

**UNIVERSITY OF VAASA  
FACULTY OF TECHNOLOGY  
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**DISCOVERING LOGISTICS FACTORS THAT AFFECT CASE COMPANY'S  
PROJECT DELIVERIES AND SUPPLIER COMPARISON**

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**TIIVISTELMÄ:**

Tämän pro-gradu-tutkielman taustalla on suomalaisen jätteestä energiaksi-alan yrityksen tarve valmistautua heidän tulevien projektiansa toimitusvaiheeseen. Tutkielma tuo laajalti tutkittuun toimittajavalintaan liittyvään ongelmaan mukaan logistisen näkökulman. Aiemmat valintakriteereihin pohjautuvat toimittajavalinnan tutkimukset ottavat logistiikan huomioon pääasiassa kokonaisuutena, tuomatta sen tarkemmin esiin logistiikan eri osa-alueita.

Tässä tutkielmassa kehitettiin ensin toimittajavertailua tukevat logistiset kriteerit sen pohjalta, miten aiemmissa tutkimuksissa logistiikkaa on käsitelty osana toimittajavalinnan ongelmaa. Kehitettyjä kriteereitä arvioitiin vielä uudelleen kahden projektinjohtajan ja kahden kansainvälisen projektilogistiikan parissa työskentelevän henkilön vastausten pohjalta. Kriteerien soveltamiseksi rakennettiin Microsoft Excel-pohjainen työkalu, jonka toiminta perustuu analyyttiseen hierarkiaprosessiin (AHP). AHP mahdollistaa työkalussa kriteerien painottamisen eri tavoin erilaisissa skenaarioissa. Työkalun avulla case-yritys voi siis vertailla toimittajiansa logististen tekijöiden, kuten toimitusajan pohjalta, sekä luoda erilaisia painotusskenaarioita projektien tavoitteiden mukaisesti. Excel-työkalun testaus osoitti AHP:sta tehokkuuden lisäksi sen haavoittuvuuden, sillä korkea tulos voimakkaasti painotetussa kriteerissä voi kompensoida huonon tuloksen muissa, vähemmän painotetuissa kriteereissä.

Haastateltujen vastausten pohjalta koottiin yhteen myös neliosainen logistinen tarkistuslista, jossa yhdistyvät kehittyviin maihin suuntautuvan projektilogistiikan parhaat käytännöt. Tarkistuslista koostuu vaikeuksista, joita haastateltavat ovat kehittyvissä maissa kohdanneet, sekä heidän jakamistaan parhaaksi todetuista toimintatavoista. Nämä yhdessä muodostavat case-yrityksen projektinjohtajille toisen työkalun, jota seuraamalla he voivat välttää logistiikkaan liittyviä ongelmia projekteissaan. Testaustiedon, sekä toimittajainformaation puutteen vuoksi vasta yrityksen tulevat projektit kertovat tarkemmin työkalujen tarkoituksenmukaisuudesta sekä toimivuudesta.

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**AVAINSANAT:** Toimittajavalinta, Projektilogistiikka, Analyyttinen hierarkiaprosessi

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**ABSTRACT:**

Behind this study is a request from an emerging Finnish waste-to-energy-sector company, who want to prepare for the logistics phase of their upcoming project deliveries. The study adds to the prior research on the topic of criteria-based supplier selection by taking a logistics aspect. Formerly developed supplier selection criteria take logistics into account mainly as a big picture without addressing different fields of logistics separately.

Logistics criteria for supplier comparison were developed in this study, based on the various prior aspects taken into logistics as a part of the supplier selection decision making process. The developed logistics criteria were then re-evaluated based on the feedback from the case company and four interviewed experts in the field of project logistics. To apply the criteria, a Microsoft Excel-based tool was built. Analytic Hierarchy Process (AHP) serves as the main method of the application, providing the possibility to weight the criteria differently in various scenarios. The application will be used by the case company to compare suppliers according to the developed logistics criteria in various project scenarios with different weightings. The testing of the Excel-tool proved both the effectiveness and the vulnerability of AHP, showing that relatively low score in some criteria may be compensated by heavily weighted high score in an individual criterion.

A four-section logistics checklist was also constructed based on the answers of the interviewees to conclude the best practices of project logistics in the developing countries. The checklist consists of difficulties experienced by interviewees as well as shared best ways of working, which then formulate a tool for the case company's project leaders to follow during the projects. Due to the lack of testing- and supplier information, the case company's first projects will show the actual functionality of the two developed tools.

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**KEYWORDS:** Supplier selection, Project logistics, Analytic hierarchy process

## 1 INTRODUCTION

Managing the supply chain in a construction project challenges the project managers to organize win-win-situations for many different parties (Pan, Lin & Pan 2010). These supply chains are often made of several participants with different interests and their structure in general is complex. (Cheng, Law, Bjornsson, Jones & Sriram 2010). However, the project supply chains also possess opportunities since remarkable improvements in project's profitability and efficiency may be achieved through successful planning of actions such as material logistics (Said & El Rayes 2011).

Cost savings achieved through the optimization of logistics-phase vary based on the methods used and the field of business. For example, in a road construction project, approximately 3,3% cost savings were calculated through the optimization of material movement (Choudhari & Tindwani 2017). The potential of cost savings through logistics optimization was also noticed in the construction industry in Sweden (Persson, Bengtsson & Gustad 2009). In addition to the potential of cost savings in optimizing deliveries, the reverse logistics capabilities of companies are reported to generate cost savings as well (Skinner, Powers & Jack 2010).

The purpose of this study is to improve a project owning company's logistics process for the upcoming power plant deliveries worldwide. Since the production of the modular power plant is outsourced, the company's suppliers' logistics performance has a direct influence on the performance of the whole project. Therefore, enhancing the whole project's logistic performance begins already in the supplier selection phase, where the suppliers are evaluated according to their logistics capabilities.

## 1.1 The case company

To understand the reasons behind this study, it is beneficial to first gain some knowledge about our case company. They are an Ostrobothnian (Finnish) company who aim to have their first projects in the waste-to-energy sector during the years 2019-2020. The company aims to solve two major problems in the developing countries: the waste-induced problems and the lack of energy. (Case company material 2018.)

With their solution, the modular waste-to-energy power plant, the case company anticipates to simultaneously reduce waste landfilling, deliver a variety of energy commodities and cut down waste logistics costs. One of the most innovative parts about the power plant is its modular structure, which allows the plant to be assembled faster and moved towards new sources of waste with less effort. (Case company material 2018.)

The manufacturing of the power plant's key modules is outsourced to a variety of suppliers, each of whom have their own expertise in certain parts of the plant. For each module, a set of suppliers have been pre-selected by the case company and this study aims to aid the decision maker with the final choice of a supplier.

The case company's projects follow a quite typical route where the components are engineered and sourced according to the customer's order. This means that everything starts from the sales phase, where the customers' needs are mapped, contracts are negotiated, and preliminary engineering is done. This is then followed by the largest phase from the project owner's perspective, the procurement. This engineer-to-order (ETO)-based procurement includes, for example, the main engineering phase, purchasing and subcontracting. However, in the future, the power plant deliveries can be considered more standardized since the modular design generated in the first project can remain the same.

The size and the scale of the case company's projects depends on various factors. First, the modular power plant may be built to consist of several lines placed next to each other. Building a larger plant naturally raises the total cost of the project but it also brings out a cost-saving opportunity through economies of scale.

The case company has estimated that the value of an entire, delivered ETO-type of power plant project would range from 17 to 20 million euros. The variance comes from the project specifications and pre-agreed terms, where the customer may take more responsibility of issues such as groundwork or installations on site. The project specifications also include negotiable factors such as insurances, planning, project management and customs clearances, which the customer may either handle completely or partly themselves or let the case company take the full responsibility. Another thing that also partly determines the project's scale is the power plant's output and whether it is meant to be electricity, heating energy or both. Each option requires modifications to both, the plant and the infrastructure and therefore the output needs are mapped already in the sales phase.

The above-mentioned issues also affect the project's timetable. The case company has estimated that the duration of the entire project would be approximately 15 months. Factors such as the location of the plant and other co-operators in the project are considered to influence the estimation positively or negatively by two months.

The logistics phase - that this study is mainly focusing on, in addition to the supplier selection phase - follows the procurement and aims to deliver the modules to the final location. The logistics phase also includes the customs processes and warehousing of the products. These actions require careful planning and preparation, which is one of the reasons why the case company wants to further investigate the best practices of logistics.

Logistics and especially the transportation of materials is considered to have a significant cost impact in international project logistics. For example, Chartron (2019) finds that several prior researchers have mentioned significant cost saving potential related to logistics of overseas wind turbine construction projects. For our case company, logistics means the processes that are needed to move the modules from suppliers across the world to the site. The case company have investigated that due to the modular structure of the power plant and the shipments in standardized containers, the cost of logistics will be lower compared to otherwise similar, non-modular international project deliveries. The project specific final cost of logistics is, however, determined by the selected suppliers and logistics

partner. Also, the supplier selection is done using not only logistics-related supplier attributes, but also the quality- and total cost-related supplier factors.

## 1.2 Objectives and research questions

The objectives of this study are determined by both, the case company's interests and the author's know-how. From the beginning, it was clear to both parts that the topic would be about logistics. The subject was then refined in close cooperation to suit the case-company's needs. It was emphasized by both parts that the topic had to be both, beneficial to the case company and meaningful for the author.

Finally, to support the case company's supplier audits and the supplier selection phase, a tool was requested by them to compare the suppliers using logistics-related factors. The emphasis on the supplier selection phase is explained by the importance of the module manufacturers' logistics competences in the outsourced production.

A research problem is identified to describe the aim of the study. First, the problem is related to the lack of specifically logistics-related supplier selection criteria in the literature. Therefore, the logistics criteria for measuring supplier's logistics position and performance need to be developed first in order to build the tool.

Second, the problem is about the supplier selection phase and the difficulty of identifying the logistically best supplier for a certain module. A solution-based mindset was needed to identify the problem, since the need for a tool to solve this problem was the first thing identified before the actual problem was considered. Based on the research problem, two main objectives are introduced in the form of research questions as following:

1. Which criteria should be used to compare critical suppliers in terms of logistics effectiveness?
2. How can the logistics criteria be applied to support the supplier selection decision making process?

To support their logistics phase even further, the case company introduced a sub-purpose for the study. Since experts on the field of international project logistics would be interviewed for the data collection, best practices in the field of logistics should be gathered simultaneously. Since the company is yet to deliver their first project, any advice or experiences on the logistics phase are considered highly useful. A checklist-form is used as a method to present the best practices and potential pitfalls that derive from the interviews. This leads us to the third and last research question:

3. What type of logistics-related difficulties occur during international delivery projects and what actions can be taken to avoid them?

The following subchapter is dedicated to explaining how these three questions will be answered. It includes the methods of data collection and -analysis as well as the builds of the actual deliverables.

### 1.3 The deliverables and data collection

The answers to the three research questions are presented in the form of two different deliverables. First, to address the research questions one and two, the logistics criteria are first developed and analyzed and finally applied in a Microsoft Excel-based supplier comparison tool. Analytic hierarchy process (AHP) is used to create weightings for the criteria and thus, formulate different kinds of project scenarios.

Second, a logistics checklist is developed based on the interviewees' experiences to conclude the best practices and potential pitfalls in the field of logistics. The checklist aims to answer the research question three as well as to provide important information for the case company regarding their upcoming projects.

Data for the study is gathered from three sources. First, a review on the 2000s literature on supplier selection and project logistics is conducted to form the baseline for the logistics criteria. Second, two project managers from globally delivering industrial companies

are interviewed to find out about experiences from the project owner's perspective. Second, representatives from two logistics operators selected by the case company are interviewed to get another aspect to the project logistics. By combining the information from these three sources, the deliverables are finally constructed to suit the case company's needs.

#### 1.4 The structure of this paper

This study consists of five main chapters. After this first introductory chapter, a closer look into the literature of the methods of supplier selection is taken. The literature review begins by looking at project logistics in a broader scale, moving on towards different types of supplying and finally introducing multicriteria models for supplier selection. After this, the supplier selection criteria proposed in the literature are overviewed with a special emphasis on the logistics criteria.

Following the literature review, chapter three intends to briefly introduce the research methods that are used for this study. The methodology-chapter is then followed by the main chapter, where the results from the interviews are analyzed and applied into the two deliverables, the Excel-tool and the logistics checklist. The applying of the analytic hierarchy process is also presented in chapter four, including the hierarchical formulation of the problem, the development of the logistics criteria and the construction of the AHP matrixes.

The fifth, final chapter concludes the study and re-evaluates it based on the research questions. The goal of this chapter is also to highlight the things that could be done differently to get even more reliable results.

## 2 METHODS AND CRITERIA FOR GLOBAL SUPPLIER SELECTION – A LITERATURE REVIEW

Outsourcing has become a popular business strategy due to the competitive environment that companies operate in (de Almeida 2007). Shortened product life cycles challenge companies to constantly look after new suppliers to keep their product portfolios diverse and competitive (Aissaoui, Haouari & Hassini 2007: 4).

Globalization and the internet have challenged the decision makers even further due to the extended opportunities in global sourcing. Increased importance and complexity of purchasing-related decisions reflect directly upon organizational structures as well as the amount of decision makers required (de Boer, Labro & Morlacchi 2001: 1). Sourcing globally and thus running a global supply chain challenges companies even further, since the supplier networks may consist of hundreds of operators and the supplier selection often needs to be done using broader criteria than when sourcing domestically (Meixell 2005; Yücenur, Vayvay & Demirel 2011).

The constant search for the optimal suppliers and contractors applies for larger scale projects as well. Even though some companies are aiming towards a more partnership-style of a relationship with a selected number of their suppliers, some companies still stick to the traditional competitive bidding-type of supplier and contractor selection (Crespin-Mazet & Portier 2010; Eriksson 2008). Partnering, for example in the French construction sector, still appears to be a fairly unknown way of supplying. Instead, short-term cost reductions and so-called intangible benefits are sought by many companies. (Crespin-Mazet & Portier 2010.)

As discussed above, selecting the optimal supplier for a product, component or service is a complex task that involves making difficult decisions. This chapter is dedicated to introducing different methods that have been developed to support the decision-making process. The focus is on logistics-related issues that affect or should affect the supplier comparison process in global delivery projects.

## 2.1 Purchasing in construction projects

Construction projects can be seen as done by virtual organizations formulated by the companies that take part in the project (Riley, Brown & Killander 1999). A typical characteristic for these organizations is that each part has their own objectives and interests (Brown, Ashleigh, Riley & Shaw 2001).

In the late 1900s, the tough competition in the construction sector resulted in competitive bidding and lowest price-sourcing of projects which then led to issues in quality, cost and schedules. Since then, new contract strategies for projects have been implemented, aiming towards deeper cooperation between the different participants of the project organization. (Brown et al. 2001.)

When buying components for a large-scale construction project for example, the supplier selection and -evaluation phases are highlighted. This is due to the fact that a single supplier's performance may affect the outcome of the whole project. Therefore, the decisions related to the suppliers of the project are an important factor when considering the overall project success. (de Araújo, Alencar & de Miranda Mota 2017.)

The importance of the decisions made in the supplier selection phase is also highlighted in the project business, because usually many of the purchased objects are high valued. This study focuses on the key modules of the modular power plant which form the majority of the project purchasing costs in our case company's operations.

## 2.2 Global sourcing in a project environment

Success in global sourcing is a sum of many different factors. Trent & Monczka (2005) identify seven success factors of global sourcing as following:

1. Executive commitment to global sourcing
2. Rigorous and well-defined processes

3. Availability of needed resources
4. Integration through information technology
5. Supportive organizational design
6. Structured approaches to communication
7. Methodologies for measuring savings

With the points above, Trent & Monczka emphasize the company's capabilities to establish and maintain contacts with their global supplier base (1), effectively share information internally and with other parts of the projects (2) and to have the right persons in their project teams (3).

Especially the fluent flow of information appears to be a crucial success factor for global project deliveries and is therefore emphasized in this work as well. The level of integration within the company has been identified as a key attribute in ensuring the flow of information. The correct type of integration helps the company to tackle uncertainty in the supply environment by ensuring a successful flow of information (Trautmann, Turkulainen, Hartmann & Bals 2009).

Global sourcing, even though mostly seen as a beneficial and value-seeking act, has also its negative sides. The negative effects can be categorized into company-related *antecedents* - causing internal and external issues, and *effects*. Together the antecedents and effects formulate a cluster of negative effects ranging from environmental to financial. (Stanczyk, Cataldo, Blome & Busse 2017.)

The supplier selection phase is considered to be the most influential phase when the success of the entire supply chain is considered. (Chan, Kumar, Tiwari, Lay & Choy 2008). This fact explains our case company's emphasis on the supplier selection phase well. Establishing a successful project supply chain appears to start by selecting the most capable suppliers for the modules.

### 2.3 Approaches for supplier selection

The supplier selection problem has been studied widely over the past two decades. Tools and models ranging from single-criteria selection to complex mathematical programming applications have been developed to aid the decision makers with both formulating and solving the problem. Comprehensive reviews on the variety of supplier selection methods have been written by for example de Boer et al. (2001), Aissaoui et al. (2007), Ordoobadi & Wang (2011) and Wetzstein, Hartmann, Benton, & Hohenstein (2016).

Wetzstein et al. (2016) conducted a profound search on the supplier selection literature. They identify 221 publications made since the year 1990 as key literature on the field. The study categorizes supplier selection literature into six research streams and corresponding subcategories. The distribution of the literature into the streams and subcategories is presented in table 1. (Wetzstein et al. 2016.)

Table 1: Distribution of supplier selection literature into research streams (Wetzstein et al. 2016: 313).

	S1: Approaches for SS			S2: Criteria for SS					S3: Green & Sustainable SS		S4: Strategy oriented SS						S5: R&D oriented SS			S6: Operations oriented SS		Contextual perspectives	
	a) Single Sourcing Approaches	b) Multiple Sourcing Approaches	c) Other Approaches	a) Application	b) Collection & classification	c) Interdependencies studied	d) Single criteria deeply studied	e) Relative importance studied	a) Green	b) Sustainable	a) Strategic relevance implicit	b) Strategic relevance explicit	c) Alignment implicit claimed	d) Alignment explicit claimed	e) Low concept building	f) High concept building	a) Product Development	b) Product Configuration	c) Product Portfolio	a) Process Quality	b) Assembly Quality		
<b>S1: Approaches for SS</b>	<b>108</b>																						
a) Single Sourcing Approaches	44	81																					
b) Multiple Sourcing Approaches	54	14	77																				
c) Other Approaches	14	2	2	40																			
<b>S2: Criteria for SS</b>				3	15																		
a) Application	82	55	60	13	121																		
b) Collection & classification	18	21	13	11	7	53																	
c) Interdependencies studied	6	7	4	5	3	5	9	15															
d) Single criteria deeply studied	3	4	1	6	4	3	15																
e) Relative importance studied	60	57	35	13	6	68	38	12	110														
<b>S3: Green &amp; Sustainable SS</b>				13	3	4	12	7	2	13	25												
a) Green	2	11	5	3	12	7	2	12	20	22													
b) Sustainable		4	2	1	4	1	1	5	11	7	12												
<b>S4: Strategy oriented SS</b>				10	6	1	8	7	3	12													
a) Strategic relevance implicit	34	28	23	9	3	28	20	4	3	36	4	3	4	6	61								
b) Strategic relevance explicit	25	22	21	7	6	38	16	5	1	40	11	8	7	9	68								
c) Alignment implicit claimed	17	14	15	10	4	20	14	2	1	26	7	4	7	2	18	15	43						
d) Alignment explicit claimed	2	9	5			8	6	2	11	1	1	1	13	6	13	21							
e) Low concept building	15	9	12	7		12	9	2	14	4	3	2		8	10	13	3	27					
f) High concept building		11	6	1		9	7	3	13				17	6	10	3	14		19				
<b>S5: R&amp;D oriented SS</b>				4	6	2	7	4	1	5				3	2	2							
a) Product Development	2	4	2		2	5	1	3			1	2	2	1	1	1	4	8					
b) Product Configuration			3	1		4	1	2			1						4		4				
c) Product Portfolio			2	3		2	1	2			1	1	2				3		3				
<b>S6: Operations oriented SS</b>				5	4	6	8	1	8	5				2	3	1				1			
a) Process Quality	4	7	3	7	1	9	2	2	9	7				1	2	5	2	1	1	1	3		
b) Assembly Quality				2		2															11	18	
<b>Contextual Perspectives</b>				5	4	10	4	9	9	1				9	12	10	5	8	2			30	

SS = Supplier Selection

S1–S6 = Research stream 1 to 6

This paper will now present an overview on the approaches for supplier selection with a focus on the stream of applying criteria for supplier selection. The criteria point of view derives from one of the goals of the study, the AHP-based tool for supplier selection.

### 2.3.1 Single sourcing versus multiple sourcing

A common approach divides the sourcing decision into two main streams: single sourcing and multiple sourcing (multisourcing). In single sourcing the supplier selection problem is seen so, that one supplier is able to meet all the requirements for a certain need and thus the best available supplier should be discovered and selected. This leads to companies

having more narrow supplier bases and stronger collaboration with their suppliers. (Swift 1995 & Wetzstein et al. 2016.)

On the contrary, in multiple sourcing the purchasing of the same part is split among several suppliers in order to ensure such factors as product quality and availability (Wetzstein et al. 2016). Multiple sourcing also helps especially smaller companies to find optimal component prices by splitting the orders between several suppliers. On the contrary, single sourcing often benefits large companies with high volumes and larger shares of the supplier's capacity (Inderst 2008).

The distribution between the two approaches can also be seen in daily purchasing decisions. Some purchasing managers see the decreased chance of information leaks as a benefit to single sourcing (Faes & Matthyssens 2009). Other arguments for single sourcing and against the model of multiple sourcing according to Faes & Matthyssens (2009) include:

- More effective spending of resources on joint development and flexibility instead of constantly negotiating new contracts
- Enhanced attractiveness as a customer and possibilities for closer future partnerships due to a reduced supplier base
- Improvement in total quality of the product

Likewise, companies preferring the shift from single sourcing towards multiple sourcing see the benefits in their own way. According to Faes & Matthyssens' (2009) case study, expected improvements in product prices, the stability of supply and the decrease of cost pressure are seen as key impacts driving purchasing managers towards multiple sourcing decisions.

Swift (1995) shows that the purchasing managers preference on single or multiple sourcing also affects the supplier selection criteria. For example, purchasing managers preferring single sourcing seem to value dependability (the supplier's reliability and keeping of

promises) more than those preferring multiple sourcing. Likewise, the managers preferring multiple sourcing seem to pay more respect to the lower price of a product than their colleagues preferring single sourcing. (Swift 1995.)

### 2.3.2 Criteria-based thinking

The importance of selection criteria in the decision-making process can be seen from the amount of studies conducted on the topic. In a normal process, a group of suitable suppliers are evaluated based on a set of predefined attributes, the selection criteria (Aissaoui et al. 2007). The process can be modeled to start with *problem definition*, continuing with *formulation of the selection criteria*, followed by *qualification and evaluation of the potential suppliers* and finally ending with the *final choice* (de Boer et al. 2001).

De Boer et al. (2001) state that the research on the topic of supplier selection mainly focuses on the final selection phase and thus there's a demand for more research on the earlier phases. Fifteen years later, Wetzstein et al (2016) show that a wide range of publications have been made especially on the topic of selection criteria.

Wetzstein et al. (2016) also divide the latest criteria research into five separate research streams. These are: the applications of already available criteria (1), collection and classification of criteria (2), interdependencies between criteria (3), single criteria studies (4) and relative importance and weightings between criteria (5).

One of the earliest contributions to the topic of supplier selection with selection criteria was made by Gary W. Dickson in 1966 (Imeri 2013; Aissaoui et al. 2007). In his study, Dickson surveys 273 purchasing managers to develop 23 criteria that are found to influence the supplier selection of a company (Dickson 1966). Even though the industrial world has changed a lot since Dickson's findings were made, most of them are still applicable in the 2000s (Aissaoui et al. 2007).

Weber, Current & Benton's (1991) review on 74 articles focusing on supplier selection criteria appears to be widely cited but also criticized in the literature. For example, de

Boer et al. (2001) state that the criteria that Weber et al. used as a backbone of the review are situational and that the categorization of the literature does not effectively support a decision maker with their problem (de Boer et al. 2001). Also, Wetzstein et al. (2016) find that the research emphasis has moved from generic criteria research, that Weber et al. studied, towards mathematic models that solve multiple criteria-related problems and criteria relations (Wetzstein et al. 2016).

Supplier selection models could also be divided into two streams according to the use of criteria: single criteria and multicriteria models. The traditional single criteria-approach bases the whole selection process on one criterion such as total cost and then selects the supplier that is superior to the others. The modern multicriteria models compare the suppliers based on several criteria such-as the customer-oriented factors quality, delivery and flexibility. Next, we take a deeper look into the strengths and weaknesses of each approach. (Ho, Xu & Dey 2010; Aissaoui et al. 2007.)

### 2.3.3 Single criterion selection

Normally, when single criterion decision making is used for supplier selection, **cost** is considered to be the selected, most important criterion (Aissaoui et al. 2007). This, however, doesn't mean that the decision would be made purely based on the cheapest price available.

Based on the literature, different factors such as delivery reliability or lead time are often calculated based on their cost-effects and then included into the **total cost** -factor. (Timmerman 1986; Aissaoui et al. 2007). Timmerman's (1986) total cost-style method is one of the early contributions on the topic. In his study *An Approach to Vendor Performance Evaluation* Timmerman proposes a matrix that can calculate **value index** for each of the suppliers based on their past performance in cost, product quality and level of service. Value index is then used to rate the suppliers using only one single criterion that defines the value, that the supplier is able to bring to the company. (Timmerman 1986.)

Ellram (1999) uses the phrase *total cost of ownership (TCO)* to describe the cost effects that a supplier's component has or would have. In the study she presents two main approaches to TCO. Dollar-based approach focuses on calculating the actual cost for each element, whereas value-based approach may be used also for elements which's exact cost-effect is not easy to calculate. In Ellram's study, TCO finally displays the combined cost-of-ownership for a supplier's product thus enabling supplier comparison with one factor. (Ellram 1999.)

#### 2.3.4 Multicriteria models

In today's supply chain management, suppliers are mainly compared using multiple criteria instead of the previously described single criteria method (Ho et al. 2010). One of the earliest contributions to **multiple criteria decision making (MCDM)** was made by Wind, Green & Robinson (1968). In their paper *The Determinants of Vendor Selection* the researchers develop a linear weighting model for supplier assessment where s suppliers are assessed according to criteria with different weights. (Aissaoui et al. 2007.)

Timmerman's (1986) approach could also be seen as a backbone for the whole criteria-based research. Even though his TCO method combines a supplier's scoring in different criteria into one total score, the idea of weighting criteria and multiplying the score with the corresponding weights has been established in several multicriteria approaches later on. (Aissaoui et al 2007.)

However, the original linear weighting model used by both Timmerman (1986) and Wind et al. (1968) does not solve the issue of compensation, where a certain supplier's poor score in one criterion could be compensated by a very high score on another criterion. This issue was later solved by for example de Boer, van der Wegen & Telgen (1998), also dividing methods into compensatory and non-compensatory. (de Boer et al. 2001; Aissaoui et al. 2007.)

Ho et al. (2010) conducted a review on 78 academic journal articles from 2000 to 2008 on the topic of multicriteria supplier selection. Based on the survey they categorize the

early 2000s literature to eight individual approaches: Data Envelopment Analysis (DEA) [1], Mathematical programming [2], Analytic Hierarchy Process (AHP) [3], Case-Based Reasoning (CBR) [4], Analytic Network Process (ANP) [5], Fuzzy set theory [6], simple multi-attribute rating technique (SMART) [7] and Genetic Algorithm (GA) [8]. In addition to these individual approaches, Ho et al. find a set of 32 articles that mix two or more of these eight approaches. (Ho et al. 2010.)

#### 2.4 The Analytic Hierarchy Process (AHP) in supplier selection

First introduced in 1980 by Thomas Saaty, the Analytic Hierarchy Process (AHP) is today a widely adapted tool for decision making. Its wide level of application results from its flexibility, simplicity and ease of use. (Ho 2008.)

The core of AHP can be seen as three-level. It consists of constructing the hierarchy, analyzing the priorities and finally, verifying the consistency. In the first step, a multicriteria problem is broken down into pieces to construct the hierarchy of the problem. After this follows the pairwise comparison of the criteria, where the relative importance between the criteria is determined. Finally, the level of the consistency of the answers is calculated to verify that the comparison was made consistently. If the comparisons seem to be inconsistent, i.e. the consistency ratio is too high, the pairwise comparisons should be done again. The process of applying AHP is modeled below in figure 1. (Ho 2008.)

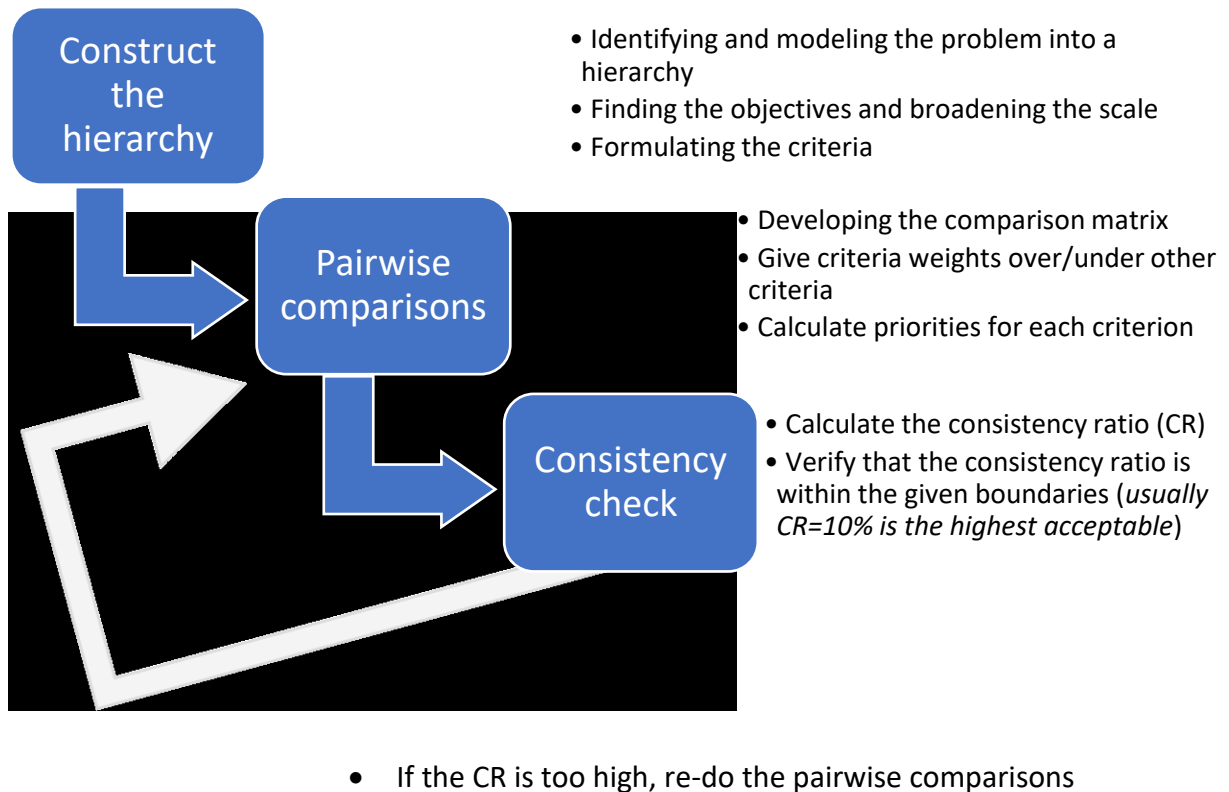


Figure 1: Model of applying the Analytic Hierarchy Process, based on Ho (2008) & Vaidya & Kumar (2006).

AHP has been used widely to solve the supplier selection problem. For example, Vaidya & Kumar (2006) found 150 articles considering AHP or its applications during the period of 1980 – 2005. The literature review shows that AHP has been applied in several fields including for example the sectors of politics, education, industry and government. Also, a wide range of different themes of literature were discovered, showing that AHP has been applied in such themes as decision making, evaluation, resource allocation, development, medicine and many others. (Vaidya & Kumar 2006.)

Ho (2008) studies the applications and combinations of AHP with other methods more precisely. Over the period of 1997-2006 he finds 66 integrated AHP applications where AHP is mixed with mathematical programming, quality function deployment, meta

heuristics, SWOT-analysis and Data Envelopment Analysis. In the review Ho emphasizes on the efficiency of the integrated AHP applications and even states that they are usually more effective than the regular AHP. (Ho 2008.)

The most researched problems in recent studies that use AHP appear to be supplier selection and supplier evaluation, followed by problems such as strategy selection, process evaluation, project evaluation and selection as well as many others. Together covering 60 of the selected 88 articles, AHP was mostly applied within the areas of manufacturing (35), logistics (10), government (5), higher education (5) and utility (5). (Ho & Ma 2018.)

The AHP has many strengths when compared to other decision-making tools. First, the modeling of a complex decision-making problem and its objectives into hierarchy can effectively be done using the AHP (Saaty 1980). Another key benefit of AHP is that the decision maker does not have to use numerical values when indicating weights. Instead, to derive the relative weights for the criteria, the AHP weighting system uses verbal statements such as “x is slightly more important than y” (de Boer et al. 2001).

Effective dealing with inconsistent inputs can also be seen as a benefit to AHP when comparing it to some other linear weighting decision-making tools. The final consistency check of AHP serves as a feedback mechanism for the decision maker as well. Calculating the consistency ratio helps the decision maker perform the final check that the weightings were made without too high inconsistency. (Ho et al. 2010.)

Also, the flexibility and the easiness to combine AHP with other tools, such as DEA or mathematical programming, advocate the tool’s effectiveness (Ho 2006; Ho et al. 2010). The wide range of integrated AHP approaches introduced by Ho (2008) and Vaidya & Kumar (2006) also show the flexibility and usability of AHP in many different fields.

## 2.5 Logistics criteria affecting the supplier selection

Discovering the logistics criteria for supplier selection is one of the main goals of this study. Although the whole criteria-based supplier selection-model has been studied and adapted widely, the logistics criteria have not been individually studied much.

Prior to the final selection of the best supplier, the number of suitable suppliers is reduced by ruling out non-suitable candidates. This pre-selection phase often aims to ease the final selection process since the selection can be made more efficiently from a selected smaller number of suppliers rather than constantly managing a larger number of suppliers. (Aissaoui et al. 2007.)

For the pre-selection and the final selection phase, a number of logistics-related criteria-style models have been developed. Considering logistics selection criteria already in the pre-selection phase might rule out supplier candidates that are otherwise suitable but are not logistically reasonable when compared to other suppliers. For example, Crow, Olshavsky & Summers (1980) propose a conjunctive rule related to a single criterion that a supplier needs to fill in order to continue to the final selection phase. (Aissaoui et al. 2007.)

### 2.5.1 Different approaches to logistics in supplier selection

Liu & Luo (2012) discuss *logistics capabilities* and sort them into three categories, each having direct or indirect effects on the company's performance. First, **process capability** indicates the company's ability to minimize total logistic cost effectively meanwhile standardizing the logistic processes and providing value for the customers. Second, **flexibility capability** tells about the company's ability to adapt and react to unpredictable conditions. Finally, **information-integration capability** within the company helps to develop the whole supply chain meanwhile possibly reducing costs and improving logistics performance. (Liu & Luo 2012.)

Ghodspour & O'Brien (2001) develop two mathematical programming models to minimize the total cost of logistics in the supplier selection. The first model is a single-criterion model that uses **cost** as the single most important criterion whereas the second model is a multi-criteria method that could take criteria weights into account. The researchers criticize prior supplier selection models for considering only the net price of the product instead of the total cost of logistics. (Ghodspour & O'Brien 2001.)

For Ghodspour & O'Brien's study the total cost of logistics consists of storage, transportation, ordering and other inventory costs in addition to the aggregate price of the product. These logistics-related costs are then viewed through the constraints set by the buyer such as supplier's capacity, budget limitations, quality and delivery-related issues. In addition to these, the researchers mention that factors such as on-time-delivery and level of service, that affect indirectly to the costs, can also be taken into account using the multi-criteria model. (Ghodspour & O'Brien 2001.)

Pisz, & Łapuńska (2016) use fuzzy logic-approach to evaluate the effectiveness of a logistic project. Just like a supplier selection process, also Pisz & Łapuńska's evaluation model requires the development of measurement criteria. Even though their point-of-view is closer to a single criterion model than multiple criteria, they emphasize that a set of both financial and non-financial criteria should be used and that the criteria could then be clustered into four categories as shown below in figure 2.

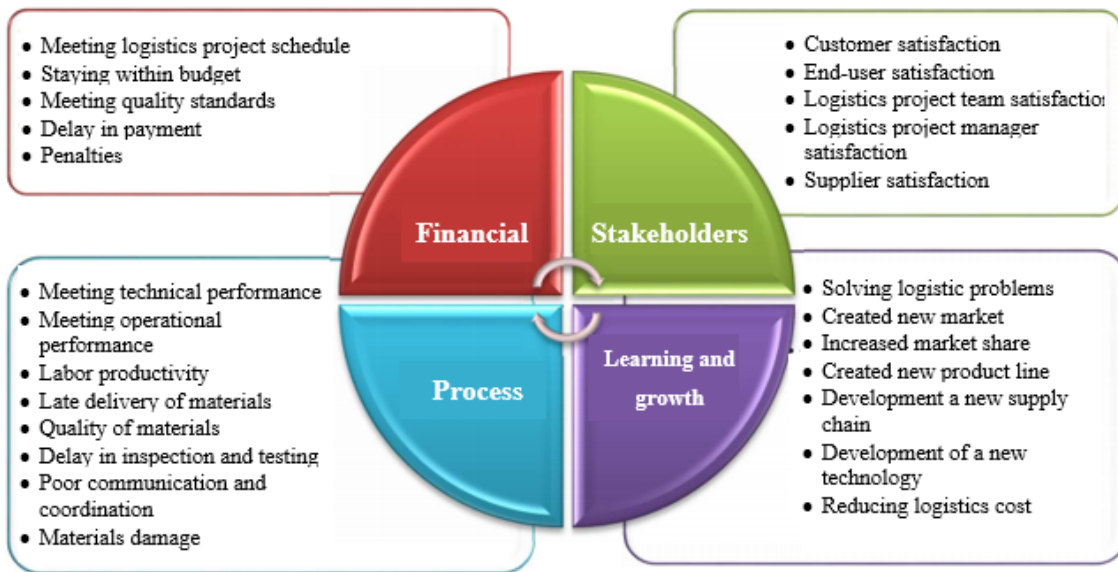


Figure 2: The key criteria of logistics project effectiveness (Pisz, & Łapuńska 2016).

Logistics capabilities are also discussed by Ireton & Blanchard (2007). Even though Ireton's paper *Global Sourcing Checklist* is written in a more professional than academic style, it has been cited several times in academic papers as well. Ireton emphasizes on transportation routes from the manufacturers plant to the port to be also considered when selecting a global supplier. Another thing that falls under the category of logistics capabilities is the supplier's and the logistics service-providers ability to deal with unexpected issues and generate alternative plans. (Ireton & Blanchard 2007.)

Researchers in the field of supplier selection appear to agree that there are more than one optimal combinations of selection criteria and the selection between them depends on the situation (Parthiban, Zubar & Katarak 2013.) Therefore, in order to find the most suitable combination for the company, a multidisciplinary group of decision makers with different interests and fields of specialization should be included in the process of supplier selection (Aissaoui et al. 2007).

### 2.5.2 Logistics criteria proposed in the literature

Following Dickson's (1966) 23-criteria-based model, several authors have proposed their own sets of criteria to make the process of supplier selection even more effective. However, from a logistics point of view, there is lack of criteria-sets that focus only directly on logistics. On the other hand, the suppliers' logistic performance is taken into account, directly or indirectly in every proposed set of criteria. Thus, from many sets of criteria it is possible to distinguish the logistics-related factors.

Table 2 below displays Dickson's 23 factors for rating suppliers. Factors such as *Packaging ability*, *Geographical location*, *Delivery*, *Repair service* and *Production facilities and Capacity* show that the logistics point of view was taken into account already over 50 years ago.

Table 2: Supplier rating factors (Dickson 1966).

Quality	Management and Organization
Delivery	Operating Controls
Performance History	Repair Service
Warranties & Claims Policies	Attitude
Production Facilities and Capacity	Impression
Price	Packaging Ability
Technical Capability	Labor Relations Record
Financial Position	Geographical Location
Procedural Compliance	Amount of Past Business
Communications System	Training Aids
Reputation and Position in Industry	Reciprocal Arrangements
Desire for Business	

Two years later Wind (1968) proposed his set of ten vendor characteristics that are used by two North American companies to compare suppliers. Wind's list of criteria (see table 3) is slightly more compact than Dickson's but covers mostly the same elements. Three of Wind's ten characteristics: *Delivery reliability*, *Geographical location* and *Supply of information and market services*, could be considered directly logistics related.

Table 3: Relevant vendor's performance characteristics (Wind 1968).

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1. Delivery reliability
2. Quality/price ratio of his product
3. General Reputation
4. Geographical location
5. Importance as a client (reciprocity)
6. Supply of information and market services
7. Extent of "personal benefits" supplied by the buyer
8. Extent of previous (satisfactory) contact with the buyer
9. Technical ability and knowledge
10. Technical innovativeness

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Later on, various sets of criteria for supplier selection and evaluation have been proposed by researchers. For example Polat & Eray (2015) propose an 8-criteria model including the following criteria: product quality (1), delivery time (2), relationship with the supplier (3), unit price (4), flexibility in payment conditions (5), communication (6), production capacity (7) and technical competence (8). The model does not have a special emphasis on logistics since factors such as geographical location or delivery reliability are not given individual values. However, delivery time is mentioned as an individual criterion and other criteria such as communication and production capacity have an indirect effect on logistics performance. (Polat & Eray 2015.)

Muralidharan, Anantharaman, & Deshmukh (2002) propose model that includes nine-criteria: quality (1), delivery (2), price (3), technical capability (4), financial position (5), past performance attitude (6), facility (7), flexibility (8), and service (9). Again, each criterion seems to, at least indirectly, affect logistics, although delivery seems to be the most logistics-focused criterion. (Muralidharan et al. 2002.)

In their review Weber et al. (1991) conclude that price, delivery, quality, production capacity and localization seem to be the most adapted criteria in the supplier selection literature. From a logistics point-of-view, delivery and localization seem to be the most relevant criteria.

Ho's et al. (2010) review on different decision-making approaches has a research goal of trying to find the most widely used evaluation criteria. After reviewing hundreds of criteria, Ho et al. conclude that **quality** is the most widely adapted supplier evaluation criterion. Being covered by 87,18 % of the studied papers, quality is then followed in popularity by delivery (82,05 % of the papers) and price/cost (80,77 % of the papers). (Ho et al. 2010.)

In Ho's et al. (2010) study the delivery criterion includes many logistics-related issues such as geographical location, delivery reliability, on-time delivery, supplier proximity, delivery mistakes and order-to-delivery lead time. Even though in the study these are combined into one large criterion, it demonstrates the importance that logistics criteria have in the supplier selection literature.

### 3 DEVELOPING THE METHOD

In order to build the two deliverables, the AHP-based Excel-tool and the logistic checklist, data is collected from both literature and experts in the field. First, to find more information about the logistics criteria and global supplier selection in in general, a literature review on the topics is conducted. The next step includes interviews with experts in the fields of project management and international logistics. Finally, based on the collected data, an AHP-based tool and a checklist are developed to compress the information into an application. Next, a closer look into the steps of data collection and analysis is taken.

#### 3.1 Interviewing project managers

Two experts on the topic of international project logistics are interviewed face-to-face to gather experiences and best practices from international projects with a special emphasis on developing countries. Both interviewees have the title *project manager* and together they possess over 30 years of experience from large-scale international delivery projects.

Following this, representatives from two project logistics-oriented companies selected by the case company are interviewed to get another point of view into project logistics. Both these experts work for internationally operating logistics companies and have the titles of *industrial projects manager* and *vice president, projects*.

Mainly qualitative questions are asked during the semi-structured interviews as the interviewer aims to just drive the conversation through the topics instead of asking specific questions. This gives the interviewee space to share their own best practices and to describe their projects in their own words rather than memorizing individual things about them. Finally, the information received from the literature and the interviews is analyzed to construct the logistics criteria.

### 3.2 Formulation of the logistics criteria and applying AHP

In the literature it is proposed that a multidisciplinary team is selected from within the company to develop the supplier selection criteria. However, since this study has a benchmarking-type of approach, the criteria is developed based on three different points of view. First, the case company's point of view is presented by those members of the organization, who are in key positions regarding the upcoming projects and especially the logistics phase. Second, a review on the current literature on the topic to find trends and best practices on criteria selection is conducted by the author of this thesis. Finally, the two highly experienced project managers from two different companies are interviewed to give their opinions and development proposals on the proposed criteria. Based on these three points of view the logistics criteria are formulated to be included in the excel tool.

Once the criteria have been formulated, each pre-selected supplier for a key component is evaluated on a nine-point scale (table 4) presented by Polat & Eray (2015) based on the developed criteria. AHP pairwise comparison matrixes are then filled by the case company representative for five different scenarios: a standard delivery project, a logistics cost minimizing scenario, a faster delivery project that emphasizes on cutting the delivery time, a quality-oriented project and a scenario that emphasizes the environmentally and ethically best suppliers.

Table 4: Nine-point scale for supplier evaluation (Polat & Eray 2015).

1	Very Bad
2	Very Bad – Bad
3	Bad
4	Bad – Average
5	Average (or unknown)
6	Average – Good
7	Good
8	Good-Very good
9	Very good

Weights for each criterion in each scenario are then retrieved from the pairwise comparison matrixes and applied into the excel tool. The excel tool is programmed to ask the user for inputs about the scenario and site location to then display the optimal combination of suppliers for the whole project.

Finally, the interview data from both, the project managers and the logistics-company representatives are analyzed to develop the logistics checklist. Mainly the checklist is to consist of potential pitfalls and notations for the decision maker to consider before making the final choice. These possible issues and ways to avoid them are discussed during all the interviews.

## 4 AN AHP-BASED APPLICATION TO ADDRESS THE LOGISTIC FACTORS IN DECISION MAKING

### 4.1 Applying AHP and defining the problem

As stated by Thomas Saaty (1980), the developer of the AHP, the process of applying AHP begins by defining the problem that needs to be solved. For our case, the problem is obvious – the best available supplier, in terms of logistics, needs to be found for each module of the power plant. This would then help the sales team to make estimations on the prices of logistics as well as help the whole company to analyze their suppliers in terms of logistic competence.

The next step in Saaty's (1980, 2005) AHP-process is to model the problem into a hierarchy. The hierarchy should start with the problem on top, this would be then followed by the objectives, the criteria that the elements depend on and finally the alternative solutions to the problem, which in our case would be the suppliers.

Hierarchically our problem, however, slightly differs from a simple one-sided problem, since we are focusing directly on one of the elements of a larger problem. The actual larger problem, at the top of the whole hierarchy would be to select the best supplier for each module in terms of all different criteria, out of which one would be logistics. Then, from logistics, we could formulate a new hierarchy that includes the logistic supplier selection criteria that are developed in the next subchapter.

According to the case company, their purchasing decision process consists of three main factors, quality, price and delivery. This thesis work focuses on the delivery-phase, for which the case company still needs an evaluation tool. The Figure 3 below presents the problem in larger scale and figure 4 follows by introducing the sub-problem that this research aims to solve.

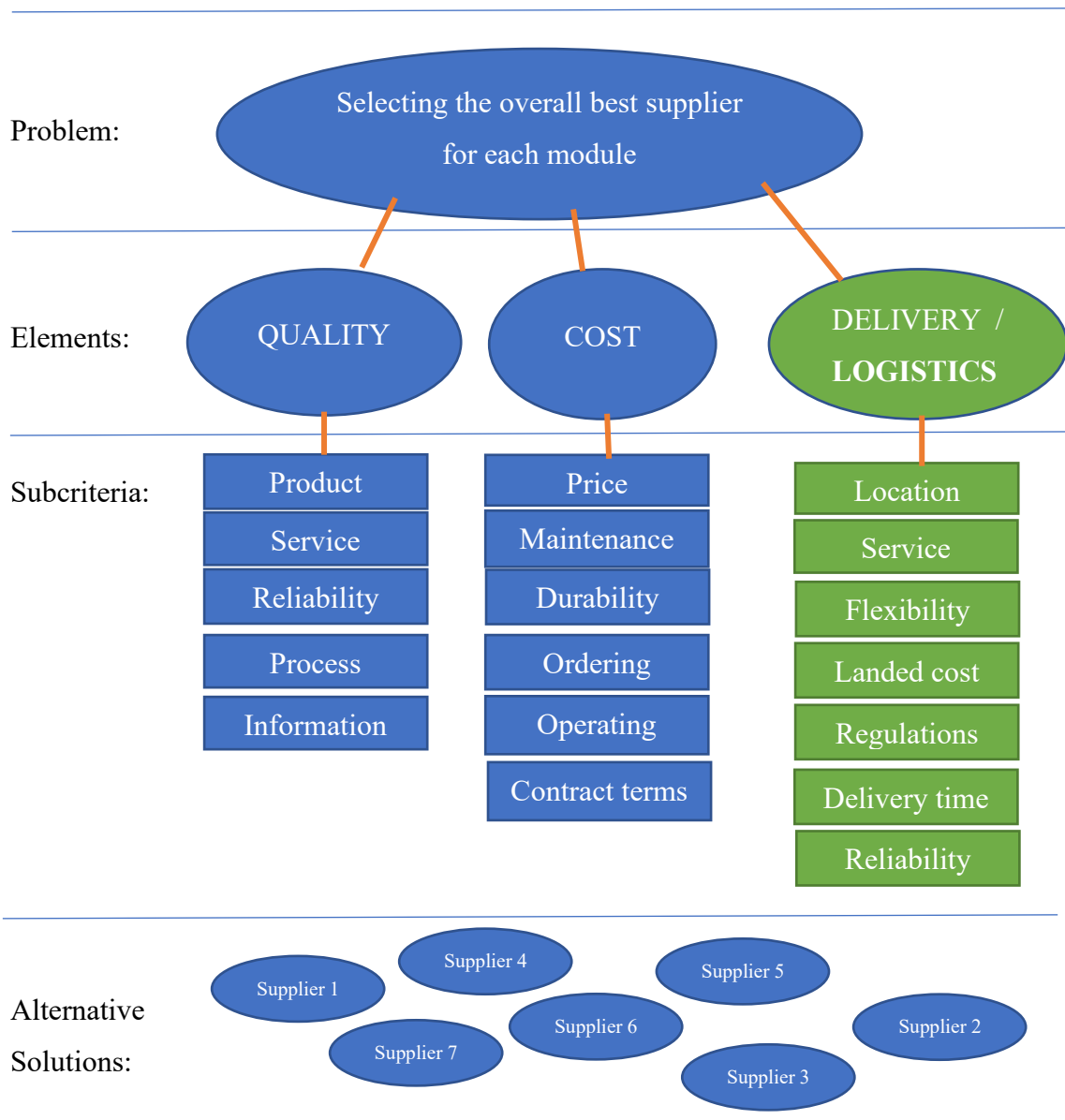


Figure 3: Modeling the supplier selection problem hierarchically

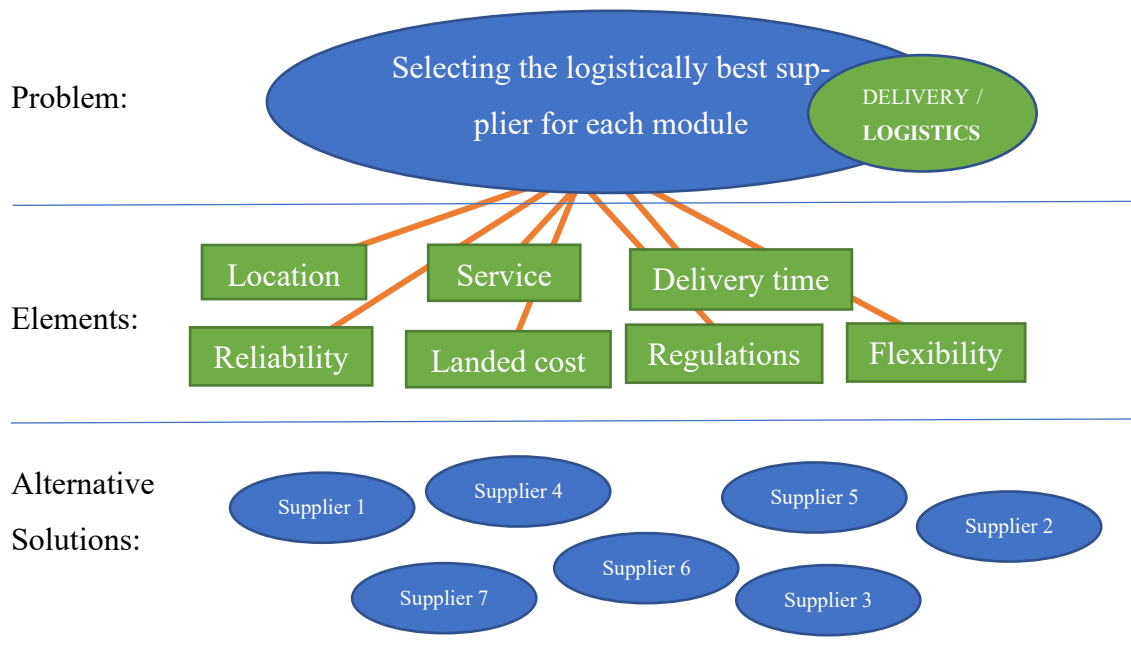


Figure 4: The research problem modelled hierarchically

Dividing the logistics criteria further into sub-criteria for the hierarchy would have been also possible because each criterion has its own rating criteria. However, since the Excel-tool does not take the numeric comparisons of the sub-criteria into account, the model displayed in figure 4 represents the actual result better. The rating criteria for each logistic criterion are displayed in the next subchapter, where the criteria are taken a deeper look into.

#### 4.2. Formulating the logistics criteria

This subsection is intended to introduce each individual logistic selection criterion that was developed in the study. This means that for each criterion, questions such as “What is the purpose of this criterion?” and “Which factors does this criterion consist of?” will be answered profoundly.

The information on the logistics criteria was collected from three different sources in order to create the most suitable combination of criteria for the case company. First, supplier selection literature was searched for pre-developed criteria and models to create the backbone of the set. After this, the author of this thesis proposed a set of criteria to the case company. This set was then brainstormed together to refine the criteria to better suit the case company’s objectives. Finally, the last corrections to the criteria were made after the interviews and based on the experiences of the project managers.

Including people with different backgrounds and expertise in the criteria formulation phase is also recommended in the literature (Aissaoui et al. 2007). A multidisciplinary team can help emphasize various points of view to consider while selecting a supplier. In this case, the case company has a view of what kind of attributes they want to use to rate their suppliers. This view, combined with the experts’ opinions and best practices from both the literature and the project managers, forms the seven logistics criteria that are presented below in table 5.

Table 5: An overview of the logistics criteria.

Criterion	Short explanation
Location	<ul style="list-style-type: none"> <li>○ How preferred is the supplier's location?</li> <li>○ Is the supplier operating globally and/or able to ship from multiple locations?</li> </ul>
Service capability	<ul style="list-style-type: none"> <li>○ Level of communication</li> <li>○ Overall level of service</li> <li>○ Testing &amp; maintenance expertise</li> <li>○ Reciprocity: Ability to learn from mistakes and share best practices together</li> </ul>
Flexibility capability	<ul style="list-style-type: none"> <li>○ Reaction to unexpected changes in e.g. delivery schedule or order quantity</li> <li>○ Return &amp; fixing policy and handling of return logistics</li> <li>○ Dealing with uncertainty &amp; unexpected issues</li> </ul>
Total landed cost	<ul style="list-style-type: none"> <li>○ Price of a shipped/delivered product</li> <li>○ Pricing and ability to make frame-agreements</li> </ul>
Regulations	<ul style="list-style-type: none"> <li>○ Customs &amp; trade-restrictions</li> <li>○ Traveling (Visas and work permits)</li> <li>○ Own, company-specific regulations</li> </ul>
Total delivery time	<ul style="list-style-type: none"> <li>○ Total time from plant to destination port</li> <li>○ Includes land-transportation in country of origin</li> </ul>
Delivery reliability	<ul style="list-style-type: none"> <li>○ Product quality</li> <li>○ Suitability of the product</li> <li>○ On time-delivery</li> <li>○ Keeping promises about deliveries</li> </ul>

#### 4.2.1 Location

The first criterion, **location**, represents the supplier's physical placement's attractiveness from the case company's point of view. As mentioned already in table 3, a question to answer with this factor could be: "How preferred is the supplier's location compared to other options?". When rating suppliers this could mean that suppliers with multiple factories and shipping points around the world should get an advantage over their competitors with only one factory.

The location-criterion also deals with the ethical aspect when comparing local- and overseas sourcing. As an example, the delivery time could be shorter and the cost of logistics lower when choosing an Asian supplier over a local Finnish supplier. However, objectives such as testing, quality control and logistics planning become harder when the modules are sourced from overseas. These objectives are hard to measure and compare in terms of total cost effect, hence rating suppliers by this factor requires qualitative estimations and the knowledge of company preferences.

The idea of including location as a separate criterion in the comparison tool derived highly from the project managers' interviews. Both interviewees stated that real global companies, the ones that are positioned and able to ship from several places around the world, should have an advantage over the local suppliers when considering international projects. Another key supplier attribute that derived from the interviews was the suppliers' capability of sending an expert to the construction site when requested. According to the interviewees, the presence of the supplier in the site reduces the amount of misunderstandings in the installation phase and might lead to discovering problems early on in both, case company's ways of working and the supplier's product quality.

The act of dividing the suppliers' physical positioning into two different criteria, location and total delivery time is unusual in the literature. Mainly because the logistics criteria have not been studied on their own, the location factor usually combines all attributes that are related to the suppliers' locations and many other logistics-related issues.

The location criterion is also used to deal with some cultural differences and working ethics-related issues between different countries. An issue that one of the interviewees had occurred with Asian- and especially Chinese suppliers was the need of making the supplier be economically dependent on the supply of the product. This means that it should not be possible for the supplier to benefit at all from the contract unless it is delivered on time and within the set quality boundaries. The issue occurs especially in Asia due to the constant stream of tight-schedule orders that are placed for the suppliers. This means that if the case company's order does not have tight penalties set for delays, other orders might be prioritized over it.

The interviewees also highlighted the fact that when supplying key components from certain Asian countries, regular visits or even constant presence of the buying firm's representative is necessary. There had been occasions where the supplier had been contacted via e-mail and everything regarding the supply of the component was considered to be in order and on time, but when a visit was made to the supplier's factory, it had come clear that the production had not even started yet.

Customer's preferences are also a thing to note when selecting suppliers. The case company's end customer might for example state that they want their power plant to be manufactured completely or mostly by European suppliers. This then reflects to the case company's supplier selection thus giving European suppliers an advantage in the selection. In the tool this type of a customer requirement would require the user to modify the points of the suppliers. Another way to address this type of a customer requirement is to think about the issue already when thinking about the company's own values. This way the supplier base can be managed from the beginning to suit the customer requirements.

The case company's own supplier audit-base does not take the location factor directly into account. Since the criterion is mainly measured via preferences and expectations, no direct audit questions were applied to address this location-criterion.

The rating scale for location-criterion has quite various objectives, thus making the rating process require the knowledge of many different fields. These fields of knowledge include

cultural issues, supplier audit results, company's own customers' preferences, and the understanding of case company's values. The rating scale for location-criterion is presented in table 6.

Table 6: Grading criteria for the location-criterion.

Grade	Verbal Grade	LOCATION - Grading criteria
9	Very good	<ul style="list-style-type: none"> <li>○ Supplier's location is preferred by both, company members and customers</li> <li>○ The supplier is operating globally and has various shipping points for the module(s)</li> <li>○ The business culture in the supplier's location supports case company's values</li> </ul>
7	Good	<ul style="list-style-type: none"> <li>○ Supplier's location is preferred by company members and not denied by customers</li> <li>○ The supplier is operating globally</li> <li>○ The business culture in the supplier's location can be understood and adapted to</li> </ul>
5	Average	<ul style="list-style-type: none"> <li>○ Supplier's location is not significantly worse or better than the competitors'</li> <li>○ The supplier is delivering worldwide from one location</li> <li>○ It is not difficult to operate in the supplier's location and the business culture is understandable</li> </ul>
3	Bad	<ul style="list-style-type: none"> <li>○ Supplier's location is unpreferable compared to other suppliers</li> <li>○ Due to the supplier's location, it is hard for people or goods to be transported to certain countries</li> <li>○ The business culture in the supplier's country is hard to understand and operate with</li> </ul>
1	Very bad	<ul style="list-style-type: none"> <li>○ Supplier's location is not preferred by the case company OR is heavily disliked by the customers</li> <li>○ Supplier is not capable to deliver to several locations due to their location</li> <li>○ The supplier's location is known for ethical problems such as child labor</li> <li>○ Cultural issues make it difficult to communicate with the supplier</li> </ul>

#### 4.2.2 Service capability

While discussing with the case company, the interviewees and the thesis supervisor, the phenomenon of selling a service instead of a product was highlighted several times. The case company's deliverable is in fact a lot more than just a modular power plant. One project includes a variety of services such as delivery, installation, maintenance, possible product fixes, warehousing and other points where expertise of the plant is required. This means that product quality is by far not the only thing that the customer is looking at when evaluating the project.

The case company cannot offer the required level of service without the help of their suppliers. This means that whatever the service level required by the customer is, at least the same level of fluency and quality of service should also be required from the suppliers.

**Service capability** as a rating criterion is adapted indirectly from Ireton's (2007) & Liu & Luo's (2012) ideas of capability-based thinking. Even though neither paper discusses service as a separate capability, the level of service can be seen integrated within other factors in each study.

During the interviews, when international projects and sourcing from Asian countries was discussed, the difficulty of communication was mentioned. As mentioned with the location-criterion, the level of communication might be very poor and even lies might be told to cover the delays in the delivery schedule. The interviewees emphasized that this is not the case with every Asian supplier, but that it is more or less a cultural issue that should be dealt with contracts.

In addition to the necessary level of service, some suppliers may offer value-adding services to stand out in the competition. The interviewees thought that these value-added services should also be notified when rating suppliers. In our case, value-added services could include warehousing the modules if the shipping is delayed, supplier's expert participating in the installation, or superior testing facilities when compared to other options.

The rating of suppliers according to the service capability-criterion was built around four main points: overall level of service, communication, expertise consultation and reciprocity. A part of the points, such as reciprocity – the ability to develop the service together, cannot be measured until the first projects have been successfully executed. This means that at the beginning the grade will mainly consist of the results of the case company's supplier audits. Table 7 represents the grading scale for the service capability-criterion.

Table 7: Grading criteria for service capability-criterion.

Grade	Verbal Grade	SERVICE CAPABILITY - Grading criteria
9	Very good	<ul style="list-style-type: none"> <li>○ The overall level of service provided by the supplier is better than many other suppliers' in terms of availability and price</li> <li>○ The communication with the supplier is fast and fluent</li> <li>○ The supplier has wide expertise on the product and does not hesitate to share it or send an expert to the site</li> <li>○ The supplier initiates joint development and reciprocity</li> </ul>
7	Good	<ul style="list-style-type: none"> <li>○ The overall level of service provided by the supplier is better than the average supplier's</li> <li>○ The communication with the supplier is fluent</li> <li>○ The supplier knows their product well and shares expertise fluently</li> <li>○ The supplier is potential in terms of joint development and reciprocity</li> </ul>
5	Average	<ul style="list-style-type: none"> <li>○ The supplier provides all the necessary services for their product</li> <li>○ There are no negative issues in communicating with the supplier</li> <li>○ The supplier knows their product and helps with it when requested</li> <li>○ Joint development is possible with the supplier in the future</li> </ul>
3	Bad	<ul style="list-style-type: none"> <li>○ There are minor lacks in the supplier's level of service, or some services are more expensive than average</li> <li>○ There are difficulties in communicating with the supplier</li> <li>○ It is difficult to get support with the product from the supplier</li> <li>○ The supplier does not make effort to develop the product or the service</li> </ul>
1	Very bad	<ul style="list-style-type: none"> <li>○ The supplier's service level is poor, or the services are very expensive</li> <li>○ Communicating with the supplier takes very long and is not fluent or the supplier is lying</li> <li>○ The supplier rarely responds to requests</li> <li>○ The supplier repeats mistakes and does not share information</li> </ul>

### 4.2.3 Flexibility capability

Capability thinking, which is used by for example Ireton (2007), is also behind the next criterion, **flexibility capability**. Flexibility could be used as a word to describe most of the criterion but including the word capability in the name represents flexibility as a supplier's competence and as a factor that can be measured.

When it comes to flexibility, what our case company wants to see from their suppliers is successful handling of unexpected issues. These can be related to for example delays in project schedules, returns and fixes of non-suitable modules or changes in product specifications or quantities.

Logistically thinking, return logistics play a significant role in the process of fixing damaged or unfit products. However, even the most effective return shipping makes no difference, if the supplier does not have the capability to fix the product once it has arrived at their plant. Some of the interviewees emphasized that at the point when a module should be installed on site and a malfunction or any other type of problem occurs, many companies tend to start trying to find someone to blame for the mistake. However, in those cases, time is critical and fixing the module should be in everyone's mind since costs are constantly running for the operating company.

Supplier's ability to either send mechanics to the site to fix the module or to take the module into their own plant for instant fixing was mentioned as a very key attribute by the interviewees. Often the supplier's workload may be too big to instantly fix the damaged module, which makes preparing for these incidents through contracting even more important. Shipping or even flying damaged products back to the supplier causes costs, for which the responsible part must be clear. In contracts, according to the interviewees, the time that the repairs take, should be taken into account, since often the construction process might have to wait for the repaired parts to arrive, thus causing large costs.

Uncertainty was also mentioned by the interviewees as a factor that suppliers should be able to deal with. Especially, since the case company's projects are large-scale and require

months of sales work before the orders can be placed, the suppliers cannot prepare their workload very carefully for the future orders. This might hurt smaller suppliers, since projects of this size may require them to even hire new personnel.

The case company's supplier audit sheet addresses flexibility of the suppliers quite effectively according to the above-mentioned issues. For example, the suppliers' claim handling processes are evaluated with several questions such as "*Is claim handling process measured (KPI)?*" and "*Is a claim management system / software in place for tracking status of claims?*". Also, the suppliers' production capacity and preparations for unexpected orders are measured with questions such as "*Is production planning done based on the customer need?*" and "*Is production planning updated based on the change from the customers' orders?*".

Based on the experiences from the interviews and the above-presented questions from the case company's audit sheet, a rating scale was developed as presented in table 8. The key attributes for a supplier that would succeed in flexibility capability-factor are the ability to succeed in a changing and uncertain environment, successful and measured way of handling claims, the ability to react to problems with products and continuity in terms of continuous reasonable workload that has space to deal with unexpected issues as well.

Table 8: Grading criteria for the flexibility capability-criterion.

Grade	Verbal Grade	FLEXIBILITY CAPABILITY - Grading criteria
9	Very good	<ul style="list-style-type: none"> <li>○ The supplier has a documented claim handling policy</li> <li>○ The typical solving time of claims is reasonable, and a system has been established to display the status of claims</li> <li>○ The supplier is constantly able to deal fast with unexpected product fixes and changes that are made to the order quantities or schedule</li> <li>○ The supplier has evidence of successfully dealing with uncertainty</li> <li>○ The supplier is not dependent on one or a few of their own suppliers</li> </ul>
7	Good	<ul style="list-style-type: none"> <li>○ The supplier has a documented claim handling policy</li> <li>○ The typical solving time of claims is reasonable, and a system has been established to display the status of claims</li> <li>○ The supplier usually reacts fast to unexpected product fixes and changes that are made to the order quantities or schedule</li> <li>○ The supplier can handle uncertainty</li> </ul>
5	Average	<ul style="list-style-type: none"> <li>○ The supplier has or will have a documented claim handling policy</li> <li>○ The typical solving time of claims is reasonable</li> <li>○ The supplier can usually deal with unexpected product fixes fast</li> <li>○ Uncertainty or changes in product specifications or schedule usually do not cause trouble for the supplier OR cause very minor issues</li> </ul>
3	Bad	<ul style="list-style-type: none"> <li>○ The supplier can handle claims but has no documented policy for it</li> <li>○ The typical claim handling time is longer than average or not measured</li> <li>○ The supplier might not be able to handle uncertainty or changes in product specifications</li> </ul>
1	Very bad	<ul style="list-style-type: none"> <li>○ The supplier does not handle claims properly or it takes very long to handle them</li> <li>○ The supplier does not take uncertainty into account when doing production planning</li> </ul>

#### 4.2.4 Total landed cost

Pricing of the product is not usually a thing to be considered when discussing logistics. Logistics has its own price that is usually separated from the product price, unless a total cost-aspect is used. For this study, the case company and all the interviewees agreed to the fact, that the **total landed cost**-criterion was useful and even necessary for rating suppliers.

The criterion is not used to compare suppliers according to market prices of the products. It is also not used to calculate the cost of shipping the product from the supplier to the site. However, these two costs are the main things that should be estimated when rating suppliers via the total landed cost-criterion.

When discussing with the case company about the supplier ratings, cost was mentioned several times as an important rating criterion. However, since the rating tool is developed to address mainly logistics-related criteria, a logistic approach to product cost was needed.

Young, Swan, Thomchick & Ruamsook (2009) propose a five-module approach for supplier total landed cost modeling. The five landed cost modules, *price*, *transportation*, *customs duties*, *inventory management* and *administrative overhead*, are developed based on models of six offshore sourcing case companies. These five modules are used to develop a rating scale for the total landed cost-criterion. (Young et al. 2009.)

Out of the five modules proposed by Young et al. (2009), product price is the easiest to measure. However, since the rating scale is qualitative by its nature, the decision maker only needs to make an estimation of the supplier's product price and use it as one of the factors when making the final choice for the grade. Young's et al. model, however, also states that some suppliers require payments by letter of credit, thus formulating additional costs for the payer. This minimal currency logistics issue could be used when determining minor differences between similar suppliers.

The transportation-module covers the costs related to moving the product from the supplier to the site, as well as storing the product in ports, truck or warehouses (Young et al. 2009). When comparing different suppliers, the cost of transportation should be equal from the point when the product has arrived in the target port, which means that the differences in transportation costs are mainly made in the supplier's country and the shipping phase.

The customs duties-module is very closely related to the next criterion in this tool – regulations. However, whereas the regulations-criterion focuses on the time and effort taken to move the goods and people between locations, cost-wise the customs-duties mean taxes, tariffs and merchandise processing fees (Young et al. 2009). For the total-cost criterion, the most important attribute of the customs duties-module is the possibility of denying it completely through free trade alliances. This means that especially suppliers located in countries that belong to several trade alliances or -unions should get advantage over suppliers whose location does not support exporting and importing that well.

The inventory management module shows that the case companies used by Young et al. (2009) mainly do manufacturing business instead of project-type business. Although the costs and risks of holding, damaging or losing the products also occur in project business, they can be better avoided with successful contracting, risk management and project schedule optimization. Mainly in our case company's projects the inventory management module should be considered when modules need to be temporarily warehoused and guarded either on site or near a supplier for testing purposes.

Finally, the administrative overhead-module consists for example of costs that occur when establishing a relationship with a new supplier. Also, especially when developing large, technologically complex modules in cooperation with the supplier, administrative and engineering costs should be noted. With some suppliers, visits to the factory by the case company might be needed more often than expected. In general, maintaining a global supplier network causes administrative costs that may get even higher, if the case company needs to supervise or develop the supplier for them to perform better. (Young et al. 2009).

As explained, calculating the total landed cost might be impossible according to these factors and thus, qualitative declarations for the rating criteria are established. The rating criteria for the total landed cost-criterion are displayed in table 9 and are mainly based on the above-mentioned five modules developed by Young et al. (2009).

Table 9: Grading criteria for the total landed cost-criterion.

Grade	Verbal Grade	TOTAL LANDED COST - Grading criteria
9	Very good	<ul style="list-style-type: none"> <li>○ The cost of the module(s) is average or lower than average</li> <li>○ The supplier can offer shipping services for modules for better cost</li> <li>○ The customs process is effortless and cheap from the supplier's country</li> <li>○ The supplier's location belongs to an alliance that makes trade easier</li> <li>○ Temporary warehousing in supplier's country is inexpensive</li> <li>○ The supplier can operate and develop without continuous supervision</li> <li>○ The total cost of using this supplier should be below average</li> </ul>
7	Good	<ul style="list-style-type: none"> <li>○ The cost of the module(s) is average or below average</li> <li>○ The export customs process is cheap in the supplier's country</li> <li>○ The supplier's location belongs to an alliance that makes trade easier</li> <li>○ Temporary warehousing in supplier's country is affordable</li> <li>○ The supplier can operate without continuous supervision</li> <li>○ The total cost of using this supplier should be average or below average</li> </ul>
5	Average	<ul style="list-style-type: none"> <li>○ The cost of the module(s) is close to average</li> <li>○ Exporting goods from the supplier's country is not very expensive</li> <li>○ Temporary warehousing in supplier's country is not very expensive</li> <li>○ Occasional visits to the supplier are required to ensure operation</li> <li>○ The total cost of using this supplier is close to average</li> </ul>
3	Bad	<ul style="list-style-type: none"> <li>○ The cost of module(s) is more expensive than the average</li> <li>○ The supplier's country has an expensive customs process</li> <li>○ Temporary warehousing in the supplier's country is expensive</li> <li>○ Visiting and supervising the supplier is required to ensure operation</li> <li>○ The total cost of using this supplier is above average</li> </ul>
1	Very bad	<ul style="list-style-type: none"> <li>○ The cost of the modules and using the supplier is extremely expensive – the supplier should only be used when: <ul style="list-style-type: none"> <li>• High cost can be compensated with other criteria such as fast delivery time</li> <li>• High cost is irrelevant to the project</li> </ul> </li> </ul>

#### 4.2.5 Regulations

The next criterion, **regulations**, is more related to the supplier's logistic position than to their actual capability to operate. However, the country- or region-specific regulations often affect directly or indirectly the company's business especially when goods are shipped to and from abroad.

The regulations-criterion is closely related to the location-criterion, since the physical or legal location of the company is the main factor behind both criteria. They are, however, divided into two separate criteria to have one criterion displaying the decision-maker's preferences and one criterion to display the fact-based, experienced logistical differences between different locations.

Based on the interviews, two issues that are relevant for supplier selection are regulated by countries or different alliances: the moving of goods and the moving of people. Regulating the moving of goods in this context means country- and region-specific customs processes. For example, moving goods within the European Union is effective and long customs processes rarely occur. However, clearing goods to a non-developed country in Africa might take several days or even weeks depending on different factors. *The average time to clear exports through customs* -dataset by The World Bank (2019) indicates that whereas the average customs clearance time in the European Union was three days in 2017, in the least developed countries determined by the United Nations the same average value was ten days in 2017.

Even though the seven-day difference in customs processes might not occur often and might not even be remarkable enough to cause actions, it should be noted that the idea of this study is to measure the logistic effectiveness of the suppliers. The study takes into account the suppliers' logistic performance from many different aspects, thus creating an overview of the suppliers' logistics-related strengths and weaknesses. Even though a supplier might score poor due to the hard regulations in their operating country, the supplier's overall score might still be compensated by other factors such as their great level of

service. The level of compensation is, of course, determined by the decision-making company's preferences that are represented in the AHP matrixes.

The movement of people to and from the supplier's location was the second point mentioned in the interviews. Again, within the European Union it is difficult to see this phenomenon as a problem, but while professionally traveling in other continents such as Asia or Africa, the time taken by visa processes and working permits should be considered. Also, between certain countries the regulatory might be so strict, that working permits for even one day might be impossible to get. China was mentioned as an example of a country, into which it might be very hard to get even a one week working permit. China rates people with work visa points into three categories according to their experience and if one does not achieve enough points in the state's point system, they might not be able to work in the country. Due to this point system, it might be harder for the case company's representatives to participate in testing or make supplier audits to a Chinese supplier.

Another point that was quickly mentioned in one of the interviews was the supplier's own specific regulation on how and with whom they can do business. This was mentioned as a minor issue that only rarely occurs, but some suppliers might be regulated by their stakeholders or customer base to operate only with certain type of companies. These issues might arise for example if the case company were to build a plant into a country that the supplier is aiming to avoid for some reason.

The case company's supplier audit form addresses the legislation in the supplier's country from a different aspect. The audit aims to confirm that the supplier's operations are up to date with the latest legislation and that they understand the legislation in the waste-to-energy business. Also, the audit aims to ensure that the supplier has no legal conflicts ongoing for their own operations. These regulations-related issues do not, however, deal directly with logistics and thus the questions from the audit form are not included with this rating criterion.

Rating suppliers via the regulations-criterion is quite straight forward and requires only minimal information about the supplier in terms of the physical location. However, the

rating requires knowledge and experience of the country-specific regulatory as well as customs, alliances and trade-limits between certain countries. The rating scale cannot address all the individual trade-restrictions and therefore it is developed to display the overall complexity of the regulatory in the supplier's location. The rating criteria can be found in table 10.

Table 10: Grading criteria for the regulations-criterion.

Grade	Verbal Grade	REGULATIONS - Grading criteria
9	Very good	<ul style="list-style-type: none"> <li>○ The legislation in the supplier's country allows fluent exporting and importing to and from almost all locations</li> <li>○ Customs times are below average to and from the supplier's country</li> <li>○ It is easy to get a visa or a working permit to the country OR it is not required to apply for one</li> <li>○ The supplier's own values support operating with the case company and their customers</li> </ul>
7	Good	<ul style="list-style-type: none"> <li>○ The legislation in the supplier's country allows fluent exporting and importing to and from most locations</li> <li>○ It is easy to get a visa or a working permit to the country OR it is not required to apply for one</li> </ul>
5	Average	<ul style="list-style-type: none"> <li>○ The legislation in the supplier's country does not interrupt exporting or importing to and from most countries</li> <li>○ Customs times are average to and from the supplier's country</li> <li>○ It is possible to get a visa or a working permit to the country, but the process might take some time</li> <li>○ No major legal issues are expected when operating in the supplier's country</li> </ul>
3	Bad	<ul style="list-style-type: none"> <li>○ Exporting and/or importing to and from the supplier's country can be difficult or take time</li> <li>○ The process of getting a visa or working permit to the country is difficult or time-taking</li> </ul>
1	Very bad	<ul style="list-style-type: none"> <li>○ The country's export/import policy is very strict, and the customs process often takes very long</li> <li>○ From certain countries it is impossible to get a visa or working permit to the country</li> <li>○ Legal issues are very likely to occur when operating in the country</li> </ul>

#### 4.2.6 Total delivery time

The **total delivery time**-criterion is the only directly measurable criterion in the tool. Some parts of other criteria may be measurable by numbers, but still parts of them require company-specific information or knowledge on supplier preferences. The total delivery time, however, can easily be estimated by using online calculators provided by many cargo carriers on their websites. The only fact that needs to be clear about the supplier is their shipping location, in other words the plant that they are going to produce the module in.

Since in this tool suppliers are compared, the delivery time estimations are limited to cover only the time it takes to move the module from the supplier's factory to the target port. Again, this is done because the delivery time from the target port to the site location can be estimated to be equal for every supplier or at least not determined by the supplier's attributes.

Maersk, CMA CGM and the Mediterranean Shipping Company (MSC) were in 2018 the three largest container shipping companies in terms of chartered ships and total owned and chartered 20-foot containers. (United Nations Conference on Trade and Development - UNCTD 2018:31). All three companies have a shipping time calculator on their websites (CMA CGM 2019; Maersk 2019; MSC 2019) . These calculators were used in combination with example ports that represent the case company's main supplier locations to estimate the shipping times from port to port.

The example ports were selected not to represent each port that the deliveries would be originating from but to represent the main supplier locations and to give an estimate of how long it would take to ship from a large port near the supplier. Only 20% of the suppliers' countries are not covered by the example ports, mainly because the countries are not located by the seas. The delivery time from these countries is estimated by the delivery time from the nearest port with the inclusion of an estimated land-transportation time from the country to the nearest port.

Some variance was noticed in the results for certain routes either between different shipping dates or between different shipping companies. The variance is dealt with by calculating a basic arithmetic mean first for each shipping company's **eight** next shipments for the route and finally combining the means of each shipping company into an average shipping time for the route.

Finally, the average delivery times for each port had to be transformed into a grade from 1-9 for them to work with the AHP-tool. For this, a rating scale had to be developed. After comparing several different scale-development methods, a neutral scale with equally large value ranges was chosen instead of weighting the best and the worst values. The grading scale's value ranges are simply calculated by taking the highest delivery time for a certain site location and dividing it by 9 – the total number possible grades. The resulting  $A$  means the length of each grade range. For example, as the table 9 below shows, for the delivery location of Mombasa, Vietnam, the  $A$  – value is calculated from the delivery time of 43,33 days from Helsinki, Finland, since that is the longest of the delivery times to Mombasa. The  $A$  – value is then approximately 5 and forms the range for the best grade – 9 (0 – 5 days). Each following grade is then represented by a range that is  $A$  days long, starting from where the previous grade's upper limit is set. If the average of one of the ports happened to be exactly on in the intersection of two grades, a higher grade should be assigned.

Table 11: The total delivery time-criterion calculations and rating scales.

Supplier's port ↓ Target port →	8-next average for Maersk		8-next average for MSC		8-next average for CMA CGM		Combined average		Grade		Grading scale	
	Ho Chi Minh	Mombasa	Ho Chi Minh	Mombasa	Ho Chi Minh	Mombasa	Ho Chi Minh	Mombasa	Ho Chi Minh	Mombasa	Ho Chi Minh	Mombasa
Helsinki (FIN)	45	43	45	47	60,2	40	50,07	43,33	1	1	1 = >44	1 = >40
Hamburg (GER)	37,4	31	50	31	40,5	34,3	42,63	32,10	2	3	2 = 38,5 - 44	2 = 35 - 40
Gdansk (POL)	40	40	39	39	43	39,8	40,67	39,60	2	2	3 = 33 - 38,5	3 = 30 - 35
Laem Chabang (TH)	3	20	9	36	2	23	4,67	26,33	9	4	4 = 27,5 - 33	4 = 25 - 30
Constanta (ROM)	43,4	23	43	47	39,1	32,6	41,83	34,20	2	3	5 = 22 - 27,5	5 = 20 - 25
Kolkata (IN)	28,3	28,3	18	29	14	26,4	20,10	27,90	6	4	6 = 16,5 - 22	6 = 15 - 20
Hiroshima (JAP)	17,5	32,2	5	41	17,7	26,5	11,25	33,23	7	3	7 = 11 - 16,5	7 = 10 - 15
Liverpool (UK)	44,1	35,8	42	45	48,6	37,6	44,90	39,47	1	2	8 = 5,5 - 11	8 = 5 - 10
											9 = 0 - 5,5	9 = 0 - 5
											$A = \frac{50,07}{9}$	$A = \frac{43,33}{9}$
											$A \approx 5,5$	$A \approx 5$

Since the grading scale is formulated from the longest delivery time that is available from all routes, it ensures that at least one of the ports of origin will get the worst grade, 1. However, on the contrary the rating scale does not ensure that one of the available ports would get the best grade, 9. As can be seen from the case Mombasa in table 11, no grades higher than 4 are awarded to the ports, since even the shortest average shipping time available is the 26 days from Laem Chabang, Thailand. Developing a grading scale that weights the best values might in Mombasa's case would be suitable to achieve spread in grades. However, since new site locations with both, extremely long and extremely short delivery times may be included in the tool later, a basic non-weighting grading scale should treat all the suppliers equally in terms of delivery time. Also, if a weighting scale was used, the values that do not belong to the highest or the lowest, in other words the average values, might have more spread than needed. For example, the delivery time of 25 days might award grade 6 whereas the delivery time of 30 days would award grade 4, even though the difference is not really that significant.

Even though the port-to-port shipping is the most time-taking part of the delivery phase, the interviewees emphasized that the land transport time from the supplier to the port of origin should be considered in the tool as well. As an example, if there was a module to be shipped from a Hungarian supplier to Kenya, the transportation of the module to a German port would require passing two country borders as well as at least two days of

time. Realistically at least three or four days alongside with more administrative time should be reserved to get the module to the port.

To address the inland transportation time, the grading system was slightly adjusted to benefit suppliers located closer to international shipping ports. Since a five days lower delivery time would usually award the port a better grade, a 1-grade compensation is given to the suppliers located close to ports. The compensation is optional, since it is not necessary, if all the suppliers supplying the module are positioned similarly close to, or far from a port. As a grading rule of thumb, if individual suppliers are superior compared to their competitors in terms of inland location, their grade should be promoted by one. Also, the minimum requirement for a grade promotion should be a one-day difference in road-transportation time for the promotion to difference to be significant enough.

#### 4.2.7 Delivery reliability

Finally, the last criterion, **delivery reliability** is one of the most mentioned criteria in the literature as well as in the interviews. Quality has been a hot topic over at least the past 10 years and delivery reliability can be considered as taking a quality point of view to logistics. Since product quality is not considered as a separate criterion in our model, the delivery reliability-criterion is used to represent many quality-related supplier factors. “Delivery reliability is much more than having the orders delivered on time”. This is a rough translation of a statement made by one of the interviewees which was agreed in the literature. Delivery reliability consists of issues such as: product quality, suitability of the product, delivery timing (not too early – not too late), keeping promises about the deliveries and finally, the belief, that the supplier is able to manufacture the products also in the future and follow the previously-mentioned factors.

In the interviews, both the industrial project managers and the logistic operators found the reliability of the suppliers’ deliveries to be a key factor when considering the success of the whole project. Especially in such construction projects that our case company is going to carry out, when modules are assembled in a certain order, even one delayed or faulty module could delay the whole construction process significantly. This issue

concerned especially the logistic operators, who highlighted the importance of supervising and auditing the suppliers' delivery-related competences such as lead time, product quality, shipping time, packing ability and sticking to agreed schedules.

Unlike the previous criteria, delivery reliability and quality issues in general are very well covered by the case company's supplier audit sheet. The first thing considering quality in the audit sheet asks whether the supplier has established a quality management system (QMS) according to the ISO9001 -set of standards. The certificate is an effective way of displaying the level of handling quality related issues within the company, which also makes it a suitable criterion for supplier comparison. Next, the supplier audit sheet mentions internal audits and asks whether they are comprehensive, done on a regular basis, supervised and whether an action plan has been established to address the found problems. An internal audit considering the delivery reliability would be a great measure for the tool, but the data might not be available for each supplier. However, the requirement of regular audits is added to the higher grades for the delivery reliability-criterion to separate the most qualified suppliers.

Production capacity is another point that is well covered by the case company's supplier audit sheet. In brief, production capacity means the supplier's ability to constantly fulfil orders coming from their clients and to manage their workload to adapt to the demand. According to the case company representative and one of the interviewees, it is important to find suppliers that have constant workload and to "fill the gaps" in their supply to satisfy both, the supplier and the customer. According to the same interviewee, failing to find a supplier with constant workload might lead to a situation, where the supplier is too dependent on the case company. In such case the supplier might be forced to hire employees only for the period of manufacturing the case company's modules. If no projects would follow, the employees would get fired right after the project, only to be hired again once the next order would be placed.

Production capacity is also a crucial supplier factor when considering the returns and fixes of modules. If a supplier's factory is constantly running on full capacity, the fixing of damaged products might either harm the supplier's own operating or, if the module cannot

be fixed once it has arrived, delay the case company's project. The problem brings us to the other side of joint dependencies, where the supplier has several more important clients than our case company. The case company's project might be just a very small piece of the supplier's capacity, even though being large from our point of view. According to many of the interviewees, this is in fact a problem that should be dealt with either selecting a supplier that is more dependent on the case company's project or by making contracts with high penalty fees for delays.

Once the supplier's capacity is known, it is easier for the case company to plan on using the specific supplier also in the future. This leads to continuity in the supplier-buyer relationship and the supplier's operating since the supplier can assume orders to be placed in the future as well. The level of potential future of the supplier-buyer relationship is hard to estimate and even harder to measure. However, the person making the decisions about suppliers should be able to make a verbal estimation on how potential they see the relationship in the future. Developing the relationship with a familiar supplier is also logistically beneficial for the case company, since after a few projects the delivery times and rates are easier to estimate already in the sales phase.

Even though the quality of the suppliers' manufacturing processes is not directly related to logistics or delivery reliability, the overall quality of the product is very important in terms of reducing returns, fixes and problems overall. Therefore, issues found in the supplier audit sheet regarding the suppliers' process control, quality and design control, material management, supplier selection and production capacity are considered when developing the rating criteria for the delivery reliability-criterion. Since the five factors are covered so profoundly in the supplier audit sheet and the sheet gives a total "OK"-marked issue -percentage for each of the sections, this percentage is used for rating suppliers by the delivery reliability-criterion instead of picking individual questions from the sheet. The rating criteria are displayed in table 12.

Table 12: Grading criteria for the delivery reliability-criterion.

Grade	Verbal Grade	DELIVERY RELIABILITY - Grading criteria
9	Very good	<ul style="list-style-type: none"> <li>○ Products are always delivered on time</li> <li>○ Over 80% or much above average score in supplier audit quality sections</li> <li>○ Comprehensive internal audits made regularly and supervised</li> <li>○ Excellent overall product quality</li> <li>○ Highly trusted supplier now and in the future</li> <li>○ No recorded product quality or delivery issues with the supplier</li> <li>○ ISO9001-based quality management system established</li> <li>○ Documentation on a continuous suitable workload / capacity</li> </ul>
7	Good	<ul style="list-style-type: none"> <li>○ Products are mainly delivered on time</li> <li>○ Over 60% OR above average score in supplier audit quality sections</li> <li>○ Internal audits are made regularly</li> <li>○ Good overall product quality</li> <li>○ Trusted supplier</li> <li>○ Only minor recorded product quality or delivery issues</li> <li>○ ISO9001-based quality management system established or pending</li> <li>○ The case company's orders have a suitable impact on the supplier's workload</li> </ul>
5	Average	<ul style="list-style-type: none"> <li>○ Products are usually delivered on time</li> <li>○ Around 50% OR average score in supplier audit quality sections</li> <li>○ Internal audits are made or are planned to be made</li> <li>○ Good overall product quality</li> <li>○ Decent supplier, not the best, not the worst opinion in terms of reliability</li> <li>○ Some issues recorded regarding product quality or deliveries</li> <li>○ Quality management of some sort has been established</li> <li>○ No production issues should occur with order prioritizing by the sup-</li> </ul>
3	Bad	<ul style="list-style-type: none"> <li>○ Delays or other issues with product deliveries or quality</li> <li>○ The supplier has spikes and gaps in their workload</li> <li>○ Below 50% or below average score in supplier audit quality sections</li> <li>○ Internal audits not done</li> <li>○ Sometimes promises about deliveries are not kept</li> </ul>
1	Very bad	<ul style="list-style-type: none"> <li>○ Severe delays or cancellations regarding product deliveries</li> <li>○ The supplier is extremely reliant on case company's orders</li> <li>○ Poor product quality,</li> <li>○ Poor score in supplier audit quality sections</li> <li>○ No internal audits or quality certificates</li> <li>○ Non-trustworthy supplier</li> </ul>

### 4.3 Building the AHP matrixes

After the formulation of the criteria, the next step in Saaty's (1980; 2007) AHP process is the pairwise comparison of the criteria. This means that the importance of each decision-making criterion is calculated by comparing the criteria pairwise. The resulting priorities can then be used in the selection tool as weights for the corresponding grades.

Instead of developing an own AHP calculation sheet, the internet was searched for an open access Excel-template. A template developed by Thomas Pyzdek for the Pyzdek institute (Pyzdek 2014) appeared to suit the purpose very well with its simple build. The template is used in our Excel tool almost as it is presented on the website. However, the template had to be copied to make separate sheets for different scenarios (see next sub-subchapter).

The pairwise comparisons should be made by someone who understand the decision-making principles in the company and follows the company's values. Since the author of this thesis is not working for the case company nor involved in their decision making, it was logically chosen that the pairwise comparison matrixes would be filled by the case company's decision makers.

#### 4.3.1 The scenarios

In addition to the normal scenario, it was requested by the case company to include optional scenarios in the Excel-tool, since the goals of the delivery projects may vary a lot. As an example, they mentioned that in one case the cost of the project might be insignificant, and the speed of the deliveries would be the key to success. On the contrary in some cases there might be plenty of time to execute the project and thus, cost savings could and should be searched for.

After a short conversation with the case company, four customized scenarios were tailored to their preferences. First, the "fastest delivery – higher cost" -scenario aims to the

fastest possible delivery by mainly ignoring other criteria including the total cost. Second, the “best product quality and service level” -scenario weights the quality- and service-related criteria highest at the cost of lowering the weights of criteria such as total landed cost, total delivery time and regulations. Third, the “cost effective” -scenario weights the total landed cost criterion the highest. It partly ignores factors such as total delivery time and location, but still pays minor respect to them as well as other criteria.

Finally, the fourth scenario, “ethical/environmental”, aims to highlight the ethically and environmentally competent suppliers by emphasizing the delivery time and location -criteria. In this scenario, it is assumed that the case company prefers to source from countries where ethical issues only rarely occur. Also, the emphasis on the delivery time -criterion ensures that the supplier with the position closest to the site, will be emphasized for lower carbon footprint. However, it should be noted that when the ethical or environmental issues are emphasized in the case company’s project, likely the most relevant data for supplier comparison can be found from the supplier audit sheet rather than logistics-related issues presented by this study.

Also, since the projects’ weightings may vary a lot, a customizable AHP-matrix was added to the excel tool to help the decision maker to set the criteria-weights manually. The manual AHP-sheet does not include the pairwise comparison matrixes, but only the weights that can be set manually. Should the company’s preferences, values or ways of working change, the pairwise comparisons of the four pre-set scenarios can also be re-done in the Excel-tool.

#### 4.4 Building the Excel-tool

To apply the criteria weights retrieved from the AHP-matrixes into the logistics criteria, a calculation tool had to be developed. In fact, a Microsoft Excel-based application for supplier comparison was agreed with the case company to be developed in this study even before AHP was chosen as the main method of the study. The choice was made early due to the Excel's easiness of use and the author's competence of using Visual Basics, the programming language behind Excel's automation and macros.

The layout of the tool is simple. This was a request from the case company and thus a driver for both, the design and the programming. The opening tab named "Start" is displayed in attachment 1. The tab is vertically divided into two sections: the left section is used to run a new project with existing parameters and the right section is used to manage the database of suppliers and site locations. The entire workbook contains eight pre-set tabs: the start-tab, the database-tab, where the suppliers alongside with their score are listed, and finally the five pre-set scenarios in their own tabs alongside with the sixth, customizable scenario tab.

A closer look into the left and right sections of the start-tab is taken in attachments 2 and 3. Each section has guide texts to help the user to navigate through the process. Guide notes will also pop up (see attachment 4), when using the macro buttons to either run a new project or to modify the database.

When the user wants to run a new project, they must first choose the location from the list (step 1 in attachment 1) or add a new one using the buttons on the right. Adding a new location, would naturally require the user to rate the suppliers according to the delivery time criterion before the new location can be used. After this, the user should select either one of the pre-set project scenarios or the customized option (step 2 in attachment 1), which requires them to set the criteria weights manually in the "AHP-Custom"-tab.

Finally, once the parameters are set, the "Run new project"-button will first ask the user, whether they want to filter the resulting new tab to contain only the best suppliers for each

product category (attachment 7). In case of a negative answer, the program will display all the suppliers for each product category (attachment 6), starting with the highest overall score. The system will automatically create a new tab (attachment 6) based on the data-base tab (attachment 5) and make calculations and modifications according to the set parameters. Colors are used to distinguish the weighted criteria values that are more than 1,3 times higher (green) than the criteria average for that product group or less than 0,7 times lower (red) than the criteria average for the product group. The values that are close to the average, in other words between the red and green areas, are marked with yellow.

Color coding is also used to distinguish the best and the worst suppliers in case the new project is run without filtering only the best suppliers for each product group. The best suppliers, for each module are marked with green light green color and the worst ones are respectively marked with red color. The colors give the user a fast expression of how the suppliers' scores are distributed. After the first glimpse, the numbers can then be analyzed to form deeper conclusions and to support the final decision.

#### 4.4.1 Demonstrating the tool in use

This sub-subchapter introduces the Excel-tool in practical use. The aim is to point out the usability of the tool, by comparing the AHP-weighted values in two different scenarios. Figure 5 below displays the fixed grading values for five suppliers in the Air blowers-category. Each supplier originates from a different country (Finland, Sweden, Poland, Thailand or Kenya) and has their own strengths and weaknesses according to the logistics rating criteria. The site was chosen to be located in Kenya. The total score-column shows that there is some variance in the non-weighted score between the suppliers.

Product area / Function key	Example Supplier	Category	MODULE(s)	Country	Homepage	Location	Service Capability	Flexibility Capability	Total landed cost	Regulations	DelTime Kenya	Delivery reliability	TOTAL
Air blowers	Supplier 1	Line	Primary Air Unit Secondary Air Unit Tertiary Air Unit Re-circulation	Finland		8	9	7	1	6	1	8	41
Air blowers	Supplier 2	Line	Primary Air Unit Secondary Air Unit Tertiary Air Unit Re-circulation	Sweden		7	8	8	2	5	1	8	40
Air blowers	Supplier 3	Line	Primary Air Unit Secondary Air Unit Tertiary Air Unit Re-circulation ID Fan Unit	Poland		5	7	5	5	5	4	7	39
Air blowers	Supplier 4	Line	Fans	Thailand		7	2	4	9	4	8	3	38
Air blowers	Supplier 5	Line	Fans	Kenya		4	4	3	8	7	9	3	40

Figure 5: Database-values for the case example

The scenarios that were selected to be compared in this case are *fastest delivery* and *best product quality & service level*. Figure 6 below presents how the weights are distributed among the criteria in both scenarios. The AHP-matrixes are filled by the author according to the scenario descriptions, but they do not take the case company's preferences into account.

Fastest Delivery		Best product quality and service level	
Criterion	Weight	Criterion	Weight
Location	5,3%	Location	10,4%
Service Capability	4,1%	Service Capability	21,8%
Flexibility Capability	12,4%	Flexibility Capability	17,9%
Total Landed Cost	3,9%	Total Landed Cost	5,1%
Regulations	4,0%	Regulations	6,3%
Total Delivery time	49,2%	Total Delivery time	5,0%
Delivery Reliability	21,1%	Delivery Reliability	33,5%

Figure 6: Criteria weights for the case example

Prior to running the application, predictions were made about the potential results. First, the suppliers are graded in a way, that suppliers 1 and 2 represent quality-oriented, developed countries and suppliers 4 and 5 represent the low-cost countries. Supplier 3

represents the middle-way, having an average score in most of the criteria. Therefore, it is easy to predict, that for the fastest delivery-scenario, the suppliers 4 and 5 from Africa and Asia would dominate the European suppliers. On the contrary, the European suppliers 1 and 2 should then dominate the low-cost suppliers in the more quality-oriented scenario 2.

Figure 7 below presents the results for the fastest delivery-scenario. Even though supplier 1 is superior to others in three different criteria, they fall last in the comparison due to the scenario's high emphasis on delivery time. Meanwhile, approximately 67% of the total score of 6,576 received by the supplier 5 comes from the delivery time-criterion. In fact, the score received from the delivery time-criterion by the supplier 5 is higher than the total score of the supplier 1. Therefore, the highly weighted score compensates easily for supplier 5's poor score in quality-related sections.

Product area / Function key	Example Supplier	Category	MODULE(s)	Country	Homepage	Location	Service Capability	Flexibility Capability	Total landed cost	Regulations	Deltime Kenya	Delivery reliability	TOTAL
Air blowers	Supplier 5	Line	Fans	Kenya		0,26373	0,1636453	0,372542119	0,352191029	0,3631067	4,4294505	0,631572246	6,576
Air blowers	Supplier 4	Line	Fans	Thailand		0,36922	0,0818227	0,496722825	0,352191029	0,1613808	3,9372893	0,631572246	6,03
Air blowers	Supplier 3	Line	Primary Air Unit Secondary Air Unit Tertiary Air Unit	Poland		0,26373	0,2863793	0,620903531	0,195661683	0,2017259	1,9686447	1,473668573	5,011
Air blowers	Supplier 2	Line	Primary Air Unit Secondary Air Unit Tertiary Air Unit Recirculation ID Fan Unit	Sweden		0,36922	0,3272907	0,99344565	0,078264673	0,2017259	0,4921612	1,684192655	4,146
Air blowers	Supplier 1	Line	Primary Air Unit Secondary Air Unit Tertiary Air Unit Recirculation	Finland		0,42196	0,368202	0,869264944	0,039132337	0,2420711	0,4921612	1,684192655	4,117

Figure 7: Case example calculated with fastest delivery-scenario

Comparing the calculated results in figure 7 to the non-calculated grades in figure 5, the effect of AHP can easily be seen. For example, supplier 1 has the highest total score of 41 in the grades, but after the weightings, even supplier 4 with the lowest total score of 38 passes supplier 1 clearly. It should be noted that weightings this heavy might be impossible to apply for real life examples, and the case company might want to split the emphasis of this scenario more equally among the criteria. However, what this example does prove, is the functionality of the tool in a case where there are strong preferences for the project's logistics-related goals.

For the second scenario, the quality-oriented criteria delivery reliability and flexibility- and service capability are weighted the highest. This means that if for example supplier 1's score from these criteria was high enough to compensate for the poor score in delivery time and total landed cost, they should be able to bypass suppliers 4 and 5 in the comparison. Also, it is interesting to see, whether the score of all suppliers is low enough for supplier 3 to gain advantage in the comparison with their average score.

Figure 8 below presents the weighted score distribution in the product quality and service level-weighting scenario. The results are as expected and suppliers 1 and 2 take the top positions in the comparison. On the contrary, supplier 4's poor score in especially service capability and delivery reliability made them fall last in the comparison.

Product area / Function key	Example Supplier	Category	MODULE(s)	Country	Homepage	Location	Service Capability	Flexibility Capability	Total landed cost	Regulations	Deltime Kenya	Delivery reliability	TOTAL
Air blowers	Supplier 1	Line	Primary Air Unit Secondary Air Unit Tertiary Air Unit Re-circulation	Finland		0,82903	1,9642246	1,252436156	0,050788243	0,3768057	0,0501671	2,683588897	7,207
Air blowers	Supplier 2	Line	Primary Air Unit Secondary Air Unit Tertiary Air Unit Re-circulation ID Fan Unit	Sweden		0,7254	1,7459775	1,431355606	0,101576485	0,3140048	0,0501671	2,683588897	7,0521
Air blowers	Supplier 3	Line	Primary Air Unit Secondary Air Unit Tertiary Air Unit	Poland		0,51814	1,5277303	0,894597254	0,253941213	0,3140048	0,2006685	2,348140285	6,0572
Air blowers	Supplier 5	Line	Fans	Kenya		0,41451	0,8729887	0,536758352	0,406305941	0,4396067	0,4515041	1,006345836	4,128
Air blowers	Supplier 4	Line	Fans	Thailand		0,7254	0,4364944	0,715677803	0,457094183	0,2512038	0,401337	1,006345836	3,9936

Figure 8: Case example calculated with best quality and service level -scenario

The importance of the weightings is now clear, as poor score in even one highly weighted criterion may cause a supplier to fall behind in the comparison. This, of course, also requires thinking from the decision maker, since the final decision should be made based on all the criteria. For example, with only 1,2 points lower total score, supplier 3 might realistically be a better choice for this scenario than supplier 1 due to the lower landed cost and faster delivery. However, this effect should still be noted already during the phase when the AHP-matrixes are filled to ensure that too great compensation cannot be achieved with a great score on individual criteria.

#### 4.5 Constructing the checklist

The logistic checklist was agreed to be the second deliverable for this study. The goal of the checklist is to track potential pitfalls and best ways of working by interviewing experienced project managers and representatives from logistic companies. The case company aims to use the checklist prior to and during the first projects to make sure possible logistic issues do not delay the projects or cause unexpected costs.

Even though the members of the case company have previous experience from large-scale overseas delivery projects, they want to make sure that any avoidable problems are avoided in terms of logistics. It should also be noted that the checklist is designed to cover the issues from the project-controlling organization's aspect. There might be logistic issues that concern the logistic operators or project-control organizations more and are thus not included in the tool. Also, these partners and their knowledge on the project logistics are already a great asset to the case company.

During the interviews the interviewees were asked questions on the topics of project logistics in general, logistics in the developing countries and potential pitfalls of logistics in overseas projects. Also, in the interviews with the logistic company representatives, issues like the use of flat racks, the cost factors of a project logistics service and the benefits of combining the shipments into larger sets were emphasized as requested by the case company.

No specific constraints or limits were set for the checklist by the case company. The author sees this as both, an opportunity and a challenge. The resulting checklist will consist mainly of information given by third-party companies and thus, such issues might be displayed, that the case company had not prepared for in advance. However, giving an assignment like this to a person outside the company might result in insignificant or already known information. For the checklist's case this could mean that the checklist would consist of such issues that are either taken care of by some other company or such issues that are clear to the case company's employees already.

Another challenge in developing this type of a checklist is to make it meaningful and easy to use. The feedback from the interviewees regarding this issue was clear – the checklist should be short enough and include the main points of consideration and not all the possible pitfalls and cultural differences for example. In addition, a one-page checklist was mentioned by one of the interviewees as a perfect tool that could be held on the corner of the desk. Checklists longer than one page were considered too arduous, and they were seen as annoying rather than helpful tools.

To begin building the checklist, the interviewees' answers were revised. During the first phase the point of analysis was in the logistics criteria and supplier selection, whereas this time the best logistic practices and the potential pitfalls were highlighted. All the interviewees had some certain things that their answers very often were based on. For example, the first interviewee appeared to emphasize the importance of contracting and trust. This led to dividing the checklist into four sections: contracts, project management, regional differences and communication - each representing a point of importance that derived from the interviews. Next, a closer look is taken into each section.

#### 4.5.1 Contracts and risk management

**Contracts and risk management** were also mentioned by other interviewees as a key part of logistic operations. The case company's contracts negotiated with every part including suppliers, customers, logistic operators and other partners should be clear according to the responsibilities and possible penalties.

However, as it was stated by one of the interviewees, not every possible issue can be prepared for by contracting. This means that the contracts form the base of the risk-management, but some rare issues need to be let outside. A 10-percent refunding-rate was mentioned as a rule of thumb for contracts. This would mean that if everything about the project went wrong, the company should not be covering the costs above a reasonable business risk.

Contracts were also mentioned several times as the best tool for risk management and risk allocation. For example, if the customer seems to put high penalties on the case company for delays or damaged products, the risk should be re-allocated to the suppliers by making contracts that punish for delays. This way the case company can ensure that they do not carry the risks for another party's such as a supplier's mistakes. This also motivates the suppliers to stay within the set boundaries according to time and quality, since the penalties would make them lose the profit for the delivery.

The checklist points for the contracts and risk management-section are developed mainly from the interviewees' answers. Questions were asked about typical problems that occur when operating in developing countries and preparing to unexpected logistic problems. With all the interviewees, the conversation, at some point, led to risk management and especially contracts that can be used to avoid or re-allocate many risks.

Table 13: The contracts & risk management-section of the logistic checklist.

<b>Contracts &amp; risk management</b>	The penalties in the suppliers' contracts are on the same level with the penalties in contracts with the customer. (A supplier cannot benefit, if we do not benefit)	<input type="checkbox"/>
	For the whole delivery process, it is clear to all parties, under whose responsibility the modules are including lifts and land transportation.	<input type="checkbox"/>
	Letters of intent with quality and time constraints have been made with suppliers	<input type="checkbox"/>
	Required test score for modules is determined in the suppliers' contracts	<input type="checkbox"/>
	The customer understands their responsibility (payments, information, preparations, customs) and this is visible in the contract	<input type="checkbox"/>
	Ethical and environmental issues are covered in the contracts with suppliers and the customer	<input type="checkbox"/>
	The customer has accepted the suppliers that are used in the project	<input type="checkbox"/>
	The time taken by customs is considered in the customer contract	<input type="checkbox"/>
	Scheduled reviews with the customer on-site are planned in the contracts and in practice	<input type="checkbox"/>

As can be seen from table 13 above, most of the checklist's points are technical issues that should be mentioned in the contract with either the suppliers or the customer.

Therefore, it is logical that this section is placed at the beginning of the checklist, since a chronological filling order is very typical for this kind of a list.

As mentioned previously, the points of the checklist are almost completely derived from the interviewees' answers. Letters of intent were seen as an important thing to keep the suppliers interested in the projects and also to motivate them to produce good quality products and stick to the agreed schedules. The customer's role in the projects was also highlighted, since if the payments are not made according to the planned schedule, extra costs might occur due to the delays in the case company's own payments. Also, it was highlighted by the interviewees to take the customer along to the reviews and thus share the responsibility of noticing faults.

Finally, another thing that popped out in three out of four interviews was the time taken by customs in the target country. This time, according to the interviewees, should be ignored in the project schedule, since it is almost impossible to predict the time that the customs process might take. Another solution to the problem was to make such contracts, where the customer would be responsible for the customs process and therefore also for the modules. Warehousing costs might turn out very high, if the customs process was to take weeks or even months. Therefore, this type of preventive risk management by contracts might turn out very worthwhile for the case company.

By filling the contracts and risk management-section of the checklist, the decision maker should have gone through a holistic thought process about the contracts that have been made and what kind of effects they could have on the project deliveries. Naturally, not all possible issues can be covered by a short checklist, but these points are the ones that the interviewees, the experts on the field, came across when thinking back their own projects.

#### 4.5.2 Project management

In general, the majority of the interviewees' answers about the potential pitfalls in overseas delivery projects were related directly to **project management**. In fact, the most

common problems that the interviewees had encountered were related to either project schedules or the assembly phase, even though logistics-related problems were discussed. The results could indicate either that the questions that were asked were not precise enough to get more answers related to the delivery phase or that the logistic providers are trusted, and problems only rarely occur with their operations.

Preparation was seen as a key to avoid the problems in project schedules for example. Since most of the delays in schedules were related to either a supplier's delayed production or the delaying of the on-site assembly phase for various reasons, preparing to these issues by monitoring the actions of the suppliers and the customers was considered a potential solution.

Flat racks and the delivery platforms of the modules in general were one key interest from the case company's side. Since most of the modules do not fit into a standard container, other more expensive shipping platforms, such as flat racks, must be used. During the interviews, the use of flat racks received contradictory feedback. The project managers stated that at least the packaging of the modules would have to be extremely firm for such highly technological components to be transported without a metal container. The logistic operators were more concerned about the shipment quantities, since patches of more than 20 flat racks are nearly impossible to ship with a single carrier ship. Therefore, the patch sizes should be optimized already in the testing phase to fit the carriers and to find the optimal quantity for cost savings.

Since most of the interviewees' concerns were related to project schedules, the project management-section of the checklist (table 14) is highly focused on developing and monitoring the schedule. Other key points in the list that help the project manager to stay safe from potential pitfalls are related to warehousing the modules in the ports or at the site and organizing the packing and the transportation of the modules from the testing site to the destination.

Table 14: The project management-section of the logistic checklist.

<b>Project management</b>	The project's timetable is in its final form and presented to all parties	<input type="checkbox"/>
	Logistic provider has been selected and they are familiar with the timetable and supplier locations	<input type="checkbox"/>
	The delivery schedule to the site has been established and communicated to suppliers, customer and the logistic partner	<input type="checkbox"/>
	Testing date and location have been determined and logistics has been organized	<input type="checkbox"/>
	Packing the modules for shipment has been organized	<input type="checkbox"/>
	The warehousing and guarding of the modules have been organized	<input type="checkbox"/>
	The transportation of modules and returning of flat racks in the target country has been organized	<input type="checkbox"/>
	Suppliers are being monitored to stay within the schedule	<input type="checkbox"/>
	On-site-supervision has been planned for key activities (who, where and when)	<input type="checkbox"/>
	The customer is preparing the site for the delivery and assembly of the modules	<input type="checkbox"/>

#### 4.5.3 Regional differences

Prior to the study, the results of the interviews were expected by the author to be based on the next section, regional differences. Even though the results did not turn out as expected, a variety of regional problems was identified by the interviewees. Generally, the local problems seen as having the biggest effect on the project were related to either time-taking customs processes, local infrastructure or cultural issues such as corruption.

The local culture was mentioned to be behind many regional problems. Lies and intentional misunderstandings were said to be more than usual when compared to the Nordic business environment. According to the interviewees, these issues could occur when dealing with any local institution, whether it is the customer, the customs or a local supplier. Cultural understanding and preparation were mentioned as potential solutions for these problems that in general can be solved by using common sense and having a backup plan when necessary.

Corruption in terms of bribing officers or company representatives was mentioned as a solution to cultural issues that many western companies fall for in developing countries.

According to the interviewees, even though the local companies might use money to solve various problems, for a western company it very often brings more problems.

Entering a completely unknown developing country was done by both project managers with various experiences. First, the ease of communication and organizing things in the Nordic countries is gone when operating in the developing countries. Also, gaining the trust of local people may turn out very hard or even impossible. Therefore, the interviewees recommended to be especially careful when dealing with the local culture, since even small mistakes could cause great problems for the project.

The time-taking customs processes were already discussed in the first section. The fact that the time taken by customs should not be included in the whole project's schedule is highlighted in the developing countries. The project managers claimed that it could take weeks or even months of storing the modules in the customs without anything happening. The reasons behind these long processing times remained unclear, but the issues highlight the difficulty of operating. As a side mention by one of the interviewees, money is often used by foreign companies to deal with the customs difficulties, but again, often leads to even greater problems.

With some exceptions, the infrastructure for heavy loads in the developing countries was described as poor. Issues had occurred where the asphalt heated by the sun had turned so soft that it was dangerous to drive a heavy truck on it. Smaller roads were also considered as inaccessible by trucks of this size. Solutions to the infrastructural ranged from modifying bridges and road network to re-locating the site to be better accessible. These solutions, however, must be used only if the problem is detected too late. A general comment from the interviewees was that they wanted the infrastructure to be considered already in the sales phase to avoid modifications later. This means that the site location should be determined not only by the waste-transportation-related factors but also according to the road network-related factors.

The checklist points presented below in table 15, again, do not cover all the regional issues that can occur when operating in a developing country. However, these points are

what the interviewees found that are often forgotten or overlooked and that can cause harm to the projects.

Table 15: The regional differences-section of the logistic checklist.

<b>Regional differences</b>	The target country has been analyzed profoundly for cultural issues	<input type="checkbox"/>
	The site is logistically available for deliveries and warehousing	<input type="checkbox"/>
	The road infrastructure is ready or is modified for the land-transportation of the modules	<input type="checkbox"/>
	Customs processes of the target country have been analyzed for potential problems	<input type="checkbox"/>
	Customs process has been started and is done by someone familiar with the culture	<input type="checkbox"/>
	Actions have been taken to avoid falling to corruption in the target country	<input type="checkbox"/>
	The modules are manufactured and packed in such way that local weather conditions cannot damage them	<input type="checkbox"/>
	The contents of the modules are documented profoundly for customs	<input type="checkbox"/>
	Potential spare part deliveries are prepared for in advance	<input type="checkbox"/>
	The danger of permanent establishment in the target country has been ruled out	<input type="checkbox"/>

#### 4.5.4 Information and other issues

The flow of information was highlighted as a project success factor as well as a potential pitfall by all the interviewees several times. Several similar points about the information could have been added to the checklist, but instead, to keep the checklist brief but comprehensive, the information-section is combined with other important points that do not fit into the previous sections.

Three kinds of errors in communication were mentioned by the interviewees. The first one that was already discussed in the previous section was direct lying. Lies had been told to the interviewees several times by the suppliers, customers or other operators in the developing target countries to either cover mistakes, delays or to gain advantages. The second error-type was misunderstandings and non-agreed issues. These issues are very often understood by parties from their most beneficial aspect, thus causing disagreements.

The final form of miscommunication was the lack of information. Sometimes it might take weeks to get into contact with a supplier or the customer to get necessary information, which might delay the whole project. Maintaining contact regularly was mentioned as a good solution to the problem by one of the interviewees.

Information integration capability is mentioned by Liu & Luo (2012) as one of the three logistic capabilities of their concept. Liu & Luo describe a company's success in information integration capability as being able to effectively collect, process and share logistics information, as well as having a stable system for using the information. They also emphasize on the information integration with the suppliers and customers. Our checklist's information-related issues also emphasize the sharing of information between the customer and the suppliers since the effects of misunderstandings and information delays were reported by the interviewees to be very negative.

The case company also wanted to investigate some specific issues such as the use of flat racks in overseas projects via the interviews. They were especially interested in the flat racks' rental times and the cost structure of the modules' deliveries and thus, some points about potential issues related to them were added to the checklist. However, since the checklist cannot go too deeply into details, the previously mentioned issues are covered only from a wide perspective.

Table 16: The information and other issues -section of the checklist.

<b>Information &amp; other issues</b>	The customer has been informed about the importance of on-time payments	<input type="checkbox"/>
	A back up plan has been established for damaged products or delays in schedule	<input type="checkbox"/>
	It is clear to every part, who to contact if problems occur	<input type="checkbox"/>
	Suppliers are being monitored for hidden mistakes in product quality or tests	<input type="checkbox"/>
	The flow of information to and from the suppliers and the customer is ensured	<input type="checkbox"/>
	The documentation of feedback and problem situations has been organized	<input type="checkbox"/>
	Lifting situations are being monitored and there is a procedure for the reporting of incidents or close calls	<input type="checkbox"/>
	The rental time of flat racks is being monitored to avoid extra costs	<input type="checkbox"/>
	Standard-sized containers are used whenever possible to transport modules	<input type="checkbox"/>
	Costs of logistics have been analyzed with the logistics partner	<input type="checkbox"/>

#### 4.6 Other marks from the interviews

The open conversation during the interviews resulted in data that does not fit in either the Excel-tool or the logistics checklist. The interviewees were happy to help our case company with as much information as they were able to share, which resulted some conversations to be slightly off the topic of the thesis. Nevertheless, this information is considered valuable from the case company's point of view. Therefore, this subchapter is dedicated to concluding the issues that emerged during the interviews but cannot be applied to either of the deliverables.

First, even though already mentioned a few times in this study, the use of flat racks in overseas projects was discussed with each of the interviewees. This was done, because the case company wanted to find out information about the flat racks' rental times and cost structure as well as any experienced problems related to them. The general feedback about the use of flat racks in the projects in developing countries was negative. The interviewees were concerned for example about the **rusting** of the modules due to the hot and humid weather conditions (1), **lifting** situations that could damage the modules directly (2), **thefts** that could occur during the land transportation of the modules (3) and the **rental times** that tend to be very tight for the flat racks (4). Also, the main message from three out of four interviewees was the recommendation to avoid using flat racks in this kind of deliveries whenever possible and to favor container-type shipments.

However, also solutions to the above-mentioned concerns were proposed by the interviewees. For the rusting problem, the interviewees told that depending on the build of the module, it could be protected from the weather and splashing seawater with either tarps or a shrink wrapping. Monitoring and avoiding unnecessary lifts were seen as a key solution to the damages caused by lifting actions. Since collisions and other damages to the modules almost always happen during the lifting situations, a special emphasis on those short moments was recommended by the interviewees.

To avoid thefts and vandalism, the interviewees recommended to avoid placing detachable parts to the module shipments, since those could arouse stealing interests especially

in the developing countries. Also, barriers for vision such as opaque (non-see-through) covering materials should be used to avoid revealing the modules to direct sunlight as well as to the eyes of possible thieves. Finally, the rental times of the flat racks, as already mentioned in this study, should be monitored and modules should be lifted off the flat racks as soon as they arrive to the target port.

The build of the containers that the modules are transported in was in general a point of concern for all the interviewees and the case company. The discussion flowed about the costs of flat racks that could rise, especially if nothing could be loaded above them. Also, if the modules could not be coated well enough to sustain the weather conditions on the deck, the costs that would occur for underdeck-type of deliveries should be noted early on to avoid surprise costs in the shipping phase.

The use of standardized containers as a main delivery platform was suggested by the interviewees to ensure that the valuable items would be transported in a locked and dry place. However, for most of the modules, the packing into a standardized container is not possible due to the oversized parts that they include. Therefore, an open-top platform such as a flat rack is necessary for the transportation of such modules.

For the logistics operations in the target country, suggestions were given especially by the project managers. According to them, local logistics providers often know their country the best and should therefore be preferred for example when considering the delivery of the modules from the port to the site. These local operators were told to have better knowledge on the country's infrastructure, have enough equipment to deliver the large amounts of modules and to possess the "get things done"-attitude. However, when operating with these local logistics suppliers, constant monitoring should be done to prevent any accidents or attempts of hoax.

The potential of cost savings that could be achieved through consolidation of shipments was discussed with the logistics operators as requested by the case company. A general belief was that cost savings could be achieved by gathering modules manufactured in nearby countries first to one place to organize a consolidated shipment to the target port. This

assumption was, however, proved wrong by the interviewees. According to them, the minor cost savings achieved by consolidation would be negated by the warehousing of the modules in the port and the difficulties of handling large amounts of containers in the target port. However, one of the logistics operators pointed out that shipments can be combined even if they originate from different ports. Also, when shipping from smaller ports, usually the shipments are automatically consolidated in a bigger port where the actual ocean carriers stop. Thus, by declaring the shipments as a large shipment originating from different countries, cost savings could be achieved, and the modules would still most likely be transported simultaneously on the same cargo ship.

For the pricing of the transportation phase, the logistics operators were on the same road. Both stated, that quite accurate bids on the deliveries can be calculated once the size (dimensions and weight), destination and the project timetable are known. In addition to this, pictures for oversized modules are necessary to determine the usage of space in the cargo ship and to estimate the difficulty of moving the module by crane or forklift. The answers show that even the deliveries of the more complex modules can be standardized for effective quotation without too specific product information.

Overall the interviewees appeared to emphasize three things behind that affect the logistics phase from many different angles. First, the flow of information was highlighted several times by each interviewee. Whether it is a project-delaying problem that has occurred or a change in product specifications, the information should be effectively shared with all the parts that are involved. Different platforms are used for this type of information sharing, such as software, email or direct phone calls. Whichever method is chosen, it should be ensured that every part has access to the needed information.

Second, the contracting was emphasized as the backbone of all project actions including the logistics phase. Informative contracts are crucial when for example determining the responsibilities in problem situations. Also, the contracts can be used to distribute business risk to either suppliers or the customer. In the logistics phase the contracts are used to determine the time boundaries for deliveries as well as the responsibilities for customs processes and product insurances.

Finally, trust was the third issue that was touched in each of the interviews. In general, trust put into suppliers and customers was seen as a positive feature. However, the level of reliability may, according to the interviewees, vary a lot depending on the size and the location of the collaborator. Issues such as direct lying were mentioned as quite typical and harmful methods to cover the problems in the process, especially in the developing countries. Therefore, attention should be paid on which parties the case company should trust and at what level. No general rule of thumb, however, was given by any of the interviewees about how to measure the reliability of a supplier. Our Excel-tool takes into account the history of the supplier's reliability, but the amount of data regarding trust has to be gathered by experience after the first projects. Therefore, the main ways to measure the suppliers' reliability are the suppliers' references and supplier audits.

## 5 CONCLUSIONS

This study has been made in cooperation with a Finnish waste-to-energy business aiming to have their first projects in the developing countries in 2019 and 2020. The limited information that the case company had about their suppliers' logistics capabilities, and how they affect the upcoming project deliveries, created the need for a supplier comparison tool.

To answer the research question one and two about the logistics criteria, a literature review on the topics of supplier selection and project logistics was conducted. Based on the literature and the qualitative interviews of two project managers and two logistics operators, the logistics criteria for supplier comparison were developed. To apply the logistics criteria, a Microsoft Excel-based application was developed.

Analytic Hierarchy Process (AHP) developed by Thomas Saaty (1980) was applied into the Excel-tool to create different delivery scenarios and retrieve weights for the proposed logistics criteria. The developed Excel-tool was finally tested as described in subchapter 4.4.1. Example suppliers with fixed grades for different criteria were used to describe the variance between the suppliers for the first module in the tool, air blowers. The tool proved to be effective in both, displaying the best and worse-in-category -values and finding the logistically most optimal supplier according to the set criteria weightings.

The Analytic hierarchy process, also, was found to be a good choice as the method behind the tool. The various scenarios created by differently filled AHP-matrixes work fluently with the excel tool, allowing the user to find the optimal suppliers for achieving any type of a project goal. Also, by adjusting the weights, the decision maker may change the focus of the project and thus, find logistically more optimal suppliers for modules. Therefore, using the tool requires knowledge of the company's preferences as well as the project's goals from the decision maker.

On the contrary, applying the logistics criteria might turn out difficult for the case company, if there is not enough information available. Evaluating suppliers using the Excel tool requires wide knowledge of both, the company's values and the supplier base. Also, most of the criteria are related to the case company's supplier audit sheet, which makes conducting supplier audits necessary before the logistics criteria may be effectively addressed. These difficulties may be reduced by investing time into inspecting and auditing the suppliers before starting the comparison.

Another issue related to the criteria is the way they are built. With mostly qualitative, verbal descriptions, determining the differences between similarly graded suppliers might be difficult. This type of separation would require the decision maker to determine the importance between the sub-criteria which the actual criteria are formulated of.

The study contributes to the case company's supplier selection decision making process in many ways. Out of the three traditional factors of decision making, cost, quality and delivery, the logistics aspect of this study focuses the most on the delivery-factor. However, the logistics criteria set, that was developed during this study, takes also quality- and cost-related issues well into account.

The customers' expectations also affect the final supplier choice. For some customers the product quality might be the most important issue, whereas another customer might want to speed up the delivery and have the plant delivered as fast as possible. For these reasons, it is impossible to measure the actual effect that the tool has on the case company's decision-making process. However, once implemented, the tool may be adjusted to suit the exact needs of each project and the information provided by the logistics supplier comparison tool may be applied as any size of a part of the entire supplier selection decision making process.

To address the research question three, the interviewees' answers were processed through again to find out about the experiences on logistics related pitfalls and best practices in the developing countries. The points were then gathered into a four-section checklist

covering the topics of contracts and risk management, project management, regional differences and the flow of information with a couple of other, non-categorized points.

Since there are no similar logistics-oriented supplier evaluation criteria sets proposed in the literature, the functionality of the criteria set in this form is yet to be proven. This applies also to the checklist, since it has been developed to combine both, the case company's own logistics interests and the general best practices in the field of logistics. The case company's future projects will show whether the criteria or the checklist need modifications to be more suitable for applying in practice. Due to this, the actual findings of this study remain unreliable and require further testing.

The logistics criteria, however, may be tailored to suit the needs of other companies as well. Since this form of the criteria emphasizes the large, international project deliveries, re-evaluation of the logistics criteria is needed to make them suit other purposes such as sourcing for a manufacturing business. The logistics checklist is also completely developed for the case company's purposes, although the points are gathered from people with years of experience in international project logistics. Therefore, with adjustments, the checklist may, as well, be implemented as a part of other companies' operations.

From the case company's point of view, the two developed tools and the information retrieved through this study, represent a scientifically studied backbone for their decision-making process. By using these tools, the case company's decision makers will be able to explain the logistics-related reasons behind their decisions in an effective way.

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# APPENDICES

The image shows a screenshot of an Excel spreadsheet with an orange background. At the top, there are three columns: 'Site location', 'Delivery type / Scenario', and 'RUN'. The 'Site location' dropdown menu is open, showing options like 'Vietnam', 'Kenya', 'AHP Normal', 'AHP Custom', 'Best product quality & service level', 'Cost-effective', 'Value-based/Ethical/Environmental', and 'Customized'. The 'Delivery type / Scenario' dropdown menu is also open, showing the same options. The 'RUN' button is labeled 'Run New Project'. Below these are two sections: 'Manage site locations' and 'Manage suppliers'. The 'Manage site locations' section has 'Add new site location' and 'Remove site location' buttons. The 'Manage suppliers' section has 'Add new supplier' and 'Remove supplier' buttons. Three numbered callouts (1, 2, 3) point to the 'Site location', 'Delivery type / Scenario', and 'RUN' buttons respectively. Each callout has a list of instructions and tips. For example, callout 1 says 'The selected location is highlighted with blue' and 'You may add a new location or delete an existing location using the buttons on the right'. Callout 2 says 'The delivery types are described in their own tabs "AHP Normal ...AHP Custom"' and 'You can create customized weightings in the AHP custom - tab'. Callout 3 says 'The button will create a new tab for your project' and 'You will be prompted to choose whether you want to sort out only the best suppliers or to show all available suppliers'. There are also general instructions for the 'Manage site locations' and 'Manage suppliers' sections.

Site location	Delivery type / Scenario	RUN
Vietnam	Normal	Run New Project

**Manage site locations**

Add new site location    Remove site location

**Manage suppliers**

Add new supplier    Remove supplier

**1** Select the location of the project

- The selected location is highlighted with blue
- You may add a new location or delete an existing location using the buttons on the right
- Locations 'Kenya' and 'Vietnam' are defaults and cannot be deleted

**2** Select the delivery type to get the right weights for the criteria.

- The delivery types are described in their own tabs "AHP Normal ...AHP Custom"
- You can create customized weightings in the AHP custom - tab
- You can modify the presets by re-filling the AHP matrixes in the tabs

**3** Click "Run New Project" to create a new spreadsheet for your project

- The button will create a new tab for your project
- You will be prompted to choose whether you want to sort out only the best suppliers or to show all available suppliers
- The best suppliers and the best score are displayed with shades of green, the worst ones with

- Use these buttons to add and remove site locations  
- Locations 'Kenya' and 'Vietnam' are defaults and cannot be deleted  
- Do not forget to rate the suppliers according to the delivery time to the new site location

- Use these buttons to add and remove suppliers from the database  
- The buttons will guide you through the process, do not forget to rate the supplier after you have added them  
- "Component categories" are marked with "stars", please do not remove them

APPENDIX 1: Excel tool's starting tab

	A	B	C	D	E
1	<b>Site location</b>	<b>Delivery type / Scenario</b>	<b>RUN</b>		
2	Kenya	Normal	Run New Project		
3	Vietnam	Fastest delivery / Higher cost			
4		Best product quality & service level			
5		Cost-effective			
6		Value-based / Ethical / Environmental			
7		Customized			

↑

Select the location of the project

**1**

- The selected location is highlighted with blue
- You may add a new location or delete an existing location using the buttons on the right
- Locations 'Kenya' and 'Vietnam' are defaults and cannot be deleted

↑

Select the delivery type to get the right weights for the criteria.

**2**

- The delivery types are described in their own tabs "AHP Normal ...AHP Custom"
- You can create customized weightings in the AHP custom - tab
- You can modify the presets by re-filling the AHP matrixes in the tabs

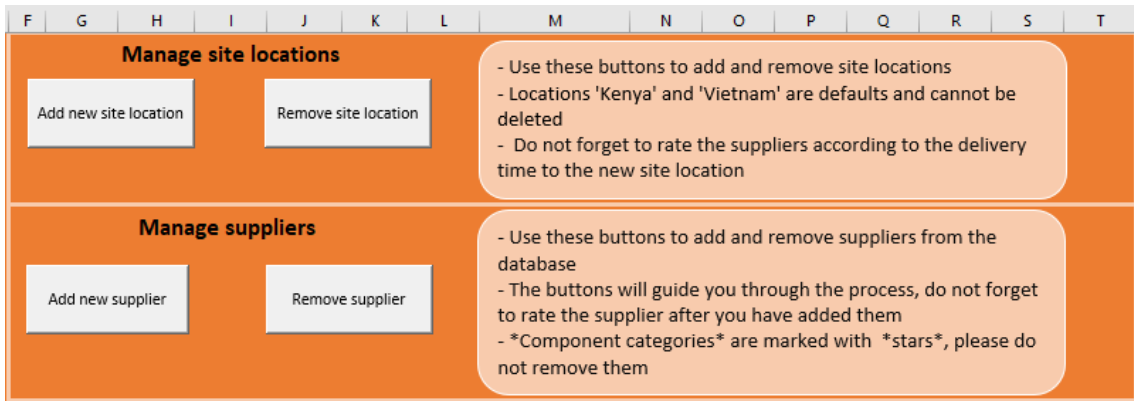
↑

Click "Run New Project" to create a new spreadsheet for your project

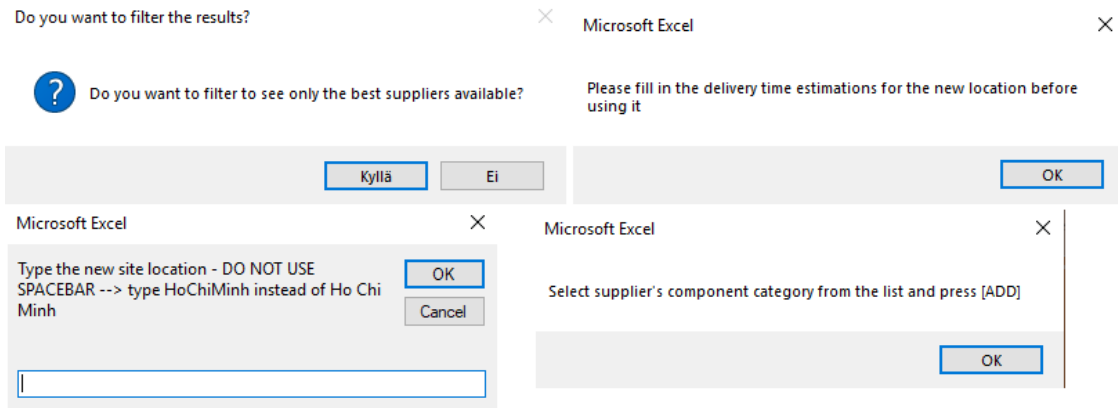
**3**

- The button will create a new tab for your project
- You will be prompted to choose whether you want to sort out only the best suppliers or to show all available suppliers
- The best suppliers and the best score are displayed with shades of green, the worst ones with

APPENDIX 2: Left section of the Excel tool's starting tab



APPENDIX 3: Right section of the Excel tool's start-tab



APPENDIX 4: Examples of messages generated by the Excel tool

Product area / Function key	Example Supplier	Category	MODULE(s)	Country	Homepage	Location	Service Capability	Flexibility Capability	Total landed cost	Regulations	DelTime Kenya	Delivery reliability	TOTAL
<b>Air blowers</b>													
Air blowers	Supplier 1	Line	Primary Air Unit Secondary Air Unit Tertiary Air Unit Re-circulation	Finland		8	9	7	1	6	1	8	41
Air blowers	Supplier 2	Line	Primary Air Unit Secondary Air Unit Tertiary Air Unit Re-circulation EG Fan Unit	Sweden		7	8	8	2	5	1	8	40
Air blowers	Supplier 3	Line	Primary Air Unit Secondary Air Unit Tertiary Air Unit	Poland		5	7	5	5	5	4	7	39
Air blowers	Supplier 4	Line	Fans	Thailand		7	2	4	9	4	8	3	38
Air blowers	Supplier 5	Line	Fans	Kenya		4	4	3	8	7	9	3	40
<b>Boiler pressure parts + Heat loop</b>													
Boiler pressure parts + Heat loop	Supplier 1	Line	Combustion chamber Retrofocoy Empty Passes Steam Drum Boiler Bank Super Heaters Economizers	Estonia		8	2	3	4	2	1	2	23
Boiler pressure parts + Heat loop	Supplier 2	Line	Combustion chamber Retrofocoy Empty Passes Steam Drum Boiler Bank Super Heaters Economizers	Thailand		1	2	6	6	5	7	3	39
Boiler pressure parts + Heat loop	Supplier 3	Line	Combustion chamber Retrofocoy Empty Passes Steam Drum Boiler Bank Super Heaters Economizers Steam drum FGI	Poland		5	2	8	3	2	3	7	33
Boiler pressure parts + Heat loop	Supplier 4	Line	Combustion chamber Retrofocoy Empty Passes Steam Drum Boiler Bank Super Heaters Economizers Steam drum	Poland		9	2	3	4	5	3	7	36
Boiler pressure parts + Heat loop	Supplier 5	Line	Steam drum	Romania		2	6	5	4	5	4	2	31
Boiler pressure parts + Heat loop	Supplier 6	Line	Steam drum	Estonia		4	1	3	4	9	2	5	30
Boiler pressure parts + Heat loop	Supplier 7	Line	Boilers etc.	Denmark		6	2	3	4	2	5	7	31

APPENDIX 5: Overview of the database-tab in the Excel tool

Product area / Function key	Example Supplier	Category	MODULE(s)	Country	Homepage	Location	Service Capability	Flexibility Capability	Total landed cost	Regulations	DelTime Kenya	Delivery reliability	TOTAL
<b>Air blowers</b>													
Air blowers	Supplier 5	Line	Fans	Kenya		0,21098	0,1636453	0,372542119	0,313058693	0,2824163	4,4294505	0,631572246	6,4037
Air blowers	Supplier 4	Line	Fans	Thailand		0,36922	0,0818227	0,496722825	0,352191029	0,1613808	3,9372893	0,631572246	6,0302
Air blowers	Supplier 3	Line	Primary Air Unit Secondary Air Unit Tertiary Air Unit	Poland		0,26373	0,2863793	0,620903531	0,195661683	0,2017259	1,9686447	1,473668573	5,0107
Air blowers	Supplier 2	Line	Primary Air Unit Secondary Air Unit Tertiary Air Unit Re-circulation EG Fan Unit	Sweden		0,36922	0,3272907	0,99344565	0,078264673	0,2017259	0,4921612	1,684192655	4,1463
Air blowers	Supplier 1	Line	Primary Air Unit Secondary Air Unit Tertiary Air Unit Re-circulation	Finland		0,42196	0,368202	0,869264944	0,039132337	0,2420711	0,4921612	1,684192655	4,117
<b>Boiler pressure parts + Heat loop</b>													
Boiler pressure parts + Heat loop	Supplier 2	Line	Combustion chamber Retrofocoy Empty Passes Steam Drum Boiler Bank Super Heaters Economizers	Thailand		0,052745	0,08182267	0,745084238	0,234794019	0,20172594	3,44512816	0,631572246	5,3929
Boiler pressure parts + Heat loop	Supplier 7	Line	Boilers etc.	Denmark		0,316471	0,08182267	0,372542119	0,156529346	0,08069038	2,46080583	1,473668573	4,9425
Boiler pressure parts + Heat loop	Supplier 3	Line	Combustion chamber Retrofocoy Empty Passes Steam Drum Boiler Bank Super Heaters Economizers Steam drum FGI	Poland		0,263726	0,08182267	0,99344565	0,11739701	0,08069038	1,4764835	1,473668573	4,4872
Boiler pressure parts + Heat loop	Supplier 4	Line	Combustion chamber Retrofocoy Empty Passes Steam Drum Boiler Bank Super Heaters Economizers Steam drum	Poland		0,474707	0,08182267	0,372542119	0,156529346	0,20172594	1,4764835	1,473668573	4,2375
Boiler pressure parts + Heat loop	Supplier 5	Line	Steam drum	Romania		0,10549	0,245468	0,620903531	0,156529346	0,20172594	1,96864466	0,421048164	3,7198
Boiler pressure parts + Heat loop	Supplier 6	Line	Steam drum	Estonia		0,210981	0,040911333	0,372542119	0,156529346	0,36310669	0,98432233	1,052620409	3,181
Boiler pressure parts + Heat loop	Supplier 1	Line	Combustion chamber Retrofocoy Empty Passes Steam Drum Boiler Bank Super Heaters Economizers	Estonia		0,421962	0,08182267	0,372542119	0,156529346	0,08069038	0,49216117	0,421048164	2,0268

APPENDIX 6: A project run with the Excel tool without filtering

Product area / Function key	Example Supplier	Category	MODULE(s)	Country	Homepage	Location	Service Capability	Flexibility Capability	Total landed cost	Regulations	DelTime Kenya	Delivery reliability	TOTAL
<b>Air blowers</b>													
Air blowers	Supplier 5	Line	Fans	Kenya		0,210981	0,16364533	0,372542119	0,313058693	0,28241632	4,42945049	0,631572246	6,4037
<b>Boiler pressure parts + Heat loop</b>													
Boiler pressure parts + Heat loop	Supplier 2	Line	Combustion chamber Refractory Empty Passes Steam Drum Boiler Bank Super Heaters Economizers	Thailand		0,052745	0,08182267	0,745084238	0,234794019	0,20172594	3,44512816	0,631572246	5,3929
<b>Burners</b>													
Burners	Supplier 7	Line	Start-up burners	Finland		0,263726	0,122734	1,117626357	0,078264673	0,04034519	0,98432233	1,052620409	3,6596
<b>CEMS</b>													
CEMS	Supplier 3	Common & Auxiliary system	CEMS	Finland		0,316471	0,08182267	0,124180706	0,156529346	0,36310669	0,98432233	1,473668573	3,5001

APPENDIX 7: A project run with the Excel tool, filtering the best suppliers