is not characterized by this construct. This method divides the particular score by the maximum value for positive relations. For negative relations the value of 1 is subtracted with the aforementioned method. This can be seen in equations 5 and 6.

$$F_{pos}^{norm} = \frac{F_i}{F_{max}} \quad (5)$$

$$F_{neg}^{norm} = 1 - \frac{F_i}{F_{max}} \quad (6)$$

The normalized scores for Product C can be seen in Table 34. The third and final step consists of the aggregation of the scores and weights. The weights obtained via the BWM are multiplied with the normalized supplier scores in order to arrive at a final supplier score per criterion. The scores are then aggregated in order to determine the final supplier score and the supplier ranking. This third step can be seen in Table 35. A complete overview of the supplier scores per raw material will be discussed in the next chapter. The final scores that are obtained with these steps will be used to rank the suppliers and determine the best performing and the supply base. These results will be discussed in the next chapter. The following and final section of this chapter will discuss the validation of the research.

Supplier Score On Product C	Criterion:	C^p_1	C^p_2	C^p_3	C^p_4	C^p_5	C^p_6	C^p_7	C^p_8
	W*:	**0,2162**	**0,1738**	**0,0559**	**0,2491**	**0,0763**	**0,1209**	**0,0457**	**0,0620**
Company Chain	**Country**								
20	Msia	X	X	X	X	X	8	9	8
Known Suppliers									
21	Msia	X	X	X	X	X	7	7	7
Local Suppliers									
4	China	X	X	X	X	X	5	9	8
5	China	X	X	X	X	X	5	9	8
13	China	X	X	X	X	X	5	9	7
34	China	X	X	X	X	X	5	9	7
9	China	X	X	X	X	X	5	5	4
		$/mt	***days***	***score 1-9***	***$/mt***	***mt/day***	***score 1-9***	***score 1-9***	***score 1-9***

Table 33: Supplier performance for Product C

Normalized Scores Product C	Criterion:	C^p_1	C^p_2	C^p_3	C^p_4	C^p_5	C^p_6	C^p_7	C^p_8
	W*:	**0,2162**	**0,1738**	**0,0559**	**0,2491**	**0,0763**	**0,1209**	**0,0457**	**0,0620**
Company Chain	**Country**								
20	Msia	0,0281	0,4956	1,0000	0,2736	0,2667	1,0000	1,0000	1,0000
Known Suppliers									
21	Msia	0,0000	0,4737	0,2222	0,2736	0,2000	0,8750	0,7778	0,8750
Local Suppliers									
4	China	0,5472	0,0351	0,3333	0,0484	0,1667	0,6250	1,0000	1,0000
5	China	0,2039	0,0000	0,3333	0,0484	1,0000	0,6250	1,0000	1,0000
13	China	0,9101	0,7368	0,2222	0,0484	0,5000	0,6250	1,0000	0,8750
34	China	0,6067	0,6930	0,2222	0,0000	0,4667	0,6250	1,0000	0,8750
9	China	0,1742	0,6053	0,6667	0,0484	0,9667	0,6250	0,5556	0,5000

Table 34: Normalized suppliers score for Product C

Aggregated Product C Scores	Criterion:	C^p_1	C^p_2	C^p_3	C^p_4	C^p_5	C^p_6	C^p_7	C^p_8	TOTAL
	W*:	**0,2162**	**0,1738**	**0,0559**	**0,2491**	**0,0763**	**0,1209**	**0,0457**	**0,0620**	**1,0000**
Company Chain	**Country**									
20	Msia	0,0061	0,0862	0,0559	0,0682	0,0203	0,1209	0,0457	0,0620	0,4652
Known Suppliers										
21	Msia	0,0000	0,0823	0,0124	0,0682	0,0153	0,1058	0,0355	0,0543	0,3738
Local Suppliers										
4	China	0,1183	0,0061	0,0186	0,0121	0,0127	0,0756	0,0457	0,0620	0,3511
5	China	0,0441	0,0000	0,0186	0,0121	0,0763	0,0756	0,0457	0,0620	0,3343
13	China	0,1968	0,1281	0,0124	0,0121	0,0382	0,0756	0,0457	0,0543	0,5630
34	China	0,1312	0,1205	0,0124	0,0000	0,0356	0,0756	0,0457	0,0543	0,4752
9	China	0,0377	0,1052	0,0373	0,0121	0,0738	0,0756	0,0254	0,0310	0,3979

Table 35: Aggregated suppliers score for Product C

5.4 Validation

As stated in the methodology the validation of the BWM is troublesome. This is because it is a perception based method. In this research the perception of the experts and decision-makers of the case company have been used to shape the framework. The difficulty of validation can easily be pointed out with a simple example. If someone is asked to state their favorite color and their answer is green. The method of obtaining this information cannot be validated by asking that same person if their favorite color is green. This same construct applies to this research. Validation in the MCDM paradigm has been a troublesome matter and over the last decades no robust method has been developed (Rezaei, 2015c). In literature this problem has been addressed by repeating the analysis with a different and often more recognized method (Pohekar & Ramachandran, 2004). This in not applied in this thesis for two reasons. First of all the method is already validated in the research of its founder, in which it is compared to the well-known AHP method. This comparison proved that the BWM method produces more reliable results and requires less comparison data to do so (Rezaei, 2015a). It must be noted criticism has been expressed on the validation of this more well-known method, as it also is based upon the subjective opinions of decision makers for the priority of the pair-wise comparisons (Dağdeviren & Yüksel, 2008). The second reason is that this research has a limit timeframe and research scope. Conducting the same analysis with a different method simply does not fit this scope. In order to include some form of validation two measures are taken that are the best at hand, given the aforementioned concerns. First, consistency indicators are used in order to validate the input of the company experts and decision makers and determine how consistent they are in their preference statements. Second, the experts are asked to provide feedback on the use of the methods in this thesis and on the outcome of the framework.

5.4.1 BWM consistency indicator

The consistency indicator of the BWM is used in order to provide an understanding of the reliability of the comparison made in the analysis. Please refer to section 3.4.3 for more details on this indicator. As can be seen in Table 36 the indicator of each of the respondents are close to zero, with a maximum score of 0.0927 which can still be regarded as a high consistency. The arithmetic mean therefore shows a very high overall consistency.

Respondent No.	1	2	3	4	5	6	Average
Consistency Indicators Palm	0,0718	0,0577	0,0609	0,0777	0,0680	0,0558	**0,0653**
Consistency Indicators Non- Palm	0,0721	0,0979	0,0768	0,0546	0,0616	0,0927	**0,0759**

Table 36: Respondents consistency indicators

Based on this overview the comparisons made by the respondents can be regarded as reliable. The respondents have answered the questionnaires with care and their statements on preferences are made with reason. The next section will go into detail on feedback provided by the company experts and decision makers on the outcome of the BWM.

5.4.2 Expert validation.

The other method of validation is based on the feedback of experts in the case company. They are asked to comment on the methodology of the thesis, the weights of the criteria obtained through the BWM and on the supplier scores and ranking as a final result of the MCDM. To a certain extend their opinion can be used in order to determine if the results provide an answer to the objective and research question. However as described earlier, this expert validation has its limitations. The experts

have been involved in the process of obtaining the weights and gathering data. Therefore they are providing feedback on their own input, something that limits their objectivity.

Expert E – Experienced Procurer for Palm Products
On the results of the weights obtained for the criteria this expert agrees to a great extent. He indicates that it is in line with the current experience on the supplier assessment. Specifically for the palm products the focus is on the price and the costs of delivery as these behave more like commodities. This is reflected in the research as the weights of the palm criteria are the highest on these two elements. Also the fact that quality has a lower importance is in line with what is actually happening in the market. The end product from palm raw materials is not as sensitive on the initial quality as the products that require soft oils. This immediately confirms the weights used for the soft oils. Here the quality is most important, something that is also reflected in the research. Furthermore the lead time has a high weight and this is realistic. This is why these two criteria should be more important than price which is indeed the case in the research. For these reasons the expert considers the distribution of the weights highly representative for the specific situation of the case company.

On the final scores and the ranking of the suppliers of palm raw materials, the experts indicates that this is according to his expectation. However some suppliers which are located far from the new plant do have a reasonable score and ranking. The expert accredits this due to the cultural compliance requirements which complicates the supply chain, limiting the number of suppliers. This distorts the image to a certain extent.

Expert D - *Experienced Procurer for Non-Palm Products*
This experts indicates that the process of supplier selection and the data collection to support this, usually has a different approach in a business environment. However the approach used in this research is highly valued and believed to generate a sound understanding of the possibilities for the new plant. The screening and selection stages are regarded as a logical method to deal with the complexity of the situation. The weights that have been obtained with the BWM are similar to what is expected by this expert. As she is an expert on non-palm sourcing she agrees with the fact that the lead time is one of the most important elements. Because the higher market segment in which these products are sold, there is more room to deal with higher cost of delivery or product pricing. This is reflected in the ranking of these products.

The result of the analysis for the non-palm raw materials, seem logical and sound for the most part to the expert. The high score of the supplier from Australia is surprising, mainly due to the fact that it has never been considered for supply to China. Also, the cost of using this supplier in Malaysia is relatively high, but after checking with the supplier the expert confirmed that their delivery to China can actually be accomplished against lower costs. Something that can be considered in a later stage is the fact the a decrease in import duties will also effect the pricing of local suppliers as they want to stay competitive, resulting in a lower price. However, this is currently too complex and out of the scope for this research.

Expert F - *Experienced in sales and sourcing in the Asian region*
The results of the analysis carried out according to the BWM makes perfect sense according to this expert and are in line with his expectations. The screening prior to the final selection is a useful way of decreasing the complexity. Also, to make the framework more simple, the RSPO Certification and Traceability could receive the same ranking, as in his view these are equally important.

With regard to the outcome of the framework, the ranking of the supplier for both the palm and non-palm raw materials make sense according to this expert. Two large industry players are ranked according to what the expert would expect. Only the performance of a third is remarkable. Their demands on ordering is odd, especially because the products are standard items and these requirements are uncommon in the industry. Perhaps the wrong representative of that supplier has provide the information and a high buffer on the price and lead time is included. Or maybe they are showing strategic behavior and are not willing to give full insight in their delivering capabilities.

The conclusion that can be drawn is that a validation for this research is possible only to a limited extent. However, indicators show a high level of consistency in the application of the BWM and it can be assumed that reliable comparisons have been used in this research. Feedback from the experts on the methods used in this research indicates that these methods are unknown but certainly supported by the case company. Selecting suppliers using a two stage approach and the BWM is believed to reduce the complexity of the process. The weights obtained in this thesis are in line with what the experts would expect. However, this last confirmation holds little value as these experts have been involved in the setup of the BWM and the determination of the weights. A number of very specific results have been indicated to be unexpected, but these are reasonably explained. Because of the overall consent of the experts on the method and the outcome, there is no need to reconsider the method or the weights used in the research.

6 Results

This chapter will discuss the outcome of the supplier selection process which has be conducted using the BWM. After presentation of the initial results an optimization is conducted in order to abstract a more meaningful result from the analysis that will assist the case company in the implementation of a supply chain strategy for their new operations in China. Because a method has been applied in a very practical and specific environment, this chapter will also include practical implications which have been discovered during the research period.

6.1 Initial Results

The initial results of the analysis are based upon a small batch size, which adheres to the start-up strategy of the new plant. Sourcing low volumes requires a suitable transport mode. For transportation by sea, this is flexibag or isotank shipment with a capacity of roughly 20 metric tons. For transportation by land, a road tanker is commonly used and this mode has a capacity of 35 to 40 metric tons. An overview is generated which provides the total score per supplier. In the following sections, the results per supplier will be discussed first for the palm products and second for the non-palm products.

6.1.1 Supplier performance on Palm products

The suppliers of palm products will be discussed in this section. In general it can be said that the scores on average are higher than those of the non-palm raw materials. There also is a larger offer of palm product suppliers compared to palm kernel which is less of a common product in China. The suppliers of palm products will be discussed in detail, their scores can be viewed in in Table 38.

Company Supply Chain – Supplier 20

The supply from the existing facility of the case company has a high performance, ranking within the top three for all products. The performance on palm products is high due to quality that can be assured because of the in-house production, the performance on the environmental criteria and the high non-competitor score. The supply from Malaysia is competitive because containerized transport to China has relative low cost.

Known Supplier – Supplier 21

This supplier is a competitor of the case company on the upstream products. It is only able to supply Product C and it is has an average to low score due to a low performance on the RSPO criterion. Their lead time and costs of delivery are average. Also there are specific requirements on the transport mode which has a high (negative) impact on the supply from Malaysia.

Local Suppliers – Supplier 3 and 4

This supplier has two supply locations and because they share most of their characteristics, the ranking on most raw materials is similar. It has a large product portfolio and is the only supplier that can deliver all required raw materials. The company has an low performance on all raw materials, mainly because of their ordering requirements. This significantly increases the lead time, which on its term has a high impact on the final score because of the weight of this criterion. Furthermore is one of their plants under construction and therefore it has a lower capacity. This supplier is competing in the same market segments, which result in a low performance on the non-competitor criterion. A high score is achieved on the RSPO and Traceability criteria because this supplier is one of the best

performing in terms of sustainability. Due to the low weight of these criteria it has not prevented this supplier from ending up last in the rankings.

Local Suppliers – Suppliers 13, 34 and 29
These three different suppliers all belong to the same group and they are performing very well albeit all on different raw materials. It is apparent that this group has a strategy in which one production location focusses on a few products, allowing a higher performance. Supplier 13 can deliver all palm raw materials and has a very high overall score. This is mainly because it is a near supply point to the new plant, giving it a high score on the lead time and cost of delivery criteria. However, it does not have a kosher certification, which could mean that it can be excluded in a later stage. Supplier 34 is an alternative, but with a higher distance, it has a lower performance on the cost of delivery and lead time criteria. Supplier 29 has roughly the same distance to the new plant, but it can only deliver two products. It has a noticeably lower lead time, but a relatively high cost of delivery. Also the traceability of the oils is limited for this plant.

Local Suppliers – Supplier 9 and 11.
These suppliers both have an average performance. Remarkably this company cannot supply any palm kernel products. The number 11 plant can supply Product A and B and it has an average performance. Although the lead time is low, the cost of delivery is relatively high. Also this plant is not kosher certified. The number 9 plant has a very high capacity but is located far from the new plant, increasing the cost of delivery. The lead time for Product A and B are relatively low, but for Product C this is not the case. Both plants have a below average performance on the sustainability criteria.

Local Suppliers – Supplier 12
This supplier is a competitor to the case company, but it also has a Chinese division which can supply to the new plant. It can only provide in Product B. It has an average performance mainly because their lead time is and cost of delivery is reasonable, but their performance on the RSPO and traceability criteria are low. This supplier also has no kosher certification.

6.1.2 Supplier performance on Non-Palm products

The suppliers for non-palm products are more widespread across the Asian and even the Oceanian continent. This is because this product group has a lower availability and stricter demands like Non-GMO the requirement. The scores can be viewed in Table 39 and the following section will discuss the suppliers in detail.

Known Suppliers – Supplier 27 and 24
These two suppliers are both from Malaysia and can only supply Product H to the new plant. Their performance is similar, but number 27 has a lower capacity. The capacity of both suppliers is actually relatively low compared to the other suppliers. Even though they have to deliver from Malaysia, their lead time and cost of delivery are still reasonable, giving them an average overall performance.

Known Suppliers – Supplier 15
This supplier can only deliver Product I and it is one of the most remote Chinese suppliers. This has considerable effects on the cost of delivery. However they do have a high capacity and quality, as the supplier is already tested and approved by the case company. This results in a decent performance and a third ranking out of the five suppliers.

Known Suppliers – Supplier 16

This is a known supplier and somewhat of an outsider as it is the only supplier from Australia. Their capacity and quality is high and surprisingly the lead time is reasonable. The transportation costs are relatively low as the route between Australia and China has a high transportation volume in which competitive transportation is available. Being this far from the case company and serving a very specific market makes for a high non-competitor score. The duty structure of an Australian supplier is something that does need to be monitored. Currently the import duty is at 170% for Australian supply, boosting the cost of delivery. According to the supplier this will be lowered as the country is soon to become a most favored nation (MFN) which will lower the duty to 9%. In the end the performance and potential of this supplier is high.

Known Suppliers – Supplier 18 and 28

These two companies are small suppliers that can only deliver Product N. Their score is nearly equal as they share a lot of characteristics. There are small differences on the purchasing price and cost of delivery, but these rule each other out. The performance of both suppliers is satisfying.

Local Suppliers – Supplier 4 and 5

On the non-palm raw materials, this supplier has a poor performance, again mainly due to their demands on product ordering and its effects on the lead time. The resulting final score is even more affected by this because the lead time is the most important criterion of the non-palm product group. Furthermore, this supplier has a large product portfolio which decreases their capacity per product as they cannot focus on a single raw material.

Local Suppliers – Suppliers 13, 34 and 29

This group has a high performance for the two locations. Supplier 34 can deliver Product H, I and L and has the highest ranking on the latter two raw materials. This is partially because for these raw materials there are few alternatives, but also because the cost of delivery are low. Supplier 29 can deliver Product J and M and also has the highest ranking on both products. This is because the plant has a very short lead time and low cost of delivery. It does have a low score for the non-competitor criterion, but due to the weight this is not reflected in the final ranking. Supplier 13 can only provide in the need for Product H from the non-palm category, but has a low performance for this raw material, due to the fact that there are many other high performing alternatives for this raw material.

Local Suppliers – Supplier 10

This supplier is able to supply all non-palm raw materials. But because of the large distance to the new plant the cost of delivery is affecting their performance. However, with a reasonable lead time and being a non-competitor this supplier still has a high score except for Product H, ranking second on the other raw materials..

Asian Suppliers – Suppliers 30, 7, 26 and 17.

This group of suppliers is based in the same country and is only able to supply Product H. The industry in this country is very large and because it is well developed, it offers a large number of suppliers. Because it is a highly competitive market, their performance is comparable and of a high level. The delivered quality is regarded as superior to the Chinese standard and the cost of delivery and lead time are competitive. These elements contribute to a top four ranking for the suppliers in this group.

6.1.3 Outcome of the initial results

Purely based on these initial results it can be stated that for the palm raw materials two suppliers are dominant in terms of performance. These are Supplier 13 and 9. The fact that the same suppliers are best performing for almost all raw materials is due to the limited differences between the products within this group. This provides an opportunity for order consolidation, which will be discussed later on. A difference in performance is found with Product C. The cost of delivery from the Malaysian the supply is higher. This is reflected in a lower final score for the palm raw materials by the Malaysian suppliers.

For the non-palm raw materials the outcome is more diverse. For Product H, two suppliers are preferred. All four suppliers from this country are actually high performing, which can decrease the risk of non-supply as there are very suitable alternatives. For Product I and L, Supplier 34 and 10 are the two top performing suppliers. It is remarkable that the distance of these suppliers to the new plant seems to have little influence on their performance. This could be due to the fact that there are less available suppliers and they are more widespread throughout the country than the suppliers of the palm raw materials. The two top performing suppliers for Product J and M are Supplier 29 and 10. A note must be made on the high performance of Supplier 16 Manufacturing, which is supplying from Australia. This is remarkable considering the distance, but due to a high capacity and quality this supplier has a high final score. Furthermore, it shows that the scores are considerable lower due to the low number of available suppliers. This is actually true for most of the soft oils, as these can only be supplied by four suppliers on average. The suppliers for Product N are the only two available and their performance is similar and satisfying.

Now that the initial scores and outcome has been presented, the next section will go into detail on optimizing the results for the effects that have not been considered in the framework up till now. The result of this will enable the process of selecting the right suppliers for an optimal supply base.

6.2 Optimization for Product Importance

In this section a post optimization will be executed in order to arrive at a more meaningful result for the case company. The optimization is executed in order to incorporate a difference in importance of the different products. The framework presented in this thesis allows a multi-product company to select a supply base for their demand of raw materials. However, this multi-product character has been represented in the framework merely by including the different raw materials to be sourced. In order to increase the value of the framework this section presents a factor that will further adhere to the differences among the products. This increases not only the value but also the robustness of the framework as it is better aligned to the multi-product character of the buying situation of the case company at hand.

6.2.1 Obtaining the factor of importance

In order to correct for the product importance a factor is created that needs to be useful yet simple to obtain. Because of this the differences in price and in volume are regarded. Importance might consist of other elements, but for a new buying task in a new market it is important to make use of available data. As discovered in the literature study of this thesis, the price of a products is regarded as one of the three most important criteria for supplier selection. Furthermore does the literature research also reveal that the cost of purchasing raw material can make up to 90% of the total turnover. This underlines the importance of the raw material costs and justifies its use in this section.

This is combined with the required volume per annum of the case company in order to include the significance of a raw material, as a the purchasing of raw material with a high volume will have a larger effect on the performance of the new plant. The factor of importance for raw materials *n* is obtained with the multiplication of these two factors which can be seen in equation 7.

$$F_i^n = P^n \cdot V^n \quad (7)$$

The volume is straightforward and obtained from the case company based on their production forecast, something which has also been used to determine the volumes of the required raw materials in section 4.1. The price is more difficult to obtain as different suppliers with different prices are available. Because the raw materials are mostly commodities, the market price is used as an indicator for the purchase price. The differences in market price per country are ruled out by the use of an average among the different countries in which the specific raw material is available. The factor of importance is then normalized in order to arrive at a more meaningful scale, which can be seen in equation 8.

$$Fi^{norm} = \frac{F_i}{F_{max}} \quad (8)$$

All required data to calculate the factor of importance can be seen in Table 37. The last column shows the normalized factor which will be used together with the supplier score from the framework to calculate the aggregated scores

Raw Material	Avg MP ($/mt)	Volume (mt)	*Fi*	*Fi norm*
A	X	X	X	0,1547
B	X	X	X	0,0932
C	X	X	X	0,1180
D	X	X	X	0,0589
E	X	X	X	0,2379
G	X	X	X	1,0000
H	X	X	X	0,6093
I	X	X	X	0,0660
J	X	X	X	0,0354
L	X	X	X	0,0238
M	X	X	X	0,0186
N	X	X	X	0,0067

Table 37: Overview of Factor of Importance calculation

The aggregated supplier score is obtained by the multiplication of the initial score of the previous section with the factor of importance. The outcome can be seen in Table 40. It shows the aggregated scores of the suppliers of both palm and non-palm raw materials. The total of the scores is also calculated. This is a summation of the score per raw material. A higher score indicates that the suppliers is either able to deliver more important products, or with a higher performance or a combination of both. A comparison of the total scores should be executed with careful consideration as some suppliers are able to supply a large number of raw materials, while others can only supply a

single raw material. To gain some more insight an adjusted score is added to the overview in the final column. This is the total score dived by the number of products that the supplier can deliver to the new plant in China. This indicates an average sore per raw material and it can be used to understand the performance of a supplier. However the selection of the supplier is should be based on the individual scores and not on merely the total or adjusted score. It is added to the table only to provide some additional insight and not the serve as a base for the final selection. This selection will be discussed in the following paragraph.

6.2.2 Selection of the supply base

Now that the aggregated scores have been presented and the importance of the products have been incorporated in the selection process, the final step is to select a supply base. First the sourcing strategy of the case company needs to be consulted. This prescribes that the company demands a minimum of two supplier s for each raw material in order to decrease the dependency and the risk of disruptions in the delivery. Second, the order consolidation can be taken into account. As some suppliers are able to supply multiple raw materials the bargaining power and scale economies can be increased when the orders for different raw materials are placed with the same supplier. When the orders for different raw materials can be consolidated the case company might be able to reap the aforementioned benefits. The selection is therefore not purely based on the two highest ranking suppliers, but other high performing suppliers can be selected if this will enable a better consolidation of the orders. Therefore an alternative third supplier is also included in the overview. In order to adhere to a selection rule for this category a performance of no less than ten percent compared to the second supplier should be achieved by the third alternative. Table 41 provides the overview of the supply base. It displays the best performing suppliers per raw material. The added value of the factor of importance will prevail when a combination of suppliers is available. A higher aggregated score should be leading in the determination of the supplier selection. In other words, a very low aggregated score indicates that the orders with that specific supplier will only have a very marginal effect on the total value of the orders.

It can be concluded from that for the palm products the highest performance is achieved by Supplier 13 and 20. The similarity in performance for this group of products is caused by the relative low product complexity against a very high diversity of the characteristics of the available suppliers. For the palm kernel products the performance is the highest of Malaysian suppliers as the market for this product is very limited in China. The supply base for non-palm group is more diverse. Product H should clearly be sources from the Philippines as the performance of the suppliers from this country is among the highest. Supplier 17 and 26 are selected as the first and second supplier, but two other suiting alternatives are available. Furthermore, it is striking that Supplier 10 is represented in four cases, providing excellent opportunities for order consolidation with this supplier. Other high performing suppliers are Supplier 34 and 29. with a representation amongst two raw materials. However the first is not selected to supply Product L because the latter also has a high performance and is supplying six products from the palm group. The supply for Product N is granted to the only two available suppliers. The selected suppliers are indicated in italic in the table. Finally it must be noted that this supply base can be altered as more information or new values enter the context. The height of the aggregated score however show that for the palm group this should be based on the supply of Product G and E. For the non-palm group Product H and I are the key raw materials and should be leading in defining the supply base.

6.3 Optimization for transport mode

Another optimization is conducted to correct for a change in transportation mode. In the initial results and supply base is configured on transportation with small batch sizes because the plant will obviously not be in full operational status when the construction is completed. It will undergo a start-up phase characterized by testing and commissioning, small production batches and thus a lower required volume of raw materials. The transport mode that is considered for this first phase is sea shipment by flexitank or isotank or transport by land with road tankers. However, like stated in the introduction of this thesis, with time the production will increase and the demand for raw materials will do accordingly. This is when the selected transportation mode will become an impediment to an efficient supply chain operation. This section will therefore go into detail on the optimization for a different transport mode.

6.3.1 Setting up the optimization for transport mode

An assumption is made on the increase of the ordering size, which is set to rise to 3.000 metric tons. This volume is chosen because a market exploration on the liquid bulk transport possibilities in South East Asia and China has indicated that it is the required minimum volume for deep sea liquid bulk shipments. For more information on this exploration and bulk shipments pricing and quotation, please refer to Appendix D. The optimization will only be conducted for those raw materials that are susceptible to an increase in order size and thus bulk shipping. This selection is based upon the required raw materials and target production volume which has been established in the raw material need of section 4.1. Only products with a high demand will have a sufficient order size to allow for bulk shipments. In this research the six products will be used. With respect to the suppliers the same subset is used, with the addition of two suppliers that are able to deliver in bulk form only. First is Supplier 19 and second is Supplier 1. The latter can only supply one product only. The information from all the suppliers on bulk shipments gathered in the data collection is used to alter the framework. The most significant change will be on the criteria ‘cost of delivery’ and ‘lead time’. The following two paragraphs will further clarify this.

The first criterion is affected because the shipping costs per metric ton can be lowered when bulk shipments are applied. This is due to the economies of scale that occur when transportation volumes are increased. These shipments are common for the liquid bulk industry, which is dominated by the chemical and petrochemical industry. Edible oil transportation is considered to be more of a niche market and therefore it has to compete with shippers from larger and more dominant industries (Buvoy, 2015). This increases the aforementioned minimum required volume for a single freight haul. However when these volumes can be reached, opportunities do emerge and costs savings on the transportation can be gained. The transfer of the raw material from and to the ship also differs from containerized shipping. Liquid bulk ships moor to a bulk jetty and subsequently the raw materials are pumped from or into storage tanks via a pipeline. This transfer method can further lower the transportation costs compared to containerized shipping, when the loading point is equipped with a bulk jetty.

Besides the transportation costs, the lead time is also affected. The ships velocity does not significantly differ from containerships but the main difference is caused by the transfer time of the goods. Liquid bulk ships mainly sail from point A to point B with a minimum number of stops. A container can be transferred in a number of ports depending on the current demand for containerized transport and the dominant routes used by container ships. A transfer of a container in

a port, which is not the final destination has a significant impact on the total transportation time and thus the lead time. Also the transfer of the raw material from and to the ship which has been discussed before, is handled faster with bulk shipping compared to container loading. The result on the final score and the ranking of the supplier for bulk transportation can be seen in Table 42.

6.3.2 Defining the optimal supply base for bulk suppliers

In order to define the optimal supply base for bulk suppliers, the same steps are repeated as with the optimization of the initial results. This entails the incorporation of the product importance by means of the obtained factor of importance per product. The result of this step can be seen in Table 43. The aggregated scores are used to extract the supply base for bulk deliveries. It shows that for all products except Product H, Supplier 19 is the best performing alternative. This is due to the fact that this plant is dedicated to supplying in bulk form. Also the advantages of bulk shipments do not manifest on short distance shipping routes. Therefore the location of this plant is less of a disadvantage than it is in the initial framework. With regard to the second or third supplier a more diverse set is selected. Supplier 9 is represented three times, solely for the palm raw materials. This provides an opportunity for order consolidation with this supplier. Palm kernel raw materials have a lower availability which can also be concluded from the lack of local suppliers in the supply base. Therefore Supplier 2 is selected for the supply of Product G and Supplier 29 for the supply of Product E. Like with the initial results, the same suppliers are preferred for Product H, although in this case only two suppliers are available to deliver their products in bulk. The complete overview of the supply base can be seen in Table 44.

6.4 Practical Implications

This chapter will be completed with a section on the practical issues that were encountered during the period of research. These can have significant consequences for the case company and will provide a basis for further analysis by the company itself. These implications are dived into three different topics which will be discussed next.

6.4.1 Suppliers

The market exploration and research has indicated a large number of suppliers for the new plant. This exploration proved to be essential, as there was little information available on possible suppliers on forehand. However due to the focus of this research, which is placed upon the selection phase, there was a limited and fixed amount of time and research effort available for this exploration. With more time and manpower it is likely that other options for supply will be found. These can simply be added to the pool of suppliers and the framework can be rerun in order to obtain an update on the ranking. Furthermore is the communication with these suppliers difficult as the langue can be a barrier with local suppliers. Chinese speaking employees are therefore a must when operating in the local market.

The market exploration pointed out that a there is an available supply from ex-tank sales in the Chinese market. Many of these sources are nearer to the plant than the identified suppliers in the framework. However these were not taken into account because the origin of the oils from these sources is unknown and the quality is dependent on the tank composition at that moment. However this might be an option if these suppliers can guarantee a cultural compliance and are aware of the product quality.

The cultural compliance mentioned in the previous paragraph is something that has a significant consequences for the supply chain. Halal is more common in the Chinese market and assumed to be a strict requirement. Kosher is less certain and depending on the customer needs this is required or not. Because the latter requirement is less common, it the options for kosher certified supply of raw materials and transportation are limited. The incorporation of this certification will therefore have a direct effect on the cost of operations and should be carefully examined and considered.

6.4.2 Shipping and transportation

Besides an exploration on the possible suppliers, the options for transportation to the new plant also had to be identified in this research. Some data was available, but only for the modes the company is used to working with. A large effort was therefore dedicated to exploration and identification of the liquid bulk transportation market in Asia. This has revealed that the minimum required volume is far higher than what was expected. Around 2.500 metric tons. This has serious consequences for the frequency and storage of bulk shipments to China. The transportation costs were also unknown and a quotation among ship brokers was conducted in order to get a better understanding of the current bulk transportation market in Asia. This has revealed that a low bulk quotation is only provided for high volumes, which are not always achievable for the case company. This has shifted the tipping point for bulk shipping, It must be noted that all information is based on the current market outlook and indication for future situations must be reinvestigated. This is because the market for bulk shipping is a spot market, especially for lower volumes. Indications are only valid for a short period and because the market is very dynamic, prices and availability of shipments need to be monitored continuously. Finally, the requirements on shipments of edible oils are stricter than other bulk shipments, because of the use in the food industry. Common standards are based on FOSFA requirements. This further complicates the bulk shipments especially when kosher certified products are transported. More details on bulk shipping and pricing can be found in appendix D.

6.4.3 Management and Organization

This last section will be on the management of the new plant and the implications on the organization. The communication with local suppliers can be difficult. Therefore the management of the project involved with the supplier selection will need to be able to communicate in Chinese. This also improves the attitude of the local suppliers as they feel more comfortable when communicating in Chinese. Finally less communicational errors are made as the interpretation of the English writing or speech by some suppliers can be ambiguous.

	Product:	A	#	B	#	C	#	D	#	E	#	G	#	Avg #
Company Supply Chain	**Country**													
Supplier 20	Malaysia	0,4958	2	0,4983	2	0,4652	3	0,5621	1	0,5995	1	0,6069	1	**2**
Known Suppliers														
Supplier 21	Malaysia					0,3738	5							**5**
Local Suppliers														
Supplier 4	China	0,3115	6	0,3184	7	0,3511	6	0,3196	4	0,3196	4	0,3196	4	**5**
Supplier 5	China	0,2791	7	0,2860	8	0,3343	7	0,2890	5	0,2890	5	0,2890	5	**6**
Supplier 9	China	0,3767	4	0,3863	6	0,3979	4							**5**
Supplier 11	China	0,3621	5	0,3935	5									**5**
Supplier 12	China			0,4408	4									**4**
Supplier 13	China	0,5408	1	0,5468	1	0,5630	1	0,5415	2	0,5415	2	0,5415	2	**2**
Supplier 29	China									0,4466	3	0,4466	3	**3**
Supplier 34	China	0,4512	3	0,4572	3	0,4752	2	0,4271	3					**3**

Table 38: Overview of the palm suppliers final scores

	Product:	H	#	I	#	J	#	L	#	M	#	N	#	Avg #
Known Suppliers	**Country**													
Supplier 15	China			0,5097	3									**3**
Supplier 16	Australia					0,3471	3							**3**
Supplier 18	China											0,4377	1	**1**
Supplier 24	Malaysia	0,5880	5											**5**
Supplier 27	Malaysia	0,5757	6											**6**
Supplier 28	China											0,4320	2	**2**
Local Suppliers														
Supplier 4	China	0,2841	10	0,3819	4	0,1828	5	0,4098	4	0,1422	4			**5**
Supplier 5	China	0,2291	11	0,3799	5	0,2144	4	0,4339	3	0,1663	3			**5**
Supplier 10	China	0,3708	9	0,5153	2	0,3716	2	0,5266	2	0,2590	2			**3**
Supplier 13	China	0,4778	7											**7**
Supplier 29	China					0,3957	1			0,3815	1			**1**

Supplier 34	China	0,4219	8	0,5213	1		0,6084	1		**3**
Asian Suppliers										
Supplier 7	Philippines	0,7433	3							**3**
Supplier 17	Philippines	0,7608	2							**2**
Supplier 26	Philippines	0,7722	1							**1**
Supplier 30	Philippines	0,7363	4							**4**

Table 39: Overview of the non-palm suppliers final scores

Product:	**A**	**B**	**C**	**D**	**E**	**G**	**H**	**I**	**J**	**L**	**M**	**N**	**TOTAL**	**SCORE ADJ**
Fi:	*0,1547*	*0,0932*	*0,1180*	*0,0589*	*0,2379*	*1,0000*	*0,6093*	*0,0660*	*0,0354*	*0,0238*	*0,0186*	*0,0067*		
Company Supply Chain														
Supplier 20	0,0817	0,0495	0,0631	0,0348	0,1498	0,6374							1,0163	0,1694
Known Suppliers														
Supplier 15								0,0347					0,0347	0,0347
Supplier 16									0,0133				0,0133	0,0133
Supplier 18												0,0028	0,0028	0,0028
Supplier 21			0,0531										0,0531	0,0531
Supplier 24							0,3626						0,3626	0,3626
Supplier 27							0,3550						0,3550	0,3550
Supplier 28												0,0028	0,0028	0,0028
Local Suppliers														
Supplier 4	0,0444	0,0274	0,0347	0,0176	0,0712	0,2992	0,1526	0,0229	0,0054	0,0027	0,0021		0,6802	0,0618
Supplier 5	0,0408	0,0252	0,0319	0,0166	0,0669	0,2811	0,1250	0,0228	0,0063	0,0032	0,0025		0,6223	0,0566
Supplier 9	0,0600	0,0370	0,0422										0,1392	0,0464
Supplier 10							0,2319	0,0342	0,0127	0,0064	0,0050		0,2902	0,0580
Supplier 11	0,0568	0,0372											0,0940	0,0470
Supplier 12		0,0419											0,0419	0,0419
Supplier 13	0,0822	0,0501	0,0634	0,0327	0,1322	0,5555	0,2938			0,0079			1,2178	0,1522
Supplier 29									0,0117		0,0058		0,0175	0,0087
Supplier 34	0,0695	0,0424	0,0537	0,0266	0,1073	0,4512	0,2652	0,0350		0,0061			1,0570	0,1174

Asian Suppliers			
Supplier 7	0,4348	0,4348	0,4348
Supplier 17	0,4435	0,4435	0,4435
Supplier 26	0,4515	0,4515	0,4515
Supplier 30	0,4306	0,4306	0,4306

Table 40: Aggregated scores of all suppliers

Product	1st Supplier	Score	2nd Supplier	Score	Alternative 3rd Supplier	Score
A	*Supplier 13*	0,0822	*Supplier 20*	0,0817	-	
B	*Supplier 13*	0,0501	*Supplier 20*	0,0495	-	
C	*Supplier 13*	0,0634	*Supplier 20*	0,0631	-	
D	*Supplier 20*	0,0348	*Supplier 13*	0,0327	-	
E	*Supplier 20*	0,1498	*Supplier 13*	0,1322	-	
G	*Supplier 20*	0,6374	*Supplier 13*	0,5555	-	
H	*Supplier 26*	0,4515	*Supplier 17*	0,4435	Supplier 7	0,4348
I	*Supplier 34*	0,0350	Supplier 15	0,0347	*Supplier 10*	0,0342
J	Supplier 16	0,0133	*Supplier 10*	0,0127	*Supplier 29*	0,0117
L	*Supplier 13*	0,0079	*Supplier 10*	0,0064	Supplier 34	0,0061
M	*Supplier 29*	0,0058	*Supplier 10*	0,0050	-	
N	*Supplier 28*	0,0028	*Supplier 18*	0,0028	-	

Table 41: The supply base with the optimal combination indicated in italic

	Product:	A	#	B	#	C	#	E	#	G	#	H	#	Avg #
Company Supply Chain	**Country**													
Supplier 20	Malaysia	0,4717	**5**	0,4781	**6**	0,4550	**6**	0,4692	**3**	0,4766	**4**			**5**
Supplier 19	Malaysia	0,5798	**1**	0,5797	**1**	0,5692	**1**	0,6604	**1**	0,6231	**1**			**1**
Known Suppliers														
Supplier 21	Malaysia					0,5343	**3**							**3**
Supplier 24	Malaysia											0,5541	**3**	**3**
Supplier 27	Malaysia											0,5334	**4**	**4**

Local Suppliers														
Supplier 4	China	0,3765	**8**	0,3766	**8**	0,3724	**8**	0,3182	**6**	0,3182	**7**	0,2670	**8**	**8**
Supplier 5	China	0,4106	**7**	0,4108	**7**	0,4041	**7**	0,3271	**5**	0,3271	**6**	0,2414	**9**	**7**
Supplier 9	China	0,5138	**3**	0,5080	**4**	0,5067	**4**							**4**
Supplier 10	China											0,4206	**7**	**7**
Supplier 11	China	0,4621	**6**	0,4622	**6**									**6**
Supplier 12	China			0,5135	**3**									**3**
Supplier 13	China	0,5434	**2**	0,5434	**2**	0,5418	**2**	0,5306	2	0,5306	2	0,4926	**5**	**3**
Supplier 29	China							0,4259	**4**	0,4259	**5**			**5**
Supplier 34	China	0,4983	**4**	0,4984	**5**	0,4933	**5**					0,4267	**6**	**5**
Asian Suppliers														
Supplier 2	Indonesia									0,4801	**3**			**3**
Supplier 17	Philippines											0,6701	**1**	**1**
Supplier 30	Philippines											0,6567	**2**	**2**

Table 42: Overview of the bulk suppliers scores

	Product:	**A**	**#**	**B**	**#**	**C**	**#**	**E**	**#**	**G**	**#**	**H**	**#**	**Avg #**
		0,1546		*0,0932*		*0,1180*		*0,2379*		*1,0000*		*0,6093*		
Company Supply Chain	**Country**													
Supplier 20	Malaysia	0,0730	**4**	0,0446	**5**	0,0537	**4**	0,1116	**2**	0,4766	**3**			**4**
Supplier 19	Malaysia	0,0897	**1**	0,0540	**1**	0,0672	**1**	0,1571	**1**	0,6231	**1**			**1**
Known Suppliers														
Supplier 21	Malaysia					0,0511	**5**							**5**
Supplier 27	Malaysia											0,3250	**4**	**4**
Supplier 24	Malaysia											0,3376	**3**	**3**
Local Suppliers														
Supplier 4	China	0,0582	**7**	0,0351	**8**	0,0440	**7**	0,0757	**5**	0,3182	**6**	0,1627	**7**	**7**
Supplier 5	China	0,0635	**6**	0,0383	**7**	0,0477	**6**	0,0778	**4**	0,3271	**5**	0,1471	**8**	**6**
Supplier 34	China	0,0771	**3**	0,0465	**4**	0,0582	**3**					0,2600	**5**	**4**
Supplier 11	China	0,0715	**5**	0,0431	**6**									**6**

Supplier 9	China	0,0795	**2**	0,0473	**3**	0,0598	**2**							**2**
Supplier 12	China			0,0479	**2**									**2**
Supplier 29	China							0,1013	**3**	0,4259	**4**			**4**
Supplier 10	China											0,2563	**6**	**6**
Asian Suppliers														
Supplier 2	Indonesia									0,4801	**2**			**2**
Supplier 17	Philippines											0,4083	**1**	**1**
Supplier 30	Philippines											0,4002	**2**	**2**

Table 43: Aggregated scores of bulk suppliers

Product	1st Supplier	Score	2nd Supplier	Score	Alternative 3rd Supplier	Score
A	*Supplier 19*	0,0897	*Supplier 9*	0,0795	Supplier 34	0,0771
B	*Supplier 19*	0,0540	Supplier 12	0,0479	*Supplier 9*	0,0473
C	*Supplier 19*	0,0672	*Supplier 9*	0,0598	Supplier 34	0,0582
E	*Supplier 19*	0,1571	Supplier 20	0,1116	*Supplier 29*	0,1013
G	*Supplier 19*	0,6231	*Supplier 2*	0,4801	Supplier 20	0,4766
H	*Supplier 17*	0,4083	*Supplier 30*	0,4002	-	

Table 44: Bulk shipping supply base with the optimal combination indicated in italic

7 Conclusion and Discussion

With the result from the framework and the optimizations presented in the previous chapter, the research can be concluded with a final chapter which will provide answers to the research questions. Subsequently a discussion will reflect on the research and the literature review conducted in this thesis.

7.1 Conclusion

This thesis has started off with the objective of creating a method of selecting suppliers for a company operating in a market in which it provides multiple products. The research has been focused on this objective with the following research question:

How should the supplier selection decision-making process be executed in order to obtain an optimal supply base for a multi-product company?

The notion made in the introduction that supplier selection is a critical step in developing a competitive supply chain has certainly been underlined by the case company of this thesis. Although the company can provide in its own demand to a certain extent, the necessity to have a structured approach on the supplier selection has become clear throughout the research. The implementation of a structural and scientific approach has warranted a new method for the case company which minimizes the uptake of subjectivity into the process. This subjectivity can be caused by the perspectives and experience of decision makers. Especially for a new buying task like the one in China, this can limit the possibilities for a fitting solution. The method has uncovered the values that are shared within the company and excluded a one-sided approach to the problem. Using the multiple-stage approach of supplier screening and subsequently supplier selection allows for a reduction in the complexity and a better understanding of the process by all associated parties to the problem. This construct as a whole actually provides the answer to the research question. The framework that is shaped through the use of the BWM can provide the case company with insight on the performance of the different suppliers. With a ranking of the supplier in combination with strategic considerations of a company, the supply base can be selected. This selection is the product of the available information at that moment in time. With more information or new insights the framework can be used to generate an update on the supplier ranking in order to make a better informed decision on the supply base. A multi-product situation can be dealt with by splitting the framework per product. The outcome of the framework then has to be optimized for product importance in order to distinguish a basis for a purchasing or order strategy among the suppliers.

A series of sub questions have been constructed in order to further specify the research and align it to the specific situation of the case company which has been used for the implementation. These question will be answered individually in the following paragraphs.

Which suppliers are available to the new plant of the case company?
The availability of suppliers that are able to provide in the raw material need of the new plant in China depends on the posed requirements. Certain requirements are very clear and inflict no difficulties for the suppliers. Others can be more complex and have a larger effect on the availability of suppliers. The kosher requirement is an example of this, as it significantly limits the number of available suppliers. Based on the screening criteria used in the supplier screening stage of this thesis,

there are 23 suppliers available for delivery to the new plant. Of these, six are known suppliers, nine are Chinese and five are from other Asian countries. Furthermore, it can be concluded that the palm oil and it fractions are widely available, both in Malaysia as well as in China. This cannot be said for the palm kernel oil and its fractions. This research revealed that the local availability is low and that manufacturers keep a stock for their own production. This limits the supply options and the ranking therefore shows a preference for own supply company group. There is a large production and trade in non-palm raw materials in China, but the strict requirements necessary because of the use in infant nutrition limit the supply options.

Which criteria can be developed both from literature and experts within the company?
This research has used the findings from the literature research to complement the criteria obtained from the case company. These have been used for the screening and selection process. These criteria address different considerations in the selection process. Purely focused on the product are the criteria *Quality* and *Price*, where quality is used as a minimum requirement in the screening stage and as a performance indicator during the selection phase. The price is the purchasing price of one metric ton of raw material. Criteria focused on the transportation are *Cost of Delivery* and *Lead Time*. These focus on the transportation cost and time, but also cover a wider range of considerations as the cost of delivery also includes duties and lead time the production time of a supplier when they are not able to deliver from stock. The criteria that purely focus on the supplier itself are *Production Facilities and Capability* and *Non-Competitor on Specialties.* The first criterion considers the production capacity in case order changes are made and with the grow of the Chinese production in mind. The other criterion is applied in order to take strategic considerations into consideration, as raw material suppliers can also be competing on the edible oil market. Therefore as a buyer it is not favorable to be dependent on such a supplier. Purchasing with such a supplier will enforce its market position which is affecting the competitiveness of the case company. Finally *RSPO Certification* and *Traceability* are criteria that focus on the sustainable practice of a supplier and only apply to the palm raw materials. RSPO Certification indicates the physical separation of certified palm oil products and commitment to the values of the RSPO organization. The traceability is purely an administrative matter and indicates the extent to which the raw materials can be traced back to their origin. Except for these last two, the criteria are used for both palm and non-palm raw materials. However, due to very different considerations on the purchase of these raw materials, the weights of the criteria are obtained separately for these groups. It has shown that for the more basic palm raw materials, the price and cost of delivery are most important. With the more sophisticated non-palm raw materials, the lead time and the quality are most important.

How do the suppliers perform on these criteria?
With the scores obtained from the framework, an extensive overview is provided on the performance of all suppliers. This gives an insight into the differences among the suppliers and the raw materials. A high performance is established for suppliers of Product H. Furthermore do the local suppliers 13, 29 and 34 have a high score, partly due to distance of their plants. Suppliers 9 and 11 have an average or above average performance on the palm group, while their number 10 plant has a very high score on the non-palm raw materials. Moreover, the supply by Supplier 20 is highly ranked. This can only supply palm raw materials, but due to the assured quality and the standardized method of shipping by flexibags it is performing better than expected. It is noteworthy that the smaller suppliers on single raw materials on average have a relatively high performance. This is due to the focus they can place upon the production and delivery of their products. Furthermore is it

striking that Suppliers 4 and 5 have a very low performance, in contrast to what was expected by the case company. This is due to their ordering requirements.

What is the optimal supply base for the product mix?
The optimal supply base for the plant in China is obtained by a number of optimizations of the initial results. These take into consideration the multi-product character of the case company and the differences in transportation modes that are available in the industry. In this way the outcome of this research is more robust and it has a greater value to the case company. The optimal supply base in the first phase of operation, which is characterized by the plant start up, a low production volume and small batch sizes, contains Supplier 13 and 20 as optimal suppliers for the palm products Supplier 26 and 17 are preferred for Product H. Product I, J, L and M are preferably supplied by Supplier 10. The options for additional supply are more diverse and spread among three other local suppliers. The supply of Product N is provided by the only two available options, Supplier 18 and 28.

In a later stage with an increase in production, the optimal supply base has a different configuration, for the largest oils which are susceptible for bulk shipments. In this case the Supplier 19 is the preferred first supplier for the palm raw materials, as is it designed to solely deliver in bulk form. The set of second suppliers shows a more diverse image. Supplier 9 has a high performance and is therefore also selected. The supply base is complemented with Suppliers 2 and 29 for the palm products. Product H is supplied by Suppliers 17 and 30.

What are the consequences of the achieved supply base on the company's facilities and organization?
Using these supply bases will affect the operation of the plant, as it has not been designed for any specific suppliers. This research has indicated a number of elements that do not align with the current design or supply strategy. The consequences of this are classified based on base of their effect on either the technical facilities or on the management and organization. An important element of the technical consequences is the storage capacity at the plant, this should be aligned to the order size with the different suppliers and the storage strategy. Furthermore, with the selection of a supply base with more local suppliers, the delivery will be more dependent on road tankers. This will put a higher load on the truck unloading facilities.

On the management and organization of the new plant, does the management need to be capable of communicating in Chinese with local suppliers. Also do the responsibilities of the different aspects of creating a supply chain need to be clear to this management.

In order to provide a better overview of the results and provide the possibility to reflect on the research questions by looking back at the related sections Table 45 has been constructed.

Research Question	Answer	Related sections
How should the supplier selection decision-making process be executed in order to obtain an optimal supply base for a multi-product company?	By implementing a framework constructed with the BWM. This can be executed per product in order to account for product differences. Optimization is required in order to fully align the framework outcome to strategic and industry specific considerations.	Section 2.4, 3.1, 3.2, 3.3, 3.4, 6.2, 6.3
Which suppliers are available to the new plant of the case company?	A combination of Chinese, Philippine and Malaysian suppliers.	Section 4.3

Which criteria can be developed both from literature and experts within the case company?	The criteria obtained from the company and literature are: Cost of Delivery, Lead Time, Price, Quality, Production Facilities and Capacity, Non-Competitor on Specialties, RSPO Certification and Traceability	Section 2.5, 3.2, 4.2 Appendix A
How do the suppliers perform on these criteria?	A high score is found on the palm suppliers as it is a common product with high availability. Palm kernel suppliers have a lower performance due to low availability. Product H has a high performance, the products I - N have an average score.	Section 5.3, 6.1, tables 38 - 44
What is the optimal supply base for the product mix?	Dependent on the optimization objective the optimal supply base consist of local suppliers for container shipments and of Supplier 19 as first supplier and Supplier 9 as second supplier for bulk shipments.	Section 6.2, 6.3, tables 41 and 44
What are the consequences of the achieved supply base on the company's facilities and organization?	A large number of consequences have been established, most important are on the raw material storage, receiving of containers, road tankers and bulk shipments, rental of tank storage, management responsibilities and language barriers	Section 6.4 Appendix D

Table 45: Overview of the research questions, answers and relating sections

7.2 Discussion

With the conclusion of the previous section answering the research questions, it is now important to reflect on this outcome on a number of levels. First the outcome is compared with the results that could have been expected based on the literature research. Then the methods used in this thesis are reflected upon. Finally a note is made to the dynamics of the problem context and the way this thesis is able to deal with this.

7.2.1 What could have been expected based on the literature research

The thesis has started with a literature research, which prepared the analysis and provide an initial format for the thesis structure. Based on the literature research certain expectations can be established and the comparison with the actual outcome can provide an insight whether this research is different from what could have been expected. A discussion on these differences will contribute to the value of this report both scientifically as well as for the case company.

The literature research starts off with the make-or-buy decision. For this thesis the decision on what to make and what to buy has been determined by the case company. In literature is found that outsourcing has become an integral part of the business strategy of a company and it can provide a considerable contribution to the profitability. However, when it comes to the execution, managers solely consider short-term benefits and economic factors like overhead cost reduction. Besides this the make-or-buy question is not a matter of selecting one or the other, partial outsourcing is possible of both services and business processes.

When the buy option is selected, the subsequent question arises, what to source from how many suppliers? Single sourcing is found to be effective when a supplier's capacities are relatively high compared to the product demand. In this case the least cost supplier might be selected. Multiple sourcing is favorable when suppliers are capacitated. Also the literature stated that single and

multiple sourcing should not be assessed using the same weight for the criteria. The other notion in this topic is made on the differences in product type, for products with a high degree of standardization and low products differentiation like commodities, the most important purchasing criteria are price and service.

The main topic of this paper and the literature research is supplier selection and it is concluded that for new task situations, like the one of the case company, little is available in literature and preparation on the various sequences of the process is difficult because the lack of information. Finally the perception of decision makers is discussed. When they are asked on their opinion on what is the most important attribute when selecting supplier they will state a different attribute from the one they actually use when they are involved in the selection process. This is a remarkable observation as even though managers understand and perceive quality to be more important than cost, in practice they do not choose suppliers based on quality. Apparently a gap exists between the perception and actual practice

On the methods and criteria used for supplier selection, it is concluded that a wide variety of methods are available in order to apply the MCDM paradigm to the selection problem. Most models do have their limitations as they often focus solely on the choice phase and their applicability in the purchasing context can be troublesome. The selection criteria is a subject of academic interest for many decades and different criteria have become popular belief. For the last two decades the change in belief is less volatile and quality, delivery and price are the most important criteria. Additional criteria have become more intangible and possibly harder to measure. Finally the use of environmental supplier selection criteria seems to take off, but these have a limited compatibility with the traditional criteria and a trade-off can arise between these categories.

The topic of sustainability can be view on multiple levels. In the literature on supplier selection a new field of research is emerging called green supplier selection. This includes more sustainable criteria, which has been mentioned in the previous paragraph. On an industry level, the topic is highly interwoven with the edible oil business. Many efforts have been made, resulting in the foundation of the RSPO and in a higher awareness. This does not mean that all is well, as many challenges on this subject still remain.

The final topic of the Chinese business culture states that China should not be perceived as a coherent nation or a homogenous market. Large differences exists between regions in terms of salary or economic development. On an individual level, face-to-face contact is important and interaction in a pleasant and comfortable way is desired. One must maintain its own composure at all times and avoid causing embarrassment to one itself or another. Another cultural aspect that is to be kept in mind is that the Chinese find it difficult to disclose bad news. Finally It is concluded that long-term and personal relationships are appreciated.

7.2.2 A comparison of expectation and actual outcome

The primary outcome of the thesis has been presented in the previous chapter and this section will focus on the less obvious results that can be found by making a comparison with the results that could be expected based upon the literature research.

With regard to the make-or-buy decision a short term focus based upon cost savings could have been expected. Within the company this is not the case as a deep consideration for the make option is

encountered. Partial outsourcing which has been identified in the literature research is found within the company as the sourcing is only required for a certain part of the raw material need.

The sourcing strategy is also provided by the company and multiple sourcing is required. The literature indicates that this is best when no single supplier can provide in the total demand for a product. This is certainly not the case with the company it is actually regarded as a small player by most suppliers. This difference is due to the fact that the company wishes to lower the risk of being dependent on a single supplier. As indicated In the literature research, the company seems to take up upon the view of Porter, that multiple sourcing prevents a supplier form obtaining controlling power over the buyer and it increases competition among suppliers.

The notion on the differences both in the weight for different criteria and differences for various type of products is encountered in the case company. This clearly is in line with the findings from the literature research. The palm products, which can be regarded as basic products, have a higher weight for the criteria relating to costs. The soft oils, which are more complicated products, have higher criteria weights for quality and lead time.

On the supplier selection process the limited amount of information did not lead to difficulties with the method itself, but the data gathering took a considerable amount of time. Also some assumptions had to be made whenever suppliers were not able to provide the required information. The BWM method is focused on the final choice phase, but a conjunctive screening process is added to the research in order to correct for this problem. Furthermore are the findings on the criteria in this thesis in line with the expectations from the literature research. Quality, delivery and costs are the most important criteria and additional criteria like capacity and non-competitor do play a role but are less important.

The addition of environmental criteria is also apparent in this thesis, albeit with low criteria weights. This is due to the new task buying situation and the novel character of the project for the company. This places a larger focus on the most crucial criteria and leaves less room for elements like sustainability. The conclusion from the literature review that traditional and environmental criteria have a limited compatibility is not supported by this research. Both are used and the combination did not present any obstacles or difficulties to the research.

The final topic of the Chinese business culture has shown a different outcome from what could have been expected. While communicating with Chinese suppliers no barriers were experienced. This could be due to the international setting of the Chinese suppliers as companies some of these companies are not Chinese by origin. The true Chinese companies also did not show any relationship that resembles to the picture drawn by the literature research. This could also be due to the reputation of the case company which is highly valued in the industry. It can be concluded that the differences in culture have posed little to no hurdles to the thesis research.

7.2.3 Reflection on the methods used

The BWM used in this thesis is relatively new and experience with the implementation within a large company is scarce. This novel character of the method leads to a number of difficulties of which the validation is one of the most prominent. A lack of robust validating possibilities exists for all methods in the MCDM paradigm, but with more well-known methods, reference material is available on how to deal with this. With the use of the BWM the consistency indicator and the feedback from experts

of the case company are the only available methods for validation. This being said, the implementation also uncovered some valuable assets of the method. The reduction in required data by the manner of comparing, is proven to be valuable and it has shown that the method is easy to work with and relatively simple to execute. For the comparisons for instance, the respondents did need a short instruction on how to state their preference, but when this was provided they found it easy to make the comparisons and express their preference. The framework which has been constructed in order to obtain the final scores and ranking of the suppliers, provides a simple approach to compare them. This framework yields a clear overview. The results and the methods have been discussed with company experts, who found it a transparent way of gaining insight in the performance of suppliers. It also allows for a number of optimizations as it is straightforward to alter the scores within the framework. In the future, this can also be easily executed by the company in order to update the ranking of the supplier with new data.

A drawback of the framework has been discovered when extreme values are encountered. A foreign supplier for instance was charged with a 170% import duty, which caused an extremely high cost of delivery. This minimized the score of the supplier on this criterion. However the supplier had an excellent score on quality and the score on the other criteria was also above average. This caused the supplier to become second in the ranking for which it was selected into the supply base. Feedback from the case company however, clarified that a supplier with those extreme costs never would and should be selected. This is clearly something that the framework is not able to deal with and can lead to a sub optimal supply base.

7.2.4 Discussions on dynamics

This section is not available due to confidentiality concerns.

7.2.5 Expansion of the method and further research

Additional research can be conducted in order to develop a method that further integrates the dynamics into the framework. Furthermore it is recommended to explore how the framework can be used when the case company is firmly settled in the Chinese market and the buying task is no longer a new situation but rebuy situations arise. Because the character of the current method is aligned to the new market and corresponding buying tasks it is useful to investigate how it can be improved. Integration of more delicate topics like supplier relationship management, supplier segmentation or order lot sizing should be considered, as it can further assist in the supplier selection process when the company has become an established player in the market.

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Appendices

Appendix A: Identifying Criteria for Supplier Selection (Step 1 of BWM)

The identification of criteria is an important step in this thesis. As described in the report. This is done both from literature and from the experts in the case company. For the criteria obtained from the literature, Chapter 2 can be viewed. This appendix will include the questionnaire that is used to obtain the criteria from the company experts. In total seven experts are used for the criteria trawling. These can be seen in Table 46.

Person	Position	Respondent No.
Person A	COO	1
Person B	GM Sales & Logistics	2
Person J	Manager Logistics	6
Person K	Manager Quality Assurance	7
Person F	Manager Sales	5
Person E	Purchaser palm products	3
Person D	Purchaser soft oils	4

Table 46: Overview of respondents for obtaining the criteria

The questionnaire that is used to obtain the criteria can be seen on the following pages. The outcome of the questionnaire is also presented in Table 48. Based on the scores of this table, the following criteria have the highest score. Based upon their applicability to the case of the new oils and fats plant in China a selection is made for the use in the framework.

Criterion		
Price	Quality	Reputation and Position in Industry
Ordering costs	Service	Delivery
Technological ability	Reciprocal Arrangement	Attitude
Financial Position	Flexibility	Management and Organization
Warranty and Claim Policies	Desire for Business	Trade restrictions
Production Facilities and Capacity	Labor Relations record	Green supply chain management
Geographical Location	Pollution of production	Environmental responsibility of product
Capabilities and standards	Political situation	Green / environmental practice

Table 47: Highest scoring criteria based on the conducted questionnaire

Criteria used for Supplier Selection

Name: *Position:*

This questionnaire is meant to identify the criteria used in the company to assess suppliers for the new plant. This is aimed at not only capturing the formal criteria used for instance in the process of vendor approval by QA, but also the less tangible factors that do play a role but are not captured in SOP's . The goal is to identify which of the criteria are important and what literature could contribute on this subject.

Could you indicate which criteria you consider relating the selection of a supplier. Anything you use can be stated here.

Could you indicate which criteria you consider relating to sustainability (if you haven't mentioned these in the previous questions)?

Could you indicate which criteria you consider relating specifically to Chinese suppliers or suppliers in the Chinese market (if you haven't mentioned these in the previous questions)?

Literature on the topic of supplier selection is substantial and also provides a vast amount of selection criteria. The most important and used are listed below. Could you indicate which one of these you think should be taken into account (and you didn't indicate before).

Criterion	X	Criterion	X	Criterion	X
Price (unit cost)		Service (after-sales support, service response time)		Quality (% in spec, quality stability, conformance to spec)	
Costs (ordering, transportation, duties and taxes, total delivery cost, payment terms, price discount)		Reputation and Position in Industry (Performance history, market position, market share, integrity, general reputation in industry)		Delivery (OTIF, lead time, mode of transportation, delivery with packaging standards, delivery in good condition)	
Technological ability (R&D, Innovativeness, diversity of product mix)		Reciprocal Arrangement (return of business, sharing resources)		Attitude (response to enquiries, willingness to cooperate)	
Financial Position (Financial stability, debt/equity ratio, total revenue, annual net profit, profit growth)		Flexibility (Responsiveness to the market trend, response to changes, volume flexibility, product mix flexibility, lead time flexibility, time-to market)		Management and Organization (HRM, organizational culture, alignment of management goals, strategic orientation)	
Warranty and Claim Policies		Desire for Business		Trade restrictions	
Production Facilities and Capacity		Labor Relations record		Political situation	
Geographical Location		Environmental responsibility of the production (pollution of production, resource consumption, waste water facilities.)		Environmental responsibility of product (certified product, green development, deforestation free)	
Capabilities and standards (halal/kosher cert, FSSC, ISO9001)		Green supply chain management (lean transport, biofuels)		Green / environmental practice (recycling, pollution control, ISO14001)	

From all the criteria mentioned before, could you indicate which should be used as a minimum requirement in order for a supplier to be considered in the selection (a poor performance on these criteria may thus not be compensated by a high performance on other criteria)?

End of questionnaire

The results from the questionnaire on criteria for supplier selection can be seen in Table 48 below.

Respondent NO	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*Total Respondents*	From literature	Total
Stated Criteria										
Quality (in spec)		1	1	1	1	1	1	**6**	1	7
Price			1	1	1	1		**4**	1	5
Total costs of delivery		1						**1**	3	4
Lead Time		1		1	1	1		**4**		4
Location			1	1	1			**3**	2	5
MOQ		1						**1**		1
OTIF (delivery)				1				**1**	5	6
Cultural Compliance				1				**1**	5	6
Service				1				**1**	2	3
Credit Term		1						**1**		1
Flexibility (in supply)		1			1			**2**	2	4
Availability			1					**1**		1
Reliability	1	1	1		1			**4**		4
Reputation				1	1			**2**	1	3
Financial Status	1							**1**	3	4
Quality Awareness	1							**1**		1
Sustainability Policy	1				1			**2**		2
Traceable oil (or willing to)	1	1						**2**		2
Non-Competitor (on specialties)	1	1						**2**	4	6
Food safety compliance				1			1	**2**		2
Company background					1			**1**		1
History / relationship					1			**1**		1
Future plan of supplier					1			**1**		1
Special for the Industry										
Base on own buying spec					1			**1**		
Mode of delivery					1			**1**		
Contract booking period					1			**1**		
Own plantation					1			**1**		
Non-GMO	1	1			1			**3**		
Use in infant formula specs		1						**1**		
Origin of the oils				1				**1**		
3MCPD					1			**1**		
Flexibility					1			**1**		
Batch size					1			**1**		
Sustainability										
RSPO Certified		1			1		1	**3**		
Traceability (to mill)	1	1			1	1		**4**		

Sedex Certification		1						**1**
Sustainable reputation			1					**1**
Policy on sustainable PO					1			**1**
Ethical compliance							1	**1**
Literature								
Price	1							**1**
Costs			1		1	1		**3**
Capabilities and standards	1		1		1	1	1	**5**
Labor Relations record	1			1	1			**3**
Quality	1							**1**
Delivery	1		1		1	1	1	**5**
Reputation and Pos. in Industry		1						**1**
Warranty and Claim Policies			1		1	1	1	**4**
Production Facilities and Capacity			1		1	1	1	**4**
Service			1			1		**2**
Flexibility			1	1				**2**
Attitude			1		1	1	1	**4**
Technological ability				1		1		**2**
Financial position				1	1	1		**3**
Desire for business				1	1			**2**
Pollution of production					1			**1**
Green supply chain management					1			**1**
Trade restrictions					1		1	**2**
Political situation					1			**1**
Geographical location						1	1	**2**
Management and Organization						1	1	**2**
Minimum requirements								
Cultural Compliance	1		1	1		1	1	**5**
Food safety Standard (GB/FSSC)	1						1	**2**
MOQ		1						**1**
Quality (in spec)		1	1	1	1	1		**5**
Reliability		1						**1**
Price					1			**1**
Sustainability					1			**1**
Delivery OTIF (high %)					1			**1**
QS certification							1	**1**

Table 48: Criteria scoring per respondent

Appendix B: Preference Statements

Interviews are conducted in order to determine the preference of each of the respondents on the selected criteria. The group of respondents is shown in Table 49

Respondent	Position	Respondent No.
Person A	COO	1
Person B	GM Sales & Logistics	2
Person F	Manager Sales	3
Person D	Purchaser Soft Oils	4
Person E	Purchaser Palm Products	5
Person G	DGM A&D	6

Table 49: Respondents on criteria preference

The interview format used to obtain the preferences can be seen on the following pages. The results of these interviews are presented in the thesis report in tables 25 until 30.

Criteria weight determination by preference statement.

Name: *Position:*

Palm products

The following criteria are the most important and have been selected to be used in the supplier selection for the new plant project considering palm products.

Can you indicate which of these criteria you find the MOST important and which one you find the LEAST important by marking the box?

Criterion	Most important	Least Important
Cost of delivery		
Lead time		
Non-Competitor on specialties		
Price		
Production facilities and capacity		
Quality		
RSPO certification		
Traceability		

You have selected …….. as the MOST IMPORTANT criterion. Could you indicate your preference of this criterion over the other criteria? Use a number between 1 and 9 to show the preference of the MOST IMPORTANT criterion over the other criteria.

A score of 1 implies an equal importance over the other criterion. A score of 9 implies the most important criterion is extremely more preferred than the other criterion.

Other criteria	Most important criterion
Cost of delivery	
Lead time	
Non-Competitor on specialties	
Price	
Production facilities and capacity	
Quality	
RSPO certification	
Traceability	

You have selected …….. as the LEAST IMPORTANT criterion. Could you indicate your preference of the other criteria over this least important criterion? Use a number between 1 and 9 to show the preference of the other criteria over the LEAST IMPORTANT criterion.

A score of 1 implies an equal preference over the other criterion. A score of 9 implies an extreme preference of the (other) criterion over the least important criterion.

Other criteria	Least important criterion
Cost of delivery	
Lead time	
Non-Competitor on specialties	
Price	
Production facilities and capacity	
Quality	
RSPO certification	
Traceability	

Criteria on Non-Palm products

The following criteria are the most important and have been selected to be used in the supplier selection for the new plant non-palm raw materials.

Can you indicate which of these criteria you find the MOST important and which one you find the LEAST important by marking the box?

Criterion	Most important	Least Important
Cost of delivery		
Lead time		
Non-Competitor on specialties		
Price		
Production facilities and capacity		
Quality		

You have selected …….. as the MOST IMPORTANT criterion. Could you indicate your preference of this criterion over the other criteria? Use a number between 1 and 9 to show the preference of the MOST IMPORTANT criterion over the other criteria.

Other criteria	Most important criterion
Cost of delivery	
Lead time	
Non-Competitor on specialties	
Price	
Production facilities and capacity	
Quality	

You have selected …….. as the LEAST IMPORTANT criterion. Could you indicate your preference of the other criteria over this least important criterion? Use a number between 1 and 9 to show the preference of the other criteria over the LEAST IMPORTANT criterion.

Other criteria	Least important criterion
Cost of delivery	
Lead time	
Non-Competitor on specialties	
Price	
Production facilities and capacity	
Quality	

End of questionnaire

Appendix C: Criteria Weights per Respondent

The tables below show the obtained weights per respondent. The average weight is used for further calculation in the framework.

Criteria Weights PALM									
Respondent No		1	2	3	4	5	6		
Criterion	w^{*p}							**Avg**	**Rank**
Cost of delivery	w^{*p}_1	0,1341	0,3408	0,1809	0,1942	0,1904	0,2569	**0,2162**	**2**
Lead time	w^{*p}_2	0,1006	0,1993	0,1809	0,3107	0,0952	0,1564	**0,1738**	**3**
Non-Competitor on specialties	w^{*p}_3	0,0670	0,0498	0,1206	0,0485	0,0272	0,0223	**0,0559**	**7**
Price	w^{*p}_4	0,3305	0,0996	0,3009	0,1942	0,3128	0,2569	**0,2491**	**1**
Production facilities and capacity	w^{*p}_5	0,0805	0,0797	0,0724	0,0259	0,0952	0,1042	**0,0763**	**5**
Quality	w^{*p}_6	0,2011	0,1328	0,0724	0,1294	0,1269	0,0625	**0,1209**	**4**
RSPO certification	w^{*p}_7	0,0287	0,0315	0,0267	0,0485	0,0762	0,0625	**0,0457**	**8**
Traceability	w^{*p}_8	0,0575	0,0664	0,0452	0,0485	0,0762	0,0782	**0,0620**	**6**
Check		1,0	1,0	1,0	1,0	1,0	1,0	**1,0**	
Consistency indicator		0,0718	0,0577	0,0609	0,0777	0,0680	0,0558	**0,0653**	

Table 50: Criteria weights per respondent of palm raw materials

Criteria Weights NON PALM									
Respondent No		1	2	3	4	5	6		
Criterion	w^{*n}							**Avg**	**Rank**
Cost of delivery	w^{*n}_1	0,2019	0,1580	0,1472	0,1949	0,1418	0,1544	**0,1664**	**4**
Lead time	w^{*n}_2	0,1346	0,2216	0,2207	0,3353	0,2127	0,3707	**0,2493**	**2**
Non-Competitor on specialties	w^{*n}_3	0,0288	0,0309	0,0320	0,0487	0,0336	0,0309	**0,0342**	**6**
Price	w^{*n}_4	0,2019	0,1185	0,1472	0,1949	0,3638	0,1544	**0,1968**	**3**
Production facilities and capacity	w^{*n}_5	0,1010	0,0948	0,0883	0,0312	0,1418	0,0579	**0,0858**	**5**
Quality	w^{*n}_6	0,3317	0,3762	0,3647	0,1949	0,1063	0,2317	**0,2676**	**1**
Check		1,0	1,0	1,0	1,0	1,0	1,0	**1,0**	
Consistency indicator		0,0721	0,0979	0,0768	0,0546	0,0616	0,0927	**0,0759**	

Table 51: Criteria weights per respondent of non-palm raw materials

Appendix D: Exploration of the Bulk and Container Shipping Market

In this appendix the transportation market in Asia is discussed. An exploration has been conducted in order to get an insight in the availability of shipments, common routes and an indication on the pricing. In order to obtain this the company expert, Person J is interviewed. Also shipping brokers have been interviewed to get an indication of the available shipments and they have provided quotations that have been used to determine an average bulk shipping price. This can be seen in Figure 12.

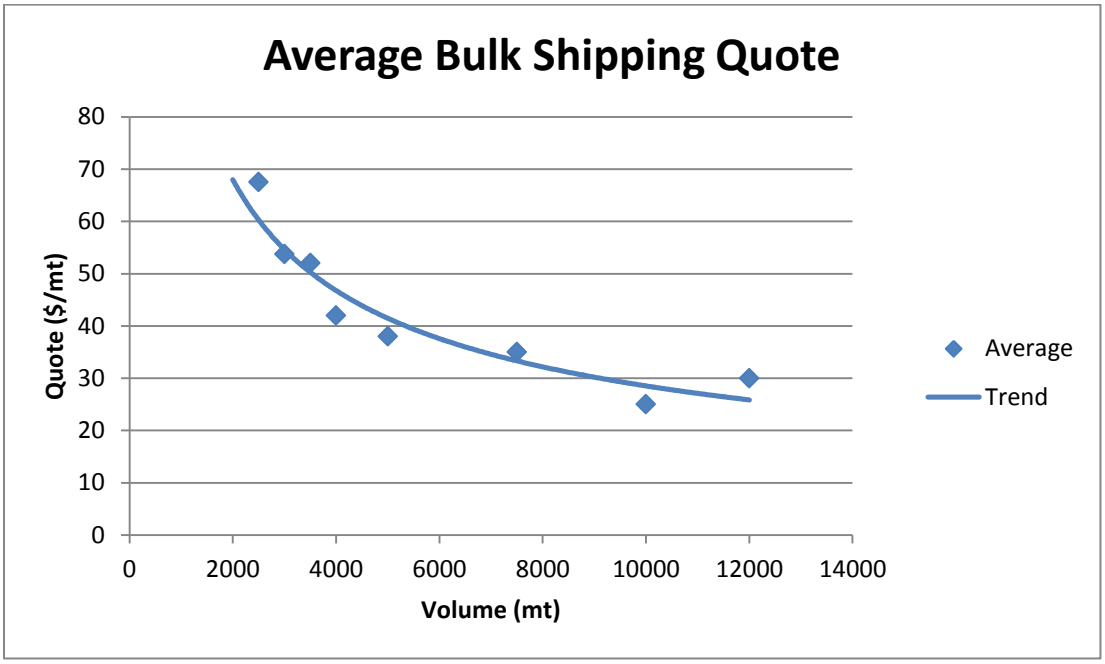

Figure 12: Average bulk shipping quotes

On the container shipments of the flexibags and isotanks, a vast amount of information has been provided by the case company. To obtain a better perspective also container shipments companies have been consulted. These also indicate the port cost and different charges which can be seen in Table 52.

Chinese Port Charges	USD	Per	Fixed	Variable
THC	X	20'GP	x	x
Document fee:	X	Bill		
D/O fee	X	Bill		
Tallying fee	X	20'GP		
Health and Quarantine fee	X	20'GP		
EIR	X	20'GP		
Port construction fee	X	20'GP		
EBS	X			
CRS	X			
CIC	X			
TOTAL	**X**			

Table 52: Chinese port charges

The final overview of container costs are based on the basic ocean freight and haulages indicated by the company and the port charges presented before. These costs can be seen in Table 53.

Container Costs	USD	Fixed	Variable
Haulage Mal	X	x	x
OTHC	X		
BOF	X		
DTHC	X		
Haulage China	X		
Total	**X**		

Table 53: Cost of container transport indication

For the bulk shipping scenario, the tipping point is of huge interest to the case company. This can be obtained based on the obtained data in this appendix. First the port charges are obtained with the help of the case company. This can be seen in Table 54.

Malaysia Port Charges	USD	Per	Fixed	Variable
Throughput	x	MT	X	X
P'line transfer	X	MT		
EDI	X	Bill		
Port Charges	X	MT		
Forwarding	X	Bill		
Chinese Port Charges	**USD**	**Per**	**Fixed**	**Variable**
Throughput	X	MT	X	X
P'line transfer	X	MT		
EDI	X	Bill		

Table 54: Bulk port charges

With these port charges and the basic ocean freight obtained from the quotations of the ship brokers, the tipping point can be calculated. It needs to be noted that no economies of scale have been taken into account for the shipping of containers. Obviously this is not the case in reality, but this effect will be less than with bulk shipments. The tipping point can be retrieved from Figure 13 and this is around the volume of 3.000 metric tons. This makes sense when the minimum bulk shipment volume is kept in mind. This is around the same volume. Lower volume bulk shipments are available, however this will be against a significant higher shipping price, making container shipments the more cost effective option below 3.000 metric tons.

It must be noted that this tipping point calculation is a first indication, carried out within the available time and research capacity of this thesis. It is absolutely necessary to further examine this tipping point as it holds many ties to other factors. For instance the consequences of unloading and steaming the flexitanks, the loss of material of both shipping manners and the required working capital are of influence on this tipping point. In the calculation executed only the most prominent factors have been taken into account.

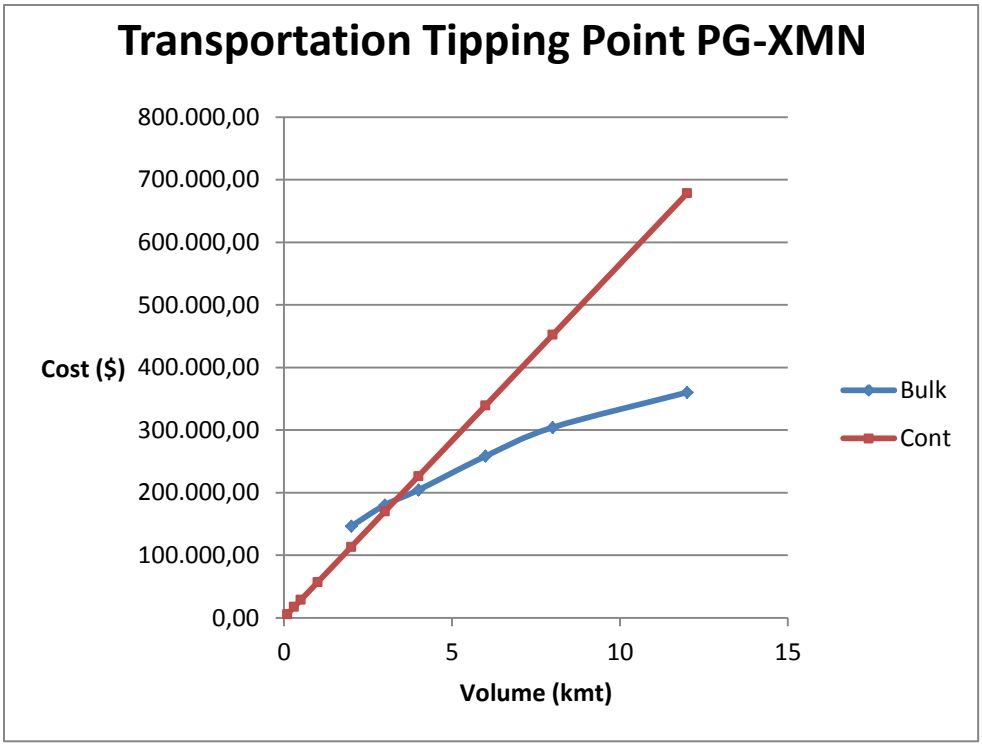

Figure 13: Bulk tipping point indication