Masterthesis

Purchasing & Supply Management

Designing a supplier performance evaluation scheme.

A qualitative design case study based on literature & workshops.

UNIVERSITY OF TWENTE.

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Abstract

In the past, much has been written about supplier evaluation in the literature. In this study, a new supplier evaluation scheme is designed to monitor the performance of suppliers. The supplier evaluation process was carried out by using the Analytical Hierarchy Process with the associated pairwise comparison to determine the weighting factors of criteria. Furthermore, a second dimension is added to the supplier evaluation scheme that examines the reasons why a supplier performs in a certain way. This provides valuable information to draw up a good supplier development plan to improve supplier performance. Finally, a good supplier development plan results in action points on which suppliers must improve. For example, the case Easy Sanitary Solutions is used for applying the supplier evaluation scheme.

Keywords: supplier evaluation; supplier development; design case study; supplier performance; analytical hierarchy process.

Management summary

The case company for this research is Easy Sanitary Solutions: the European market leader of drain systems and sanitary solutions. In order to remain the leadership role in the market, the company strives for the best quality and wants to bring the most innovative products to the market that is as easy as possible to install for the end user. Due to an annual growth of 20% of ESS, various challenges have arisen in the field of quality management and efficiency within the supply chain. The growth of the company also results in the fact that suppliers must grow in order to guarantee and maintain the business strategy of ESS. This has created an increasement in need for mapping the performance of current suppliers.

In order to map supplier performance, a new supplier evaluation scheme needs to be designed. At first, information was gathered through a literature research regarding supplier evaluation in a manufacturing company. Also, workshops are conducted with business decision makers of ESS to gather information in order to design the new supplier evaluation scheme. In these workshops, information was gathered regarding criteria, weighting factors and the actual performances of suppliers. More importantly, it is interesting that the criteria *support* increases popularity in not only literature but also in the workshops. The information gathered from workshops and the literature are shown in

Table 1. The complete supplier evaluation model including anchor phrases and scores are shown in Appendix I. This mainly shows that quality and delivery are the most important criteria when assessing suppliers. After many years, it is interesting that these criteria are still the most important on which suppliers are assessed.

Table 1. Results of the pairwise comparison workshop

Criteria	**Weight**	**Sub criteria**	**Weight**	**Effective weight (criteria weight * sub criteria weight)**
Quality	42%	Acceptance ratio	40%	0.42 * 0.40 = ***16.8%***
		Quality control at the supplier	60%	0.42 * 0.60 = ***25.2%***
Costs	14%	Product price	100%	0.14 * 1.00 = ***14%***
Delivery	21%	Lead time	50%	0.21 * 0.50 = ***10.5%***
		On time delivery	50%	0.21 * 0.50 = ***10.5%***
Support	14%	Supplier accessibility	20%	0.14 * 0.20 = ***2.8%***
		Quality of communication	80%	0.14 * 0.80 = ***11.2%***
Innovativeness	9%	Technical capability	67%	0.09 * 0.67 = ***6%***
		Knowledge/patents	33%	0.09 * 0.33 = ***3%***
Total	**100%**		**100%**	**100%**

Furthermore, suppliers are assessed by using the supplier evaluation scheme shown in Table 17. As a result, it lists the top 25 suppliers of ESS based on performance. The results of this assessment can be seen in Figure 13. In Figure 13, the results of supplier performance shown in Figure 12 are divided into three groups; saying goodbye to the supplier, the supplier must improve and the group with high-performing suppliers. ESS has only one supplier which is located in the group "to say goodbye to" who performs poorly on several criteria. Additionally, a large group of suppliers need to implement a number of improvements in order to meet the ESS standards. In conclusion, ESS has a lot of work to do to ensure the quality of its products.

Final score	*Action*
Say goodbye (0-60 points)	Supplier 70
Needs improvement (61-80 points)	Supplier 1, 2, 13, 14, 17, 22, 27, 29, 32, 34, 43, 50, 58 & 65
Good performance (81-100 points)	Supplier 5, 8, 11, 12, 18, 24, 35, 45, 47 & 74

Figure 1. Suppliers divided into three groups based on Table 17

In order to improve supplier performance, actions have been proposed to ensure that the supplier development process runs smoothly. By adding a second dimension, comparing the core suppliers of ESS, a better answer can be given these core suppliers can improve themselves in order to maintain the demanded quality by ESS. These reasons, why a supplier act in a certain way, are indicators of improvement points for the supplier. This group of suppliers are the second sources of ESS. Second sources are supplier that can produce each other's products when necessary. This group is compared with each other because they supply the core materials in high volumes for ESS. In addition, it is important that these suppliers can learn from each other in order to raise the core supplier portfolio to a higher level. The urgency to compare core suppliers stems from the mutual dependence on supplier and ESS. These suppliers namely supply the most important and most parts to produce the products that contain the largest share of the turnover. It is striking that all suppliers score poorly on the criterion delivery. The cause is probably the tight scheduling of deliveries by ESS and the actual late deliveries by suppliers. Therefore, a misconception can be found in the planning between ESS and its suppliers. To solve this, ESS should communicate more intensively with their suppliers. It is important that suppliers learn from each other by connecting them to each other. ESS needs to indicate the pain points on which they need to improve. This will result in a more efficient supply chain for both ESS and its suppliers.

To conclude, the implementation of the supplier evaluation process will lead to more efficiency in the supply chain. Additionally, the new supplier evaluation scheme ensures a clear overview of the current performance of suppliers. In order to improve the performance of suppliers a good supplier development plan is needed. Through a good supplier development, the supplier portfolio will raise to a higher level. In order to increase supplier performance, concrete action points must be drawn up for suppliers that clearly state what a supplier needs to improve and how suppliers can achieve this. The process of supplier management will have a positive effect on the relationship between buyer and supplier with the strive to perfectionism their performances. In short, it is important to continuously perform the supplier evaluation in order to demand a consistently high level from suppliers.

Preface

This master thesis is the final step in obtaining my degree in Business Administration (Msc) at the University of Twente. Writing this master thesis would never have succeeded without the help of colleagues and supervisors in this process. There are many people who have contributed to this process and helped me design a new supplier evaluation scheme.

In particular, I would like to thank René Kroeze & Erik Grootenhuis for providing me all the feedback & support during the process. Moreover, I would like to thank the business decision makers of ESS that have contributed and helped me a lot during the analysis.

Furthermore, I would like to thank my supervisor Holger Schiele in particular for the feedback and active thinking during the research process. In addition, it is special to mention that ESS and the University of Twente may enter into a collaboration in an innovation project. Hopefully this will lead in a good cooperation for both parties. Also, I want to thank Mr. de Visser for the constructive and extensive feedback that was a good addition to Mr. Schiele's feedback.

I proudly present you my graduation assignment and hopefully you will enjoy reading this master thesis.

Mitchel van der Kolk

Enschede, 2019

Table of contents

List of figures

List of tables

List of abbreviations

AHP	Analytical Hierarchy Process
ESS	Easy Sanitary Solutions
CSR	Corporate social responsibility
IoT	Internet of Things
JIT	Just in Time
KPI	Key performance indicator
MCDM	Multi criteria decision-making
NPD	New product development
SME	Small and medium-sized enterprise
SMO	Supply management orientation

1. Introduction to Easy Sanitary Solutions and the needs for supplier evaluation

1.1 Company description: ESS is the inventor of the bathroom drain

Easy Sanitary Solutions (ESS) is a Dutch company that has been offering sanitary solutions since 1928 and it corporate office is currently located in Oldenzaal. Twenty years ago, the brothers Keizers turned the core business into assembling drain solutions. Since then, the company has gradually grown to become the market leader for drain systems and sanitary solutions. Nowadays, ESS can be defined as a small and medium-sized enterprise (SME). The assembly takes place in Bad Bentheim (Germany) and the development of products is realized in Oldenzaal (the Netherlands). In the last 15 years, the company has become well-known through its invention of the bathroom drain as a drain solution. Customers of ESS are mainly wholesalers. For example, ESS uses 1 distributor to serve the sales market in the Netherlands. In other countries, products are sold to wholesalers who are selling to plumbers.[1]

ESS mainly assembles drainage products, of which there are 1650 articles in their assortment. Thereby, ESS sells a hybrid drain solution where a lifetime warranty is given. The hybrid drain solution is a shower drain with a slope and seal that results in an efficient and effective placement of the drain through the plumber. Lastly, ESS sells also bathroom accessories toilet accessories to wholesalers. However, this is a relatively low number compared to the drain solutions.

Furthermore, ESS is the European market leader of drain systems and sanitary solutions. The organization has achieved this by applying an interesting strategy. ESS strives to produce innovative solutions for the end user with the best quality products. Because the level of end users (such as plumbers) is decreasing due to a tight labour market, ESS wants to develop innovative products that are as easy to install with the best quality. For the reason that product quality is important to the end customer of ESS.

As a result of international expansions of the sales market to various areas such as Europe, North America, and the Middle East, ESS has experienced a gigantic growth. The market in which ESS is most active, is currently the European market. However, in the upcoming years the focus will increasingly shift to America and the Middle East. In recent years, the company grows annually by around 20%.

[1] See https://www.easydrain.nl/over-ess/

The growth of ESS creates new challenges for the organization that needs to be resolved. Automatization of the production process is a hot item within the organization. In doing so, the organization is very focused on making improvements into the supply chain in order to optimize the process. Especially, the focus on quality management is important for ESS. In the past years, suppliers have also had to grow with ESS to meet the entire need. This has always originated and grown in a very natural way. This has resulted in good long-term relationships with the suppliers of ESS where people have a lot of trust in each other.

However, due to the expected growth of ESS in the upcoming years, suppliers are expected to maintain delivering the same quality of products. Otherwise, this can cause many bottlenecks in the supply chain of ESS. It is of great importance that the performance is measured in order to guarantee the quality of the products in the future. In addition, it is important to take suppliers to a higher level in order to come up with innovative solutions for the end user in the long term.

1.2 Supplier evaluation: the importance of supplier evaluation for ESS

Supplier evaluation is one of the most vital actions of companies in a supply chain.[2] Selecting and working with the wrong supplier could be enough to deteriorate the whole supply chain's financial and operational position. In today's highly competitive, global operating environment, it is impossible to produce low cost, high quality products successfully without satisfactory suppliers.[3] For example, ESS is focussing on regional suppliers to ensure quality, fast delivery and good communication. Therefore, it is unnecessary to require a code of conduct for suppliers because of the legal rules in the Netherlands and Germany. However, the above factors for regional suppliers, among others, can still be improved considerably with ESS.

In recent years there has been an increase in suppliers that brings a new complexity. For example, there are complications of maintaining good product quality and delivery reliability. Within the organization there is an idea about the performance of suppliers, but this is not yet analysed on the basis of data. As a result of a growing organization, it is becoming increasingly important to have suppliers on which to build on and in which there is a lot of trust. That is why it is important to measure the performance of suppliers and gain insight into whether suppliers need to improve or perhaps have to say goodbye.

[2] See (Tahriri, Osman, Ali, Yusuff & Esfandiary, 2008) p.2.
[3] See (Vokurka, Choobineh & Vadi, 1995), p.107.

In this research, the subject supplier evaluation is derived from the goal of improving the collaboration between ESS and their suppliers. As mentioned before, making a supplier evaluation scheme will improve the availability of information for decision making units. A supplier is assessed by an evaluation scheme in order to map out the performance of all suppliers. [4] In the end, this research will describe a supplier evaluation scheme for a manufacturing company in Germany. This supplier evaluation model will be designed via the analytical hierarchy process (AHP). The AHP is described in detail in Chapter 3.

1.3 Research outline: Designing a supplier evaluation scheme in order to measure supplier performance

In order to make a supplier evaluation scheme, there will be looked at which criteria are important according to the literature and business decision makers of ESS. The need for evaluating supplier performance derives from improving supplier performance and the relationship between ESS and the supplier. Therefore, the research goal of developing a supplier evaluation scheme leads to the following research question:

"How should Easy Sanitary Solutions design and implement a supplier evaluation scheme in order to monitor the performance of suppliers?"

In order to answer the central research question, three sub questions need to be answered:

1. *How does a perfect supplier evaluation model look like according to the literature?*

The first sub-question will be answered by conducting a literature review to define the importance and criterion for making a supplier evaluation scheme. The literature review provides insight into which method can be used to design a supplier evaluation model. Therefore, it is important to draw up a list of criteria that, according to the literature, is important for assessing suppliers. Also, it is important to see which weights were previously based on criteria. This indicates which criteria are the most important to take into account when assessing suppliers.

2. *How does a perfect supplier evaluation model look like according to the business decision makers of Easy Sanitary Solutions?*

[4] See (De Boer, Labro, Morlacchi, 2001), p.5.

The second sub-question will be answered by conducting a workshop with business decision makers of ESS in order to map the wishes of ESS for evaluating supplier performance. After the workshop, it is determined on which criteria suppliers must be assessed in order to measure the performance of suppliers. In addition, the importance is indicated per criteria to make a ranking of criteria.

3. *How do suppliers of ESS score on the designed supplier evaluation model?*

The last sub-question will be answered by conducting individual interviews with business decision makers of ESS. In order to determine the performance of the suppliers, interviews are conducted with business decision makers. Thereby, the interviews will provide a clear insight into the performance of suppliers based on criteria determined by the literature review and workshops. So, the performance indicators in the supplier evaluation model will consist of a combination of wishes of ESS and the literature. Lastly, the results of the interviews will be combined in one table with the final scores of all suppliers to give an overview for the performance of all suppliers. The general research approach for researching supplier evaluation at ESS is given in figure 1.

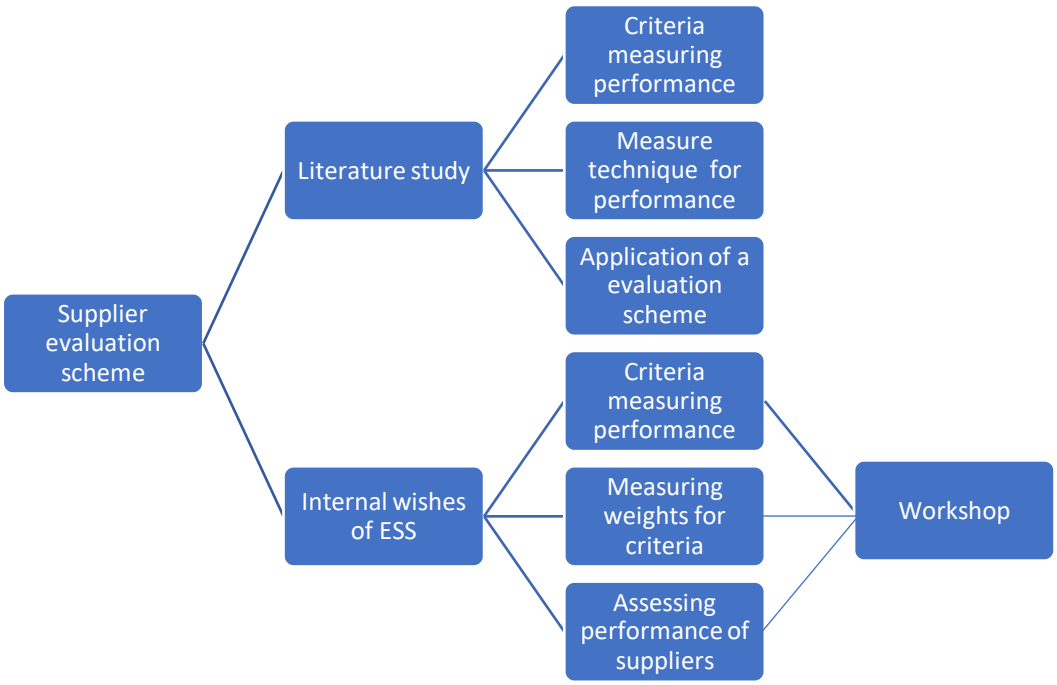

Figure 2. The general approach for researching supplier evaluation at ESS

1.4 Thesis overview

In chapter 1, an introduction is given for assessing supplier performance via a supplier evaluation model. After that, in chapter 2 a literature review will be conducted for supplier evaluation. Here, the importance of supplier evaluation and the method for evaluating suppliers will be described in detail. Thereby, the most important criteria will be assessed according to the literature. The literature review will give an overview of how a supplier evaluation scheme should look like. In chapter 3, the methodology of this research will be described. This chapter explains why workshops and interviews are used to design a supplier evaluation scheme. In chapter 4, the results of the workshop and interviews will be given which results in a supplier evaluation scheme. Therefore, the results that comes from the literature and the workshop will be combined to complete the supplier evaluation scheme. In chapter 4, an overview will be given of the performance of all suppliers. In chapter 6, the limitations of this research will be discussed. Thereby, the contribution to the academic literature will be reviewed. Lastly, in chapter 7, the conclusion of this research will be described in detail which answered the central research question.

2. Literature: analysing multiple existing studies for evaluating suppliers for a manufacturing company

2.1 Definition of supplier evaluation scheme

First of all, it is important to describe the term supplier evaluation in order to get a clear picture of the meaning of this term. In addition, it is good to describe why supplier evaluation is important for a company like ESS. The first step is to perform a literature study. This literature study will provide an in-depth insight into the supplier evaluation criteria, measurement techniques and the difficulties in implementing a supplier evaluation scheme.

In general, much has been written about evaluating supplier performance and selecting the best supplier. The studies of Dickson (1966)[5] and Weber (1991)[6] are the foundation of many recent studies in the field of supplier evaluation. Supplier evaluation can be described as "a tool that used to measure and monitor current suppliers for their overall performance."[7] Especially in purchasing departments, evaluating suppliers is a continuous process which has been one of the critical responsibilities for the purchasing manager. According to Tahriri et al. (2008) supplier selection and evaluation is one of the most critical activities of purchasing management in supply chain. Supplier selection is a complex problem involving qualitative and quantitative multi-criteria.[8] A supplier is assessed by an evaluation scheme in order to map out the performance of all suppliers.[9] In order to map the performance by an evaluation scheme, suppliers are assessed on various criteria in order to obtain the best possible overall picture of the performance of suppliers. [10] In chapter 2.3, the criteria and evaluating method will be described in more detail for designing a supplier evaluation scheme.

Thereby, there are several reasons to monitor performance of suppliers. According to Elanchezhian et al. (2010), there are three reasons for the need for measuring supplier performance. [11] Namely, increasing performance visibility, uncover and remove hidden waste and cost drivers in the supply chain and to improve supplier performance. [12] Also, the supplier evaluation will help to monitor the best performing supplier in order to develop a relationship where there is a high dynamic for innovation and the supplier is able to react

[5] See (Dickson, 1966) p.1.
[6] See (Weber, Current & Benton, 1991) p.1.
[7] See (Bruno, Esposito, Genovese & Passaro, 2012) p.1.
[8] See (Tahriri, Osman, Ali, Yusuff & Esfandiary, 2008) p.2.
[9] See (De Boer, Labro, Morlacchi, 2001), p.5.
[10] See (Narasimhan, Talluri & Mendez, 2001) p.2.
[11] See (Elanchezhian, Ramnath & Kesavan, 2010) p.2.
[12] See (Elanchezhian, Ramnath & Kesavan, 2010) p.2.

fast at market requirements. [13] Furthermore, evaluating supplier performance gives a better insight in supply management orientation (SMO) which positively influence the relationship between buyer and supplier.[14] Especially, when the buyer-supplier relationship is based on the long term, an effective supply chain of a company through good supplier evaluation creates one of the strongest barriers to entry for competitors.[15]

According to Alkahtani et al. (2019), the process of supplier evaluation always starts with the objective to monitor supplier performance in order to improve the buyer-supplier relationship.[16] After that, the criteria are defined on which suppliers are assessed. Then, a multi-criteria decision-making tool (MCDM) will be chosen to determine how the criteria are weighted and analysed. In Chapter 2.2 the term MCDM is explained in more detail. Finally, the results of each supplier are entered into the model to obtain a clear overview of the performance of all suppliers. The overall process of designing a supplier evaluation scheme is shown in Figure 3.

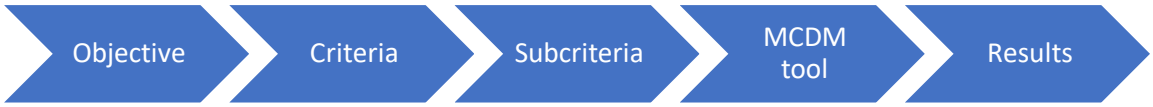

Figure 3. Designing a supplier evaluation scheme according to Alkahtani et al. (2019)

2.2 Criteria for assessing supplier performance

After defining the objectives, criteria for evaluating suppliers will be studied, as these criteria will help to assess the performance of the suppliers of ESS. Many studies described a lot of criteria where a supplier should be assessed on. These studies have been conducted in various environments and situations from which can be learned from. In addition, there will also looked at literature reviews about supplier evaluation to make the best criteria generally comprehensible.

Aksoy & Öztürk described evaluation criteria in a Just in Time (JIT) manufacturing environment. [17] In this environment, the most important evaluation criteria are Quality, Delivery, Price & Location. [18] Govindan et al. (2013) agreed on these economic criteria designed by Aksoy & Öztürk. However, they have added supplier technical capacity to

[13] See (Bruno, Esposito, Genovese & Passaro, 2012) p.1.
[14] See (Shin, Collier & Wilson, 2000) p.3.
[15] See (Chen, Lin & Huang, 2006) p.2.
[16] See \Alkahtani, Al-Ahmari, Kaid & Sonboa, 2019) p.4.
[17] (Aksoy & Öztürk, 2011), p.5.
[18] (Aksoy & Öztürk, 2011), p.5.

criteria on which suppliers should be assessed.[19] The criterion "technical capacity" helps to assess the innovative capacity of a supplier. In Table 2, an overview is given for economic supplier criteria according to the before mentioned literature. This overview can be used as a setup for defining criteria for ESS.

Table 2. An overview of most used criteria which can be applied for ESS described by Govindan et al. (2013) & Aksoy et al. (2011)

Criteria	**Sub criteria**	**Definition**
Price/Cost	Product cost	Costs per product
	Logistic cost	Costs of transportation per product
Delivery reliability	Lead time	Time between placing order and receiving goods
	On time delivery	% of products which are delivered on time
Quality	Certifications or supplies from specific supplier	Certifications which ensures a certain quality of products
	Rejection ratio	% of rejected products which have been sent back to the supplier
Location	Distance from supplier to factory ESS	Logistic distance in KM between supplier and ESS
Innovativeness	Technical Capability	Technology development of the supplier to meet current and future demand of the firm

Therefore, in the literature, there are already many criteria found on which suppliers must be assessed. To provide a clear overview of the importance of each criteria, Ho et al. (2010) described criteria for supplier evaluation which are most used in the literature from 2000 to 2008. The most important criteria for evaluating performance (customer-oriented criteria) are Quality, Delivery & Price.[20] The five most important criteria are summarized and described in the literature review as followed:[21]

[19] See (Govindan, Khodaverdj & Jafarian, 2013), p.3.
[20] (Ho, Xu & Dey, 2010), p.16.
[21] (Ho, Xu & Dey, 2010), p.17.

1. Quality
2. Delivery
3. Price/cost
4. Manufacturing capability
5. Service/support

According to this literature review, the most used criteria in the literature is *quality,* which is defined in many different ways. Definitions as “compliance with quality control” and “percentage acceptable parts” are mostly used to describe and measure *quality* of the supplier. So, the quality of the products needs to pass the quality control of the buying company. The second most popular criterion is *delivery* for supplier evaluation. Delivery is mostly described as “delivery lead time” and “compliance with due date”. This means that the lead time and on-time delivery of the supplier is important to measure. Thereby, the criteria *price/cos*t of the product is very simply defined. Namely, a check whether the supplier's price is in line with the market which makes this criteria more a comparison. The last two criteria *manufacturing capability* and *service/support* are defined and measured as the “capacity of manufacturing requested goods” and “the helpfulness and accessibility of the supplier”.

Furthermore, the increase in importance of CSR in companies can also be seen in the literature on supplier evaluation. In recent years, a gigantic growth has emerged in the importance of green supplier evaluation in the literature.[22] Because this is such a large and important topic in recent years, a separate chapter is made of it. This is discussed in more detail in Chapter 2.4.

In before mentioned criteria a distinction can be made between qualitative and quantitative criteria. Quantitative criteria are more based on hard facts and numbers received in the past and can therefore be seen as objective. [23] In contrast to quantitative criteria, qualitative criteria are more based on feeling with the business decision maker and therefore these criteria can be seen more as subjective. [24] Therefore, it is really important that the feeling of business decision makers is rationalized as well as possible so that the answers correspond better with reality. In order to analyse the combination of qualitative and quantitative

[22] See (Büyüközkan & Cifci, 2012) p.1.
[23] See (De Boer, Labro, Morlacchi, 2001), p.5.
[24] See (De Boer, Labro, Morlacchi, 2001), p.6.

performance measures, there will be made use of a multi criteria decision making method.[25] MCDM methods will be discussed in more detail in the following chapter.

2.3 The process for measuring supplier performance

2.3.1 Supplier evaluation problem is solved via multi criteria decision making

After describing the most common criteria in the literature for supplier evaluation, the next step is describing several methods for this topic. Therefore, to know which method can best be used, it is important to give a short overview of all methods and to choose the most suitable option.

Evaluating supplier performance is a complex problem that often uses quantitative and qualitative criteria. The problem of supplier evaluation will be investigated through multi criteria decision making (MCDM). MCDM is an analysis that takes different multiple criteria into account in its assessment. In the case of comprehensive problems such as supplier evaluation, several criteria can therefore be assessed in order to make a well-founded decision by the decision maker. Wang et al. (2009) described that MCDM methods are increased in popularity in decision-making processes because of the complexity of nowadays social-economic problems. [26] Thereby, the traditional single criterion approach based on lowest cost is decreasing in popularity. Reason for this, described by Ho et al. (2010) criterion as quality and delivery are more popular than the criteria price or cost.[27] Namely, the traditional single criterion approach can not guarantee the best performing supplier globally while the MCDM method is focussed on the overall best supplier.[28]

After drawing up different criteria, the supplier evaluation scheme can then be analysed using different methods. Talluri et al. (2006) made an overview of all kinds of evaluation methods for assessing suppliers.[29] In Table 3 an overview is shown of all kinds of methods that are used to evaluate suppliers.

[25] See (Dulmin & Mininno, 2003) p.2.
[26] See (Wang, Jing, Zhang & Zhao, 2009) p.1.
[27] See (Ho, Xu & Dey, 2010) p.19.
[28] See (Ho, Xu & Dey, 2010), p.19.
[29] See (Talluri, Narasimhan & Nair, 2006) p.4.

Table 3. Most vendor evaluation methodologies according to Talluri, Narasimhan & Nair (2006)

Weighted Linear Models (WLM)	Multi-objective Programming (MoP)	Game Models (GM)
Linear Programming (LP)	Matrix Method (MM)	Statistical Analysis (SA)
Mixed Integer Programming (MIP)	Human Judgment Models (HJM)	Discreet Choice Analysis Experiments (DCAE)
Grouping Methods (GP)	Total Cost of Ownership (TCO)	Neural Networks (NN)
Analytical Hierarchy Process (AHP)	Principal Component Analysis (PCA)	Data Envelopment Analysis (DEA)
Analytical Network Process (ANP)	Interpretive structural Modeling (ISM)	Change-constrained Data Envelopment Analysis (CCDEA)

In Table 3, a lot of methodologies for solving the supplier evaluation problem is been shown. All methodologies have their own characteristics and can be used in various situations. There are also methodologies that are very similar and mainly differ in applicability in certain situations. However, Ho et al. (2010) have divided many methods into a number of categories. For the purpose of clarity, the methods were therefore reduced to *Data Envelope Analysis, Mathematical programming, Analytical hierarchy process, Case-based reasoning, Analytical network process, Fuzzy set theory, Simple multi-attribute rating technique and genetic algorithm*.[30] Reason for this, these are the most commonly used methods in the literature. In Table 3, there are too many methodologies to explain their goals, therefore the focus will be primarily on the most commonly used methodologies according to Ho et al. (2010). The explanations for the most common methodologies are shown in Table 4.

[30] See (Ho, Xu & Dey, 2010), p.2.

Table 4. Most common methodologies according to Ho et al. (2010) explained by Velasguez & Hester (2013)

Methodology	Explanation
DEA	DEA uses a linear programming technique to measure the relative efficiencies of alternatives.[31]
Mathematical programming	Mathematical programming tends to automatization of supplier evaluation based on data.[32]
AHP	AHP is "a theory of measurement through pairwise comparisons and relies on the judgments of experts to derive priority scales".[33]
CBR	CBR is "a MCDM method that retrieves cases similar to a problem from an existing database of cases, and proposes a solution to a decision-making problem based on the most similar cases". [34]
ANP	ANP is a generalized form of AHP, that takes more account of interdepencies between criteria. However, as the number of relationships increases, ANP becomes very complex to use.[35]
Fuzzy set theory	Fuzzy set theory is an extension of classical set theory that "allows solving a lot of problems related to dealing the imprecise and uncertain data"[36]

2.3.2 Analytical Hierarchy Process is the most popular approach for supplier evaluation

In this research, the Analytical Hierarchy Process (AHP) will be used to measure the performance of suppliers. Chen (2006) defined AHP as an approach based on pairwise comparisons between criteria, to construct an evaluation structure with criteria and associated weights of convention site selection for meeting planners.[37] The last part of this definition does not apply to the problem of supplier evaluation. However, the first part of the definition describes the way this method is realized in practice. In order to perform supplier evaluation correctly, AHP uses literature and empirical experiences to design a model that should improve the decision-making process for business decisions makers.[38]

[31] See (Thanassoulis, Kortelainen, and Allen, 2012). p.2.
[32] (Ng, 2008) p.2.
[33] (Saaty, 2008) p.83.
[34] (Daengdej, Lukose & Murision, 1999) p.240.
[35] See (Sarkis & Talluri, 2002) p.19.
[36] (Balmat, Lafont, Maifret & Pessel, 2011) p.172.
[37] (Chen, 2006) p.2.
[38] See (Chen, 2006) p.3.

Thereby, Alkahtani et al. (2019)[39] summarized and defined AHP for supplier evaluation based on the study of Nydick & Hill (1992)[40] as followed:

> *"AHP is a decision-making method for ranking alternative courses of action when multiple criteria must be considered. Thereby, AHP is an approach utilized for supplier evaluation and selection problem and included the following procedures shown in Table 5."*

Table 5. Analytical Hierarchy Process for evaluating supplier performance according to Nydick & Hill (1992) & Alkahtani et al. (2019)

1.	Identify the criteria and sub-criteria for the assessment of suppliers
2.	Based on relative importance, build pairwise comparisons of the criteria in accomplishing the goal and calculate the weights or priorities of the criteria
3.	Identify measures, which present the accomplishment of criteria by each supplier
4.	Based on step 3, for suppliers, build the pairwise comparisons of the relative importance with regard to the criteria, and then calculate the corresponding weights
5.	Based on the results of steps 2 and 4, for each supplier, calculate the weights in accomplishing the hierarchy goal

The first step is identifying criteria for the assessment of suppliers. This is done by reviewing literature and including the input of business decision makers. After that, the criteria will be weighed together in terms of importance by performing a pairwise comparison. A pairwise comparison is comparing the importance of criteria with each other by a qualitative judgement of business decision makers.[41] Thereby, it is indicated how a certain score can be achieved by a supplier. Finally, the effective weights are implemented in the supplier evaluation scheme.[42]

Now that the definition of AHP is known, it is important to map out the importance of AHP. In the literature for supplier evaluation, AHP is the most popular approach to solve the

[39] See (Alkahtani, Al-Ahmari, Kaid & Sonboa, 2019) p.4.
[40] See (Nydick & Hill, 1992) p.2.
[41] See (Akarte, Surendra, Ravi & Rangaraj, 2001) p.6.
[42] See (Alkahtani, Al-Ahmari, Kaid & Sonboa, 2019) p.5.

supplier evaluation and selection problem.[43] Because supplier evaluation consists of qualitative and quantitative criteria, AHP is the approach that gives an insightful picture of the performance of suppliers. Namely, it shows the performance of suppliers on each criterion by measuring performance on criteria via a pairwise comparison.[44] Also, the approach has a low level of complexity and deals very well with imprecision in supplier choice which creates an easier and more objective understanding of the results.[45] Furthermore, Velasquez & Hester mentioned the benefits and disadvantages of AHP.[46]

Benefits[47]

The biggest advantage of using AHP is the ease of use. Namely, it is very easy for business decision makers to weigh criteria and compare multiple criteria with each other relative easily. AHP approaches are easier for the practitioners to understand and provide greater transparency.[48] Also, the process is scalable and adjustable due to the hierarchical structure of AHP. Thereby, to perform a pairwise comparison, the business decision maker is not overloaded with data, which means this process is not data intensive.

Disadvantages[49]

Although AHP is very user-friendly and easy to analyse, there are also a number of disadvantages to use AHP. Especially the interdependence between criteria during performing a pairwise comparison can be a disadvantage. Namely, in practice, when one criteria scores well it can influence other criteria. However, this should not be possible in theory. Also, the subjectivity in judgements of ranking criteria from business decision makers is seen as a disadvantage. Business decision makers comparing criteria with each other without a fixed instrument for ranking.

The main reason for using AHP in this study is because of the user-friendliness of AHP, the combination of literature and the influence of business decision makers and, finally, the transparent representation of method and result to check the results after the study. As mentioned before, this process is easy to understand and the results are easy to interpret for both the researcher and for the business decision maker.

[43] See (Govindan, Rajendran, Sarkis & Murugesan, 2015) p.6.
[44] See (Govindan, Rajendran, Sarkis & Murugesan, 2015) p.7.
[45] See (De Boer, Labro, Morlacchi, 2001), p.5.
[46] See (Velasguez & Hester, 2013) p.3.
[47] See (Velasguez & Hester, 2013) p.3.
[48] See (Govindan, Rajendran, Sarkis & Murugesan, 2015) p.7.
[49] See (Velasguez & Hester, 2013) p.4.

2.4 Green supplier evaluation

In recent years, an emerging growth occurred of green supplier evaluation in the literature. The widespread support in society that companies must take social responsibility effects the policy of companies to better structure the supply chain.[50] In order to obtain a green supply chain, companies are focussing more on "green supply management" that requires participation of every member in the supply chain.[51]

In the earlier days of supplier evaluation, the main focus was on economic criteria. Nowadays, beyond the traditional economic criteria, green supplier evaluation is added which measures the effect of suppliers on the environment and social economy in order to guarantee a green supply chain and a well-designed CSR.[52]

For example, to give a better picture of green supplier evaluation in practice, a number of examples will be given of green supplier evaluation criteria. This clarifies the difference between economic and green criteria. Handfield et al. (2002) mentioned various criteria on which suppliers should be assessed in the field of green supply management.[53] These criteria are shown in Table 6.

Table 6. Criteria for green supplier evaluation according to Handfield et al. (2002)

Criterion	Definition
Product attributes	Supplier's internal recycling activities
Waste management	The amount of waste realized by the supplier
Labeling/certification	The extent to which the supplier's processes have been certified by third parties (government or non-government).
Packaging	The extent to reusing and reducing packaging material
Government regulations	The extent to which the activities of the supplier are being carried out according regulatory requirements
Environmental progams	The presence of environmental systems within the supplier's management system

Therefore, it is very clear that a green supply chain is important for a company to be competitive in the market. However, CSR supplier evaluation criteria will not be used in this

[50] See (Lee, Kang, Hsu & Hung, 2009) p.2.
[51] See (Liao, Fu & Wu, 2016) p.2.
[52] See (Büyüközkan & Çifçi, 2012) p.3.
[53] See (Handfield, Walton, Sroufe & Melnyk, 2002) p.82.

study. During the selection of suppliers at ESS, suppliers are obliged to meet certain conditions such as certifications. As a result, almost all suppliers of ESS meet the same requirements that ESS sets for suppliers. If ESS wants to design a supplier selecton model, they will absolutely have to add CSR to the selection model. Due to the increasing importance and requirements of the environment, this criterion is very important to take into account in order to comply with a good CSR for ESS.

2.5 Difficulties of implementing an evaluation scheme

In order to achieve a flawless implementation of a newly designed supplier evaluation scheme, general pitfalls for the implementation of a supplier evaluation scheme will be researched. Sundtoft Hald & Ellegaard (2011) have conducted a case study on the design of a supplier evaluation scheme. They found four barriers for implementing a supplier evaluation scheme which are as followed: [54]

1. Rating/translation models on supplier performance
2. Buyer logic on how to motivate suppliers
3. Instability of supplier evaluation system
4. Resource consumption in updating data

The first barrier is the *translation of rating scores* to the actual performance of suppliers. Rating scores are ultimately reduced to 1 figure as an end score. Therefore, the performance of suppliers is more complex, so that a nuance must be made by the researcher after the assessment. Secondly, *buyer logic* can influence the assessment for a supplier because a business decision maker can have an idea for the potential of the supplier. When a supplier scores slightly less, but the buyer has an idea how they can improve this quickly, it is possible that the performance is still rated higher because there is a chance that the supplier can perform better according to the buyer. Thirdly, *data instability issues* must be taken into account during implementing a supplier evaluation scheme. Therefore, data must be handled with care to avoid incorrect data. Namely, this can result in a supplier evaluation scheme generating rating score for suppliers that are not in line with reality. Finally, *resource consumption in updating data* is a barrier for mainly SMEs. Supplier evaluation should be able to be performed at any time. However, for SMEs supplier evaluation is often reduced to a small number of suppliers and is carried out once a year on average.

[54] See (Sundtoft Hald & Ellegaard, 2011) p.5.

2.6 Supplier development

Supplier evaluation is part of the supplier management process. The complete supplier management process can be seen in Figure 4. The supplier management process consists of supplier *selection*, supplier *evaluation*, supplier *optimization*, supplier *phasing-out* and supplier *development*. After the supplier evaluation has been carried out, there are two options for optimizing the supplier portfolio.[55] Namely, depending on the performance of the supplier, the phasing-out phase or supplier development phase is started. Poorly performing suppliers will be placed in the phasing-out phase in order to take leave off these poorly performing suppliers. When suppliers perform excellently, only small areas for improvement will be looked at in order to strive for perfection. The moment a supplier performs on average, some improvements could be made on a multiple number of points, this will result in a placement in the supplier development program. Therefore, Hahn et al. (1990) mentioned that supplier development is triggered by an evaluation of the supplier which performance does not meet the requirements of the company.[56] The supplier development program aims to bring suppliers to a higher level. The main reason for carrying out supplier evaluation is to monitor the current performance of suppliers in order to improve the performance of suppliers in the long term. [57] Thus, it is important to conduct a supplier evaluation to raise the level of the supplier portfolio of a company. Namely, the evaluation process of suppliers helps to determine which suppliers need improvement and is therefore placed in the supplier development program.

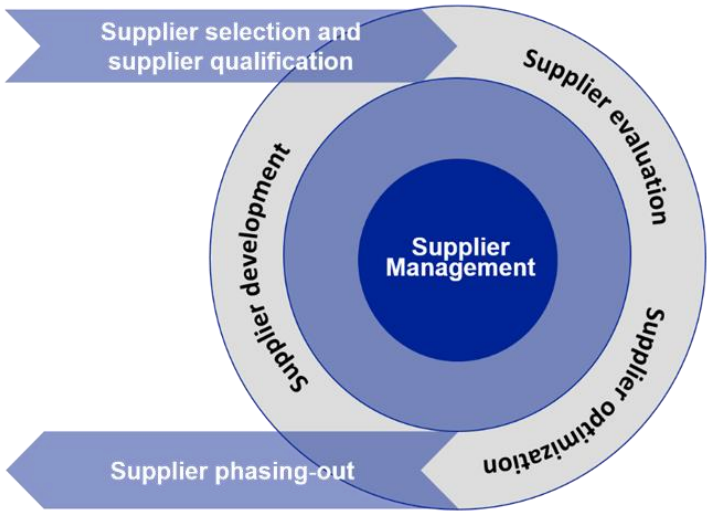

Figure 4. Supplier management process

[55] See (Hahn, Watts & Kim, 1990) p.4.
[56] See (Hahn, Watts & Kim, 1990) p.5.
[57] See (Krause, Handfield & Tyler, 2007) p.528.

According to Krause, Handfield & Scannel (1998, p.40) buying firms use two different approaches in supplier development: "1) reactive efforts to increase the performance of laggard suppliers, and 2) strategic efforts to increase the capabilities of the supply base to enhance the buying firm's long-term competitive advantage."[58] Both kind of efforts increase the buying company's involvement in suppliers. This will lead to a better communication and better use of resources of the supplier.

Moreover, the supplier development process can ensure that the level of process-based and product-based performance of a company is increased in the total supply chain. [59] This means that through a more intensive cooperation with suppliers, the process and products in the supply chain will be improved. Also, the repeated evaluation of current suppliers would encourage them to better align capacities with the changing priorities of companies in their product portfolio.[60] Because suppliers are evaluated more often, a company has a better picture of its suppliers. This will lead to a better communication between buyer and supplier, which ultimately leads to better supplier development.[61] Namely, when the supplier and buying firm discuss the obstacles within the supply chain, both parties can focus to improve themselves accordingly. So, evaluating suppliers often leads to the improvement of the obstacles in the supply chain between the supplier and buyer.

Most important, a well-organized supplier management is important for the overall success of firms. [62] A well-organized supplier management leads to better relationships with suppliers. This can be transformed into better access to the supplier's resources that provides an advantage for a firm. As a result, supplier development is one of the most important cornerstones in the supplier management process.[63] Evaluating the performance of suppliers is one thing, but improving the pain points in the supplier development part is the process in which a sustainable competitive advantage can be achieved. In short, the supplier development process has a positive impact on product, supplier and firm performance.[64]

[58] See (Krause, Handfield & Scannel, 1998) p.55.
[59] See (Vachon & Klassen, 2008) p.308.
[60] See (Narasimhan, Talluri & Mahapatra, 2006) p.598.
[61] See (Narasimhan, Talluri & Mahapatra, 2006) p.599.
[62] See (Cannon & Perreault Jr, 1999) p.455.
[63] See (Wagner, 2006) p.565.
[64] See (Prahinski & Benton, 2004) p.60.

2.7 Conducting supplier evaluation in order to improve the level of the supplier portfolio

In this chapter, the complete process of evaluating supplier performance is described. The importance of supplier evaluation lies primarily with the aim of improving the supply chain of a company. In order to start designing a supplier evaluation scheme, it is important to state the most important criteria. According to the literature, *Quality, Delivery* and *Price/Cost* are the most important criteria on which suppliers are assessed. In recent years, green supplier evaluation has increased in popularity. Due to the change in society's awareness of sustainability, companies are more forced to do business sustainably with greater social responsibility. Because a supplier assessment contains quantitative and qualitative criteria, this will be examined by a multi-criteria decision-making method. Therefore, the most common method for assessing suppliers is the *Analytical Hierarchy Process*. This method will be used in this study because of the user-friendliness and the simple interpretation of the results. During this process, a number of difficulties in implementing a supplier evaluation scheme must be taken into account. Sundtoft Hald & Ellegaard (2011) found four barriers that could complicate implementing a supplier evaluation scheme.[65] Namely, rating/translation models on supplier performance, buyer logic on how to motivate suppliers, instability of supplier evaluation system & resource consumption in updating data. If these barriers are taken into account by the researcher, the implementation of the supplier evaluation process will be simpler to execute. Moreover, the process of supplier management is shown in Figure 3. The reason for carrying out supplier evaluation is to raise the supplier portfolio to a higher level. To increase the performance of mediocre suppliers, supplier development is needed for this. Together, the supplier and the buying company, they can ensure better performances at the supplier that results in a more efficient supply chain.

[65] See (Sundtoft Hald & Ellegaard, 2011) p.5.

3. Methodology: conducting workshops and internal interviews in order to design a supplier evaluation model

3.1 Designing a new supplier evaluation model based on previous work

In the past, various supplier evaluation models have been designed. Via the search engine Scopus, 1274 articles can be found with the search term supplier evaluation with Business, Management and Accounting as subject area. However, it should be noted that a lot is written in this selection of articles about supplier selection instead of supplier evaluation. This considerably reduces the number of articles about supplier evaluation. In some cases the supplier selection and evaluation process is described in one article. Reason for this, is because many criteria are applicable in both cases, but some criteria are not applicable in both situations. As a result, the consideration of several criteria must be taken into account carefully. Furthermore, most of the articles used in this research are sources that have been cited a lot by other researchers. This means that the content is recognized and acknowledged by other scientists which are very important in the supplier evaluation literature. In addition, some articles are literature reviews that have been cited a lot by other researchers. These literature reviews are a summary of the many literature written about supplier evaluation. In appendix IV, an overview is given of the keywords and journals that is used during this research.

The preparation of a supplier evaluation model was carried out in many different ways. There are many differences between supplier evaluation models on a number of factors. The differences mainly relate to the criteria on which a supplier is assessed and the method on which the supplier evaluation process is carried out. The literature first determines the criteria on which a supplier should be assessed and after that, a choice is made to use a certain method for evaluating suppliers. The reason why the is no use made of an already existing designed supplier evaluation model, is that it cannot be used in its entirety for ESS. No model can be copied exactly on the basis of the criteria that is used to assess suppliers in the situation of ESS. However, existing literature is used to determine and define criteria that fit for ESS. A lot can be learned about criteria and their importance from the already existing literature.

3.2 A literature review for the supplier evaluation process

The first step towards the design of a supplier evaluation scheme, is to perform a literature study, as is shown in Chapter 2. The literature study will form the basis for a new design of

a supplier evaluation model. The criteria and method for evaluating supplier performance will be supplemented later by the internal wishes of ESS.

In the literature study, the term supplier evaluation is defined first. Therefore, there can be no misunderstanding about the significance and importance of measuring supplier performance. In addition, the entire process of designing supplier evaluation is described to get a clear picture of the process. This process is shown in Figure 3 at page 6.

After this, it is important to determine criteria on which suppliers are assessed. These pillars are the foundation of the design for a new supplier evaluation scheme. In this research, the choice is made to design a supplier evaluation scheme by means of the Analytical Hierarchy Process. This MCDM method is relatively a good way to combine subjective and objective criteria. In addition, the results are easy to interpret by the business decision makers. Pairwise comparison is used to determine the importance/weights per criteria. With pairwise comparison, the importance of criteria is determined by determining per pair which criteria are the most important. Finally, a number of barriers are mentioned for designing a supplier evaluation scheme. The barriers are described to prevent errors during this process of designing a supplier evaluation scheme.

An ipsative method was chosen by using the pairwise comparison as a result of AHP. Therefore, no use is made of a normative method to assess the importance of criteria via a normal rating score of 1 to 5. Furthermore, an ipsative method indicates actual preferences of the respondents in the process. [66] That is also the purpose of determining the importance for criteria. This ultimately results in a supplier evaluation model with the importance that the business decision makers prefer. When normative questions are asked about the importance, criteria are not really compared but are assessed on their own. This must be avoided precisely because the aim is to put the importance of criteria in the larger picture. Because of this, the alignment of importance per criteria is precisely reflected in the complete supplier evaluation model by using the ipsative rating.

This research mainly uses literature that has been cited a lot by other studies. Many citations mean that recognition is given by different scientists in this field. The studies on supplier evaluation started with 2 studies; Dickson (1966)[67] and Weber (1991).[68] In addition, much used literature in this study dates from the period 2005 - 2015. In this period a lot has been

[66] See (Tamir & Lunetta, 1977) p.3.
[67] See (Dickson, 1966) p.1.
[68] See (Weber, Current & Benton, 1991) p.1.

written in terms of methods and the movement from importance to criteria such as Quality & Delivery. Furthermore, use has been made of literature written in recent years in the field of supplier evaluation. This has mainly been used to investigate how the methodology of supplier evaluation has been described in recent years and to give an overview for the process. The literature reviews used in this study, are mainly used to determine which criteria are important. The articles in the literature reviews are in fact recognized by other scientists and, because of the large number of articles, confirm that the importance of criteria is correct. Moreover, the use of "grey literature" is only made in the methodology sector. Many books that are used in Dutch education describe much about research methods and possibilities for gathering information that is considered reliable and valid.

3.3 Research design: A single firm multi-case study

The used research design in this study can be regarded as a single firm multi-case study. This contains a single firm multi-case study because it contains the company ESS based on the research question. However, within the firm, multiple actors are involved to collect information which can be regarded as multiple cases. Next to this, the multiple cases are carefully chosen in order to obtain in-depth perspectives about the subject. Namely, random sampling is neither necessary, nor even preferable according to Eisenhardt (1989).[69] Furthermore, a case study has the objective to obtain multiple perspectives of a single organization at a point in time or over a period of time.[70] The actors participating in the workshop have different perspectives within the organization. Moreover, a case study can be suitable to answer a research question that starts with '"how."[71] The goal of this master thesis is to describe and explain "how" ESS can design and implement a supplier evaluation scheme to monitor supplier performance. The methodology is shown in Figure 5 to obtain a clear overview.

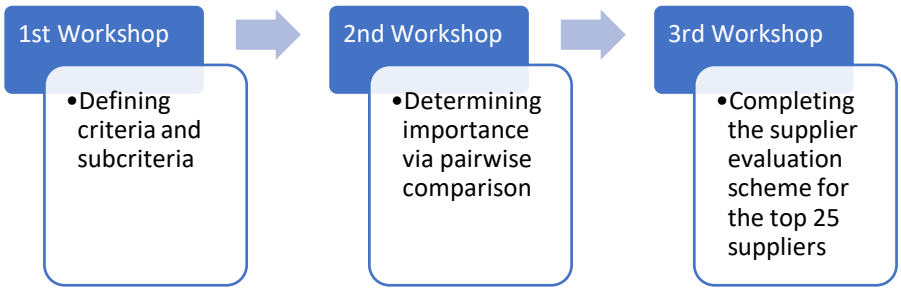

Figure 5. Overview of the methodology

[69] See (Eisenhardt, 1989) p.537.
[70] (Cooper & Schindler, 2013) p.165.
[71] See (Baxter & Jack, 2008) p.545.

3.4 Data collection: mapping internal wishes within cross-functional workshops

By conducting a literature study, a basis has been laid for designing a supplier evaluation scheme. Multiple workshops are used to identify the internal wishes of the organization. This research consists of a combination of quantitative and qualitative research, which the latter playing the largest role in this research. The combination stems from the fact that supplier evaluation is a multi-criteria decision making method that uses qualitative and quantitative criteria. Criteria are described and determined by organizing cross-functional workshops with business decision makers. A number of criteria will have to be calculated via a quantitative method in Excel. As these criteria are easily traceable due to the presence of existing data within the company, the focus will mainly be on collecting qualitative data. In addition, the facts arising from quantitative data are confirmed or contradicted by qualitative data collection. The qualitative data works as an explanatory means to answer the question why suppliers perform in a certain way.

3.4.1 Defining criteria and their importance via cross-functional workshops

The first step in mapping the wishes of ESS in the field of supplier evaluation is held in semi-structured cross-functional workshops. All business decision makers of ESS participate in all cross functional workshops. In the first cross-functional workshop, the criteria and sub-criteria are determined by business decision makers of ESS. Firstly, the ideas and opinions for criteria of the business decision makers is asked, when this process completed, a list of criteria from the literature is discussed and the business decision makers could determine whether they consider criteria from the literature as important to adjust the list of criteria. These business decision makers are selected based on different perspectives that relate to and interact with suppliers. Reason for this, business decision makers are chosen in the purchasing, quality and research & development department to ensure that all business decision makers are brought together who come into contact with suppliers. Therefore, the group which attended the cross-functional workshops had the following composition; the purchasing manager, manager of quality control, logistic manager, supply chain manager, manager of R&D and the general manager which is shown in Table 7:

Table 7. Composition of business decision makers

1. Purchasing manager
2. Manager of quality department
3. Logistic manager
4. Supply chain manager
5. General manager
6. Manager of research & development department

Cross-functional workshops were chosen to view the supplier evaluation problem through different perspectives. All workshops will have a semi-structured character to create discussions between the business decision makers. The semi-structured nature ensures open discussions that collect in-depth information, but also that the discussion does not transfer to another topic and therefore remains with the supplier evaluation problem. This exposes the different perspectives between different departments to provide more in-depth insight information about supplier evaluation within ESS. During the first workshop the following steps shown in Table 8 were followed to design a supplier evaluation scheme:

Table 8. Structure of the first workshop

1. Determining criteria on which suppliers must be assessed
2. Extend criteria to sub criteria
3. Subdivide criteria into quantitative or qualitative criteria
4. Determine the measuring method; How can quantitative criteria be measured?
5. Comparing criteria with the literature; Should some criteria still have to be added?

As mentioned before, the Analytical Hierarchy Process was chosen as the method to design the supplier evaluation scheme. Therefore, a second workshop with the same composition was organized to determine the importance per criteria and sub-criteria. This is done via the so-called pairwise comparison. The criteria established and determined in the first workshop are compared with each other via pairwise comparison. To give an insight into what this looks like in practice, the process of pairwise comparison is described in the following tables. The following figures on the next page shows how the pairwise comparison method was set up during the second workshop. The actual results of this workshop will be shown in Chapter 4.

The first step is to weigh criteria against each other on a scale from 0 to 9 as shown in Table 9. Therefore, Wind & Saaty (1980) described the fundamental scale of absolute numbers, that can be assigned to comparing the criteria which is shown in Table 10.[72] Based on this, the business decision makers will discuss the importance of each criteria and fill in Table 8 together.

After that, the following steps will be done by the researcher. Namely, calculating the values relative to the column totals to determine the eigenvector per criteria as shown in Table 11. Next to this, the given values from the business decision makers and the eigenvector are multiplied by each other to calculate the standardized sum/the weighting factor per criteria shown in Table 12. These are ultimately the weighting factors used in the supplier evaluation scheme. Finally, a consistency check rate is calculated to check the consistency of the results as shown in the Table 13. As a rule of thumb, the consistency rate must be below 0.1 to determine the results as consistent.[73] The numbers in the figures are fictional and are not results of this research.

Table 9. Weighting criteria against each other

	Criteria 1	*Criteria 2*	*Criteria 3*
Criteria 1	1.00	2.00	4.00
Criteria 2	0.50	1.00	2.00
Criteria 3	0.25	0.50	1.00
Total	**1.75**	**3.5**	**7**

Table 10. Fundamental scale of number based on Wind & Saaty (1980)

Intensity of importance	*Definition*
1	Criterion “a” and “b ” are of equal importance
3	Criterion “a” is weakly more important than criterion “b”
5	Criterion “a” is strongly more important than criterion “b”
7	Criterion “a” is very strongly or demonstrably more important than criterion “b”
9	Criterion “a” is absolutely more important than criterion “b”
2,4,6,8	Intermediate values

[72] See (Wind & Saaty, 1980) p.644.
[73] See (Saaty, 2008) p.94.

Table 11. Calculating Eigenvector

Criteria	*1*	*2*	*3*	*Eigenvector*
1	0.571429	0.571429	0.571429	0.571429
2	0.285714	0.285714	0.285714	0.285714
3	0.142857	0.142857	0.142857	0.142857
Check →	Sum of Eigenvector	needs to be 1.00		**1.00**

Table 12. Calculating standardized sum (weightings factor per criteria)

Criteria	*Sum (Given values * Eigenvector)*	*Standardized sum*
1	1.714286	0.57
2	0.857143	0.29
3	0.428571	0.14
Total	**3.00**	**1.00**

Table 13. Consistency rate check

Consistency Check	
Sum of Table 11	**3.00**
Consistency Index = (Sum of Table 11 -N) / (N-1)	**0.00**
Consistency Rate	**0.00**

The tables above provide a representation of a fictional pairwise comparison. The pairwise comparison and the consistency check take into account the incorrect filling of the matrix by business decision makers. During the intermediate steps, it is very important to check the sum of the eigenvector and the standardized sum to check if this results in 1.0. If this is not the case, something went wrong during the calculation and the pairwise comparison will have to be performed again. Also, a consistency rate above 0.1 indicates that the pairwise comparison matrix has not been consistently filled in by the business decision makers.[74] As a result, the pairwise comparison needs to be repeated.

[74] See (Saaty, 2008) p.94.

3.4.2 Measuring supplier performance via a cross-functional workshop

As mentioned before, a supplier evaluation scheme can be designed based on the two workshops with business decision makers of ESS. However, the next step is to map the insights of business decision makers about assessing supplier performance. Therefore, the third workshop is organized with the same composition as before. Furthermore, the designed supplier evaluation model based on the two workshops is used as a common thread during this workshop. The reason for organizing a workshop is that consensus must be reached about determining supplier performance. As a result, everyone will ultimately agree and accept the results from suppliers. If a different form were chosen such as individual interviews, differences in results would arise. As a result, it could be that respondent A has a much more positive image about the supplier than respondent B. Therefore, this could lead to many discussions and grey areas when presenting the results for supplier performance. These situations will be prevented by organizing a workshop with these different business decision makers. Moreover, within the workshop, the model is used to determine the performance of the top 25 suppliers. These top 25 suppliers are selected based on purchasing volume from ESS. Suppliers who together are responsible for a large part of the purchasing volume of ESS are monitored via the supplier evaluation model. The designed supplier evaluation model clearly describes the requirements which a supplier should meet in order to achieve a certain score per criteria. Figure 6 shows the scale of scores in the supplier evaluation model.

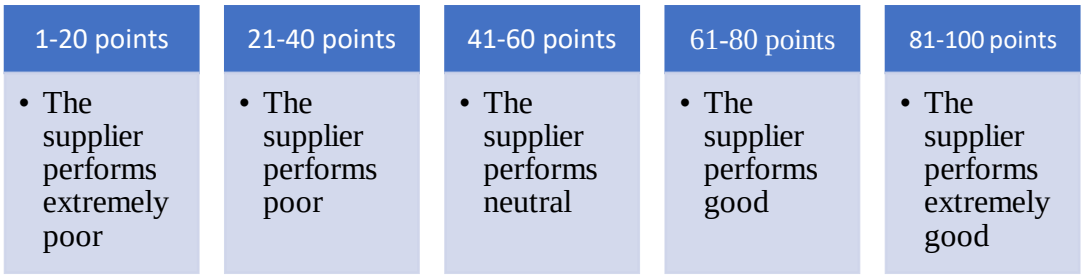

Figure 6. Scale of scores in the supplier evaluation model

The higher the number of points achieved, the better a supplier performs. A disadvantage of assessing qualitative criteria may be that when someone has 20 points, the supplier just does not enter the following scale and therefore the supplier's performance is less well represented. However, this can be an extra motivation for the supplier to take that little extra step to be classified in a better scale. The quantitative criteria result in exact percentages. Therefore, the number of percentage points will be the literal number of points in the supplier evaluation model.

The final score per supplier will be displayed in one table in Chapter 4. When a supplier scores more than 75 points, this means that the supplier is performing well. Results between 55 and 75 points means that the supplier will have to improve their performance. The moment a supplier scores below 55 points, ESS will have to seriously consider whether they should continue to cooperate with this supplier.

Approximately, the first two workshops had the same duration of two hours. The third workshop lasted a little longer, namely 2.5 hours (Table 14). This is mainly due to the fact that assessing 20 suppliers takes just a little more time and this has led to slightly more discussions than before. In the workshops, valuable information was obtained and the predetermined goals of the workshops have been achieved. After each workshop, the information is processed into a clear overview. These overviews were later shown to the participants again to check whether the information, as processed, corresponds to the results according to the same participants. This action was taken after each workshop to increase the validity of the research. The collected information was processed correctly and no information was missing.

Table 14. Overview of all workshops

Workshop	***Goal***	***Duration of the workshop***
1	Defining criteria and sub criteria to measure supplier performance	1:55 hr.
2	Defining the importance of each criteria using the pairwise comparison	2:05 hr.
3	Determining supplier performances using the designed supplier evaluation model	2:40 hr.

3.4.3 Comparing second sources with each other in order to implement a second dimension

In the previous steps, the performance of the suppliers was measured. In the final step, an extra dimension will be added to interpret the results of the core suppliers in a better way. In order to guarantee the quality of products in the long term in order to maintain the high quality and innovation strategy of ESS, it is advantageous to look at the largest and most important suppliers on which ESS depend most. The second dimension must answer the question why the core suppliers perform in a certain way. Second sources are suppliers that can produce the same products when necessary. These second sources are compared with each other because they supply the core materials in high volumes for ESS. In addition, it is important that these suppliers can learn from each other in order to raise the core supplier portfolio to a higher level. The urgency to compare core suppliers stems from the mutual dependence between supplier and ESS. Namely, these suppliers supply the most important and most parts to produce the products that contain the largest share of the turnover. Schiele et al. (2012) studied the differences in customer attractiveness, supplier satisfaction in achieving a preferred customership status. The preferred customership has a significant impact in the relationship between buyer and supplier. This dimension reflects the difference between relationships with and without a preferred customership. A customer is best treated by the supplier when he is in possession of a preferred customership. In addition, a customer that is the least attractive to the supplier is therefore treated differently than a customer for whom it is very attractive to deliver. According to Vos et al. (2016), customers can achieve a preferred customership status by increasing their supplier satisfaction.[75] For example, growth opportunities and expected profitability have a positive impact on increasing supplier satisfaction. In addition, high supplier satisfaction positively influence to reward the customer with a preferred customership.[76] Such a preferred customership provides preferential treatment which is positive for the customer.

In the case of ESS, the main suppliers are approximately 50% owned by ESS. This means that the group of core suppliers of ESS is owned by ESS. Approximately, ESS has a share of around 50% by their core supplier. This makes it difficult to add an extra dimension based on how Schiele et al. (2012) described where suppliers will be compared with and without a preferred customer status.[77] Because of ESS experiences by almost all suppliers the preferred

[75] See (Vos, Schiele & Hüttinger, 2016) p.4614.
[76] See (Vos, Schiele & Hüttinger, 2016) p.4615.
[77] See (Schiele, Calvi & Gibber, 2012) p.16.

customer status, the dimension of Schiele et al. (2012) is not applicable for ESS. Because ESS is now in a growth phase, this strategy of ownership and preferred customership is used. As a reason, ESS guarantees that suppliers grow with them and that the interests do not end up with a competitor. Therefore, suppliers are not allowed to supply to a competitor that is in the same market as ESS. Furthermore, a dimension can be added based on Schiele's work by comparing second sources suppliers. Suppliers that can produce the same products can be compared with each other to see how the performance differs. Even when they experience a preferred customer relationship with both suppliers, a difference can probably be made in the relationship between the buyer and supplier. This allows different suppliers from ESS to learn from each other, which means they will perform better in the future.

3.5 Reliability & validity of the research

When conducting a scientific research, it is important to consider reliability and validity of a research. After all, it is of great importance that a study can be carried out again that produces the same results. In order to achieve reliability and validity, bias of the researcher needs to be eliminated.[78] Also, triangulation is an important resource to improve the reliability and validity of a research. Triangulation is a "validity procedure where researchers search for convergence among multiple and different sources of information to form themes or categories in a study."[79]

According to Hoffman (1994) reliability can be defined as "the consistency with which an individual will tell the same story about the same event on a number of different occasions." [80] In short, reliability is the extent to which measurements and observations are consistent.

To ensure reproducibility, use has been made of many cited scientific studies and literature reviews in the field of supplier evaluation. The key words for the literature study are; supplier evaluation, vendor rating, green supplier selection & Analytical Hierarchy Process.

The reliability of the workshops is guaranteed by the use of AHP and the associated pairwise comparison. The researcher has tried not to lead the workshops in order to stimulate open discussions between participants. For example, no questions were asked by the researcher during the workshop and only one introduction and conclusion was made by the researcher. Action has only been taken if the discussion deviated by far from supplier evaluation.

[78] See (Golafshani, 2003) p.603.
[79] See (Creswell & Miller, 2000) p.126.
[80] See (Hoffman, 1994) p.109.

During the workshops it is possible that different participants can influence each other. Therefore, participants from different perspectives have been brought together to make these influences visible. Also, it is important that after the first workshop a list of criteria based on the literature is discussed. It may be that within a certain focus group there is less or more knowledge available on the subject of supplier evaluation. As a result, no criteria are forgotten and input is only given by the researcher during the conclusion of the workshop to increase the reliability of the results from the workshop. Finally, it is important the native language needs to be considered while performing a workshop. There is one participant which has the German language as native language. All other participants have the Dutch language as native language. However, all participants speak Dutch, German and English very well. The researcher also speaks these three languages. In the event of uncertainties, it is therefore possible to switch to another language to clarify a point for the sake of simplicity and intelligibility. This will reduce misunderstandings due to language barriers.

After explaining the reliability of this research, it is important to ensure the validity. Validity is the degree of conformity between the reports of the event and the event itself as reported by other documents. [81] Moreover, Joppe (1998) described validity as the determination whether the research truly measures that which it was intended to measure or how truthful the research results are. [82] In conclusion, does the research measure what the original intention was to measure.[83] Therefore, is a combination of the literature and wishes within ESS. In addition, the wishes of ESS have been confirmed by all business decision makers after every workshop. After all, feedback and comments were asked after each workshop to ensure that the results actually match reality. In order to measure supplier performance, the sampling of the cross-functional workshops consist of participants that cooperates intensively with suppliers. All these participants have decision-making authority within the organization, so that extra value is weighed on these perspectives. It is important to note that the sampling has therefore been very accurate and specific. As a result, the increase of the availability of knowledge within the workshop in the field of supplier evaluation. Therefore, this method prevents people who do not have knowledge of supplier performance from having any input in this process. This would otherwise disrupt the validity of the data collection.

[81] See (Hoffman, 1994) p.109.
[82] See (Joppe,1998) p.1.
[83] See (Kogovšek, Ferligoj, Coenders & Saris, 2002) p. 2

3.6 The use of scientific literature and organizing workshops in order to develop a new supplier evaluation scheme

In this chapter, it is explained why certain choices were made during the research. Firstly, in the literature review, this mainly concerns the choice for using AHP and the choice of certain scientific articles. Articles were chosen for the period from 2005 to 2015 because these articles are acknowledged by other scientists about supplier evaluation. In addition, this study concerns a single firm multi-case study. Reason for this, the subject of the workshops is ESS and multiple business decision makers are asked to participate. The business decision makers of ESS are asked to participate in several workshops in order to determine criteria on which suppliers must be assessed. In addition, the relative importance of each criteria is also asked. Finally, a last workshop was held to determine the performance of suppliers. Workshops have been chosen so that discussions arise which can be used to chart different perspectives on supplier evaluation. By conducting these discussions, consensus will eventually arise so that everyone agrees with each other in the field of designing a supplier evaluation scheme. Finally, reliability and validity are guaranteed by various factors. For example, only literature that is often quoted and therefore recognized by other scientists has been used. A passive attitude was also adopted in the workshop so as not to influence the participants.

4. Results: combine the analysis of the internal wishes and academic literature to design a supplier evaluation scheme for ESS

4.1 Defining evaluation criteria through a cross-functional workshop

The first step in designing a supplier evaluation scheme is to define criteria on which suppliers must be assessed. As described in Chapter 3, the business decision makers of ESS have defined the criteria by which a supplier should be assessed in a cross-functional workshop. The results of the first workshop for defining criteria is shown in Table 15.

Table 15. Overview criteria resulting from the first workshop

Criteria	**Sub criteria**	**Definition**
Quality	Acceptance ratio	The number of products in % that are accepted by Quality control.
	Quality control at the supplier	The extent which the supplier ensure their quality in their process.
Costs	Product price	The costs per product in comparison with other suppliers in the market
Delivery	Lead time	The timeframe between placing an order and the receipt of goods
	On time delivery	The number of products in % that are delivered on time by the supplier
Support	Supplier accessibility	The extent which a supplier can be reached for questions and/or remarks.
	Quality of communication	The extent which the communication is experienced as useful and helpful
Innovativeness	Technical capability	The extent which a suppliers' technical capability results in innovation
	Knowledge/patents	The extent which a supplier has unique patents and knowledge to create innovative solutions that lead to a better NPD.

According to the participants of the workshop, the first criteria on which a supplier must be assessed is *quality*. Therefore, quality is defined as; “the extent which products comply with the quality control of ESS.” In order to make the criteria quality more measurable, the criteria quality is further subdivided into two sub criteria; *acceptance ratio* & *quality control at the supplier*. The acceptance ratio is described as the number of products that must be returned in relation to the total. Moreover, when a supplier has to send back many products, this means that the supplier does not meet the ESS quality requirements. In addition, quality control at the supplier can also help to achieve higher quality at the supplier. A better link between the quality control of ESS and the quality control of the supplier can result in better coordination of the quality of products.

Next to this, the business decision makers of ESS consider the *costs* criteria an important component on which a supplier must be assessed. The criteria costs is described as; "The extent to which the supplier's price is in line with the market." This means that the supplier's price must be in line with the rest of the market. Suppliers will score poorly if their price is higher than the competition and score better if the price is lower than the competition. It is important to map the price levels of suppliers in order to remain competitive even as a company. If an organization has too expensive suppliers, this has an effect on the price that the customer has to pay and it can become unattractive for customers to buy these more expensive products.

Furthermore, *delivery* can be considered as an important criterion on which suppliers should be assessed according to the participants of the workshop. This criteria is subdivided into two sub criteria; *on time delivery* & *lead time delivery*. On time delivery is the number of products that were delivered on the agreed date or earlier. Lead time delivery is the period in days in which an order is placed and the goods received by the organization. These criteria have a lot of effect on the buyer's supply chain. A long lead time can result in higher inventories to be able to serve the customer directly. In addition, too many late deliveries can result in problems in the production process of the buyer. It is therefore important that the delivery criteria is taken into account in the supplier evaluation process.

Besides that, the *support* of a supplier is mentioned as a criteria on which a supplier should be assessed. In order to make these criteria measurable, it is subdivided into two sub criteria; the *accessibility of the supplier* & *the quality of communication* of the supplier. The accessibility of the supplier is defined as the extent to which a supplier can be reached by the buyer and can contact him at any time through various channels. The sub-criteria quality of the communication is defined as the extent to which the communication from the supplier is considered useful and usable by ESS. Support from a supplier is a crucial factor in the buyer-supplier relationship. Good support can contribute to a high resolving power and increase the quality in the supply chain. Namely, through good communication between supplier and buyer, problems are resolved faster and by sharing knowledge with each other, quality in the process can be increased.

Thereby, *innovativeness* is an important criteria during evaluating suppliers. A supplier's high innovative capacity has positive effects on the buyer's NPD. Innovativeness is subdivided into two sub-criteria; *technical capability* & *knowledge/patents*. The technical capacity of a supplier is the capacity to make products or solutions that meet the ESS requirements. The knowledge and patents indicate the degree of knowledge for creating innovative solutions that will provide a competitive advantage in the future.

Finally, the list of criteria from the literature, shown on the next page in Table 16, is submitted to the business decision makers of ESS. They mainly discussed the *green supplier evaluation* in detail. Although this is a very important aspect when selecting suppliers for ESS, it is less important when evaluating current suppliers. Current suppliers meet all the sustainable requirements that ESS sets for suppliers. This is organized by obliging suppliers to use certain types of material that they prescribe and to comply with various certifications in order to determine the sustainability of the production process.

Table 16. Criteria based on the literature (Table 1 & Table 5)

Criteria	**Sub criteria**	**Definition**
Price/Cost	Product cost	Costs per product
	Logistic cost	Costs of transportation per product
Delivery reliability	Lead time	Time between placing order and receiving goods
	On time delivery	% of products which are delivered on time
Quality	Certifications or supplies from specific supplier	Certifications which ensures a certain quality of products
	Rejection ratio	% of rejected products which have been sent back to the supplier
Location	Distance from supplier to factory ESS	Logistic distance in KM between supplier and ESS
Innovativeness	Technical Capability	Technology development of the supplier to meet current and future demand of the firm
Corporate social responsibility	Waste Management	The amount of waste realized by the supplier
	Certifications	The extent to which the suppliers' processes have been certified by third parties

However, in order to assess supplier performance on the criteria that have been drawn up, definitions must be made of how a supplier can achieve a certain score. This reduces the subjectivity of assigning a score to criteria for a supplier. Therefore, the way in which a supplier can achieve a certain score is shown in Appendix I. Since these definitions are only for increasing reliability and validity, the explanation per criteria is not presented in this chapter. In addition, these definitions are not shown in the results to reduce the amount of pages.

Moreover, some criteria scores must meet certain conditions. For example, the quantitative criteria such as; delivery & quality must meet the same conditions as the supplier's final scores in order to continue to deliver to ESS. The minimum scores and the corresponding actions can be seen in Table 17. If a supplier has a final score between 0 and 60 points, then the best choice will be for ESS to say goodbye to the supplier. The supplier performs poorly on various indicators and this cannot be repaired in the short term. The moment a supplier has a final score between 61 and 80 points, the organization will have to draw up an improvement plan with the supplier to improve the bad indicators in the short term. Finally, when a supplier achieves a final score between 81 and 100 points, that means that the supplier scores well. However, any small points for improvement should be considered, but in general the supplier does not have to make improvements in the short term.

If a supplier has a final score between 0 and 60 points, then the best choice will be for ESS to say goodbye to the supplier. The supplier performs poorly on various indicators and this cannot be repaired in the short term. The moment a supplier has a final score between 61 and 80 points, the organization will have to draw up an improvement plan with the supplier to improve the bad indicators in the short term. Finally, when a supplier achieves a final score between 81 and 100 points, that means that the supplier scores well. However, any small points for improvement should be considered, but in general the supplier does not have to make improvements in the short term.

Table 17. Final score scales

Final score	*Action*
0-60 points	The organization will probably have to say goodbye to the supplier. The supplier performs poorly on several crucial criteria with a too large gap for improvement in the short term.
61-80 points	The supplier of the organization performs properly. However, there are still areas for improvement on a number of criteria. The organization will have to talk to the supplier to discuss the points for improvement and to prepare a development plan for the future.
81-100 points	The supplier in this category performs very well and does not have to follow any actions. They meet all the requirements of the organization.

4.2 Defining the importance of each criteria for ESS via pairwise comparison in a cross-functional workshop

4.2.1 Calculating relative importance of each criteria for ESS

After defining evaluation criteria, the next step in the process is to determine the relative importance of each criteria and sub criteria. As described in the methodology, the supplier evaluation problem is solved by the Analytical Hierarchy Process. This means that the importance of criteria is determined by the pairwise comparison method as described in Chapter 3.3.1.

Criteria	1	2	3	4	5
1. Quality	1,00	4,00	2,00	3,00	3,50
2. Costs	0,25	1,00	1,50	1,00	1,00
3. Support	0,50	0,67	1,00	0,50	2,00
4. Delivery	0,33	1,00	2,00	1,00	4,00
5. Innovativeness	0,29	1,00	0,50	0,25	1,00
Kolomtotalen	2,37	7,67	7,00	5,75	11,50

Figure 7. Weighting criteria against each other

Firstly, the participants in the workshop begun to outweigh the criteria against each other from Table 15. The relative importance has been determined on a scale of absolute numbers based on Wind & Saaty (1980) which can be seen in Table 10.[84] The results of the weighting of importance can be seen in Figure 7.

Next to this, the eigenvectors are calculated for each criteria to determine the priority per criteria. The eigenvector indicates the ranking of the evaluation criteria.[85] The higher the value of the eigenvector, the higher the criteria are in the ranking.

Criteria	1	2	3	4	5	6	Eigenvector
1	0,42211	0,52174	0,28571	0,52174	0,30435		0,411130
2	0,10553	0,13043	0,21429	0,17391	0,08696		0,142224
3	0,21106	0,08696	0,14286	0,08696	0,17391		0,140348
4	0,14070	0,13043	0,28571	0,17391	0,34783		0,215718
5	0,12060	0,13043	0,07143	0,04348	0,08696		0,090580
6	0,00000						0,000000
						Check-->	1,000000

Figure 8. Calculating Eigenvector for criteria

[84] See (Wind & Saaty, 1980) p.644.
[85] See (Saaty, 2003) p.86.

Score criteria		Weighting factor
Criteria	**Sum (Given values Criteria * Eigenvector)**	**Standardized sum**
1	2,224906	0,42
2	0,761826	0,14
3	0,729748	0,14
4	1,138002	0,21
5	0,474373	0,09
6		
totaal	5,328854	1,00

Figure 9. Determining weighting factors for criteria

In order to find out for what percentage a criteria actually counts in the assessment, the standardized sum must be calculated. This is done by first multiplying the given values for criteria in the workshop by the eigenvector. Moreover, this result is called the sum. The sum is then divided by the total of all sums together, so that the standardized sum is calculated. Therefore, results for this step are shown in Figure 9. The standardized sums are the weighting factors for each criteria on which ESS suppliers are assessed.

Finally, the consistency rate of the completed pairwise comparison is below 0.1 which is shown in Figure 10. This means that the matrix has been consistently filled in by the workshop participants.[86] Also, interim checks in Figure 6 & 7 all comply with the norm of 1.0. As a result, the results of the pairwise comparison matrix can be considered reliable and valid.

Consistency check	
λmax	5,30
CI = (λmax - n)/(n-1)	0,07401
Consistency Rate	0,08224

Figure 10. Consistency rate check for criteria

[86] See (Saaty, 2008) p.94.

4.2.2 The results of pairwise comparison process

After calculating the weightings factor for each criteria, it is important to describe the meaning of the results. As a result, it will gain a deeper understanding for the effect of each criteria in the supplier evaluation scheme. The results of the pairwise comparison matrix filled in during the workshop are shown in Table 18.

Table 18. Results of the pairwise comparison workshop

Criteria	**Weight**	**Sub criteria**	**Weight**	**Effective weight (criteria weight * sub criteria weight)**
Quality	42%	Acceptance ratio	40%	0.42 * 0.40 = 16.8%
		Quality control at the supplier	60%	0.42 * 0.60 = 25.2%
Costs	14%	Product price	100%	0.14 * 1.00 = 14%
Delivery	21%	Lead time	50%	0.21 * 0.50 = 10.5%
		On time delivery	50%	0.21 * 0.50 = 10.5%
Support	14%	Supplier accessibility	20%	0.14 * 0.20 = 2.8%
		Quality of communication	80%	0.14 * 0.80 = 11.2%
Innovativeness	9%	Technical capability	67%	0.09 * 0.67 = 6%
		Knowledge/patents	33%	0.09 * 0.33 = 3%
Total	**100%**		**100%**	**100%**

The business decision makers of ESS have determined that *quality* is the most important criteria on which a supplier must be assessed. For the organization, everything depends on the quality of the products that are delivered to the company. Most problems in the production process are caused by the quality of a supplier's products that do not meet the requirements of ESS. The two sub-criteria of quality have also been compared with each other and it emerged that quality control at the supplier is more important than the acceptance ratio of a supplier. Although this may be related, this is by no means the case. A well-designed quality control at the supplier does not necessarily mean that the acceptance ratio of ESS is high. Because of the quality requirements of ESS may differ from those of the supplier, the acceptance ratio can be low while the supplier has a well-organized quality control.

Besides quality, *delivery* is an important criteria on which a supplier must be assessed by ESS. Both, *lead time* and *on-time delivery* of products, are equally important within the delivery criteria. Lead time has an effect on how long customers need to wait on their products, so this can lead to a competitive advantage or disadvantage. Because suppliers can handle good delivery times, the process of ESS becomes more efficient and effective. Also on the other hand, on time delivery is important for an efficient business process. If companies do not deliver on time, this can have a significant negative effect on planning and forecasting. As a reason, it makes it extremely important that suppliers can deliver on time. Therefore, the two sub criteria combined are extremely important in the supplier evaluation process.

In addition, the *costs* of suppliers' products are seen more as a threshold by business decision makers of ESS. Therefore, the criteria costs are less important than quality and delivery. Certainly, the costs of suppliers' products must not be too high or much higher than the market price. As a consequence, the margins of ESS would be damaged and reduced to much by the price of the supplier. Although other criteria are therefore more important than the costs, suppliers must therefore in no way charge a too high price for ESS. As a reason, the criteria costs is in the middle of the ranking of supplier evaluation criteria.

Also, the *support* of a supplier is of medium importance when evaluating suppliers for ESS. The support of a supplier largely determines the quality of the relationship between both parties. In addition, the most important thing is the advice and solution orientation of suppliers are experienced as useful and helpful by ESS. In short, the quality of the communication is extremely important for a good relationship. The accessibility of suppliers is of less importance since it is fairly normal in the present time to be accessible to customers via at least one channel. Therefore, the support criteria is an important indicator of the quality of the relationship between ESS and supplier. As a result, the support criteria is in the middle of the importance of criteria.

According to the business decision makers of ESS, the *innovative capacity* of suppliers is the least important criteria compared to the other criteria determined in the first workshop. This is mainly because the innovation process takes place internally. The R&D department designs ideas for new products. Only then do they go to current suppliers to ask if the new designs are practically feasible. This means that ESS demands a high level of the *technical capacity* of the suppliers. Suppliers must be able to meet the future demand of ESS in order to be considered as a good supplier. Because the process mainly takes place within ESS, the *knowledge and patents* of suppliers are of less importance. Therefore, there is simply a low demand for input from suppliers. All things considered, the supplier's capacity for innovation is of little importance for ESS because the capacity for innovation comes from within the organization.

4.3 Measuring supplier performance in a cross-functional workshop

4.3.1 Assessment on quantitative criteria

In order to assess performance on different criteria, a distinction has been made between quantitative and qualitative criteria. Firstly, the performance in terms of quantitative criteria has been assessed in the supplier evaluation scheme. The quantitative criteria are calculated on the basis of available data in the ERP-system SAP. Therefore, this information has been transformed into excel documents to link data to each other in order to calculate the different ratios. The information consists of 3 tables (Appendix II) in which the following is shown; delivery time, number of times that products were delivered on time and the number of products accepted by the quality department. As a result, these 3 tables were then merged into one well-arranged table on which the results are displayed on the quantitative criteria. However, the criteria lead time will be displayed as a qualitative criteria later on. Because of the amount of days does not clarify if this is a long or short delivery time. This must be determined by the business decision makers based on the quantitative data of the lead time criteria. The clear table has been reduced to the top 25 suppliers of ESS based on purchasing volume. Furthermore, the results are shown on the next page in Figure 11. These results will be entered in the supplier evaluation scheme per supplier so that the final score can be determined per supplier. In the end, the results were presented to the business decision makers in the last workshop. This validates the results to ensure that the results are correct. Human errors can always be made in the system, and checking the results provides assurance that the results match reality.

Name	Acceptatie ratio	Leadtime	Ontime
Supplier 1	97%	35	30%
Supplier 2	99%	21	33%
Supplier 5	100%	17	77%
Supplier 8	100%	10	58%
Supplier 11	100%	14	79%
Supplier 12	100%	8	75%
Supplier 13	97%	11	26%
Supplier 14	94%	63	0%
Supplier 17	95%	26	26%
Supplier 18	100%	14	46%
Supplier 22	99%	32	28%
Supplier 24	99%	23	56%
Supplier 27	100%	32	46%
Supplier 29	84%	36	55%
Supplier 32	100%	101	3%
Supplier 34	91%	25	5%
Supplier 35	91%	22	77%
Supplier 43	100%	21	61%
Supplier 45	100%	31	0%
Supplier 47	100%	14	37%
Supplier 50	91%	32	19%
Supplier 58	100%	21	23%
Supplier 65	99%	18	58%
Supplier 70	86%	51	9%
Supplier 74	98%	25	31%

Figure 11. Assessment of quantitative criteria for top 25 suppliers

4.3.2 Assessment on qualitative criteria

In the last workshop, the supplier is assessed on the qualitative criteria; quality control at the supplier, price per product, supplier accessibility, quality of the communication, technical capability and knowledge/patens. Use was made of the descriptions per score shown in Appendix I. As a result, every participant in the workshop has a clear picture of which requirements the performance of a supplier must meet in order to achieve a high score. The results on the qualitative criteria from the last workshop are shown in Figure 12. These scores are not yet the effective scores, these scores are given by the business decision makers to the supplier per criteria on a rating of 0-100.

Supplier	Qcontrol	Price	Supplier accessibility	Qcommunication	Lead Time	Technicalcapability	Knowledge
Supplier 1	85%	70%	30%	39%	55%	90%	95%
Supplier 2	70%	80%	95%	95%	90%	90%	85%
Supplier 5	75%	80%	80%	90%	70%	85%	95%
Supplier 8	95%	90%	85%	85%	95%	50%	50%
Supplier 11	90%	70%	90%	90%	80%	90%	90%
Supplier 12	90%	90%	80%	80%	80%	50%	50%
Supplier 13	95%	70%	85%	85%	80%	50%	50%
Supplier 14	60%	80%	60%	60%	70%	95%	85%
Supplier 17	55%	85%	55%	55%	55%	90%	95%
Supplier 18	95%	70%	80%	70%	85%	95%	95%
Supplier 22	75%	85%	90%	65%	60%	80%	60%
Supplier 24	85%	90%	90%	80%	60%	95%	95%
Supplier 27	90%	60%	90%	75%	80%	70%	80%
Supplier 29	85%	85%	90%	78%	55%	95%	95%
Supplier 32	95%	75%	90%	65%	60%	50%	50%
Supplier 34	80%	40%	90%	60%	75%	90%	80%
Supplier 35	90%	75%	85%	85%	75%	50%	50%
Supplier 43	90%	55%	80%	75%	65%	90%	85%
Supplier 45	90%	85%	90%	90%	80%	95%	90%
Supplier 47	90%	90%	90%	90%	90%	95%	95%
Supplier 50	90%	60%	90%	85%	80%	60%	80%
Supplier 58	90%	60%	90%	75%	80%	95%	90%
Supplier 65	80%	90%	90%	40%	85%	80%	80%
Supplier 70	55%	60%	65%	40%	55%	70%	70%
Supplier 74	85%	90%	90%	80%	78%	85%	90%

Figure 12. Assessment of qualitative criteria for top 25 suppliers

4.3.3 Final end scores per supplier

In Figure 12, the final end scores per suppliers are shown. Therefore, this final end score is based on the assessment of a supplier on both the qualitative and quantitative criteria multiplied by the importance per criteria. Also referred to as the total effective score per supplier. Also, a sequence has been maintained from the best-performing suppliers to the worst-performing supplier.

Supplier	Final score	Supplier	Final score	Supplier	Final score
Supplier 11	86,7%	Supplier 45	80,7%	Supplier 22	73,1%
Supplier 47	86,5%	Supplier 2	79,7%	Supplier 32	72,0%
Supplier 8	85,8%	Supplier 43	79,0%	Supplier 1	70,0%
Supplier 12	84,0%	Supplier 29	78,9%	Supplier 34	66,4%
Supplier 18	82,9%	Supplier 27	78,6%	Supplier 17	66,2%
Supplier 24	82,8%	Supplier 65	78,5%	Supplier 14	66,1%
Supplier 5	82,6%	Supplier 58	78,0%	Supplier 70	56,0%
Supplier 74	81,2%	Supplier 13	77,5%		
Supplier 35	80,9%	Supplier 50	74,8%		

Figure 13. Final scores based on effective weights

Based on Table 16, the suppliers are divided into three groups using the scores from Figure 13. The subdivision of suppliers is made on the basis of the overall performance of the supplier. As shown in Figure 14, poor-performing suppliers will be said goodbye, mediocre performance needs to be improved and good performance suppliers will be mapped so that other suppliers can learn from this.

Final score	*Action*
Say goodbye (0-60 points)	Supplier 70
Needs improvement (61-80 points)	Supplier 1, 2, 13, 14, 17, 22, 27, 29, 32, 34, 43, 50, 58 & 65
Good performance (81-100 points)	Supplier 5, 8, 11, 12, 18, 24, 35, 45, 47 & 74

Figure 14. Suppliers divided into three groups based on Table 17

There is only one supplier that needs to be said goodbye to according to Figure 14. This supplier scores on several criteria below par with too many points having to be improved before the supplier performs to the standard of ESS. In addition, there are 14 suppliers that have to implement improvements in order to meet the standard of ESS. The general tendency for these mediocre performing suppliers is that improvements must be made in terms of quality, delivery and communication. However, where the communication criteria are scored reasonably well, but really small improvements must be made to perform excellently on the criterion support. Thereby, slightly larger improvements must be made to the criteria quality and delivery. Mainly the criterion quality control at suppliers must be raised to a higher level in order to reach a better performance. At the moment, it is noticeable that quite a few suppliers do not carry out an own quality check before the goods are sent to ESS. With regard to the criterion delivery, the on-time delivery of goods is a point of particular interest. The lead time of suppliers is experienced as sufficient, with some suppliers perhaps could the lead time be slightly accelerated according to the business decision makers of ESS. On-time delivery is very poor at the mediocre suppliers. However, this also applies to a number of high-performing suppliers. This criterion, on time delivery, is the criterion that needs to be improved most. This is because almost all suppliers do not achieve a sufficient score on this criterion.

4.4 Adding a second dimension in the supplier evaluation model

4.4.1 The reason why suppliers perform in a certain way

As mentioned in Chapter 3.3.3, a second dimension will be added to the supplier evaluation model. This allows the results to be better interpreted and gives the reason why suppliers perform in a certain way. By finding out why a certain supplier performs at a certain level, the buying company can set up a better supplier development program to increase performance. By implementing this dimension, it is indicated where the issues lie and how this can be resolved or improved by the supplier in collaboration with ESS.

Firstly, it is striking that the acceptance ratio of goods is high while the suppliers perform poorly in terms of quality control. One reason for this, is that a number of orders which not meet the standards of ESS are not returned to the supplier. Goods for which a small adjustment must be made to meet the quality standard of ESS are processed by the technical department within ESS. This takes both time and money for ESS, while the supplier must actually ensure that they immediately meet the quality standard. Therefore, the goods are wrongly accepted for a small part and sometimes the goods still cost time and effort to be processed in the production process.

In addition, the performance on the criterion on-time delivery is very poor according to the data from the ERP system SAP. There are several reasons that make suppliers score so poorly on this criterion. Delivery dates are kept very tight at some suppliers, so it is very likely that suppliers will deliver “late” according to the available data. If this data is compared with the average lead time of the supplier, it can be seen that lead times are not always realistic planned by ESS. Furthermore, the booking of goods sometimes needs a little bit more time, so in reality it is delivered on time but this is not registered in the system. Better communication and working methods with regard to booking goods could solve many problems.

Finally, the criterion support is experienced differently by different perspectives within the organization. The business decision makers who are related to logistics, quality and purchasing experience a more poorer communication with suppliers than where the R&D department can experience this as positive with the exact same supplier. Within the organization, the business decision makers have the opinion that the difference in communication is due to the interests of the supplier. Communication between R&D and supplier provides new trade for the supplier, whereby quality and supply questions can be

experienced as annoying by the supplier. However, it is important to note that this does not clarify every problem regarding the communication between ESS and suppliers.

4.4.2 Assessing second sources

In addition, in the second dimension suppliers will also be compared that can deliver the same type of products. In other words, the second sources of ESS will be compared with each other. Most suppliers are specialized in producing one type of product, but have the expertise and technical capacity to produce other products that other ESS suppliers are specialized in. Because ESS has taken a major interest in its most important suppliers, suppliers cannot be compared on the basis of preferred customer status. ESS has the preferred customer status at all major suppliers. That is why it is important to compare the important suppliers who have the ability to produce each other's products. This can provide an insight into the difference between supplier performance and where this difference comes from. In this way, ESS can learn from different suppliers to increase the level of the supplier portfolio.

Furthermore, supplier *1, 2, 24 & 74* are suppliers who can produce each other's products. These are also three suppliers who produce a high volume and supply the most important materials for ESS. Because these suppliers provide important materials for the assembling process and are similar in terms of product type, the suppliers are compared with each other to gain a better understanding of the second sources of ESS.

Supplier	Acceptance ratio	Qcontrol	Price	Accessibility	Qcommunication	Lead Time	On time delivery	Technicalcapability	Knowledge	Final score
Supplier 1	97%	85%	70%	30%	39%	55%	30%	90%	95%	70,0%
Supplier 2	99%	70%	80%	95%	95%	90%	33%	90%	85%	79,7%
Supplier 24	99%	85%	90%	90%	80%	60%	56%	95%	95%	82,8%
Supplier 74	98%	85%	90%	90%	80%	78%	31%	85%	90%	81,2%

Figure 15. Comparing second sources for ESS

The results of the comparison between the second sources of ESS are shown in Figure 15. The red cells in Figure 14 are the results that are below the 80% limit. Therefore, the supplier must make some improvements on these criteria which are below the 80% limit. Supplier 1 has the most red cells and therefore needs to improve on most criteria. In addition, the overall performance with 70.0% is also the lowest in comparison with other suppliers. Supplier 1 can learn the most from other suppliers on the criteria support while other suppliers perform much better on these two sub criteria. The problems arise in communication are mainly experienced in the field of logistics, in contrast to communication with the R&D department where the communication is perceived as excellent.

Moreover, it is striking that all core suppliers perform poorly in terms of lead time and on-time delivery of goods. It is plausible that the reason of poor performance on these criteria lies with both ESS and the supplier. The reasons for this may be the tight scheduling of deliveries by ESS and the poor communication between the two parties to achieve an optimum planning. Communication can help to coordinate the production and logistics planning of both ESS and the supplier. Since the development of poor delivery can be observed at all core suppliers, ESS will also have to improve in terms of communication with the supplier.

Finally, the quality control at supplier 2 require some improvement in order to be considered as good. It is the only supplier that underperforms on this criterion while comparable suppliers perform excellently at the sub criterion quality control. Therefore, supplier 2 can learn from the working methods of the other core suppliers to improve the quality of its products. In addition, it is also necessary to take this step so that the final score of the supplier exceeds the 80% limit in order to be considered as a well-performing supplier.

The overall performance of the core suppliers can be described as excellent. Two of the four suppliers perform below 80%, with one supplier taking a small step to qualify as a high-performing supplier. In general, it can be ascertained that the group of core supplier perform well. However, there is one supplier that must improve on several criteria in order to be considered as a well-performing supplier.

4.4.3 Action points for improvement for suppliers

The performance of the suppliers has been mapped and it is clear where the issues lie with the suppliers of ESS. A number of action points will be displayed in this subchapter that can raise the level of the supplier portfolio.

Most suppliers perform poorly on the criterion delivery. Of this, suppliers perform reasonably on the sub-criterion lead time, with dramatic performance on the on-time delivery criterion. In order to improve the performance on these criteria, better communication is needed with the supplier in the field of deliveries. At the moment, deliveries are very tightly planned by ESS, which making it difficult to achieve an on-time delivery for multiple suppliers. Naturally, suppliers sometimes do not deliver on time, but this is partly due to the high pressure on suppliers. ESS should better coordinate the planning with the suppliers in order to realize a more fluid process in the supply chain.

Finally, it is important to take the criterion quality control at suppliers to a higher level. Within the organization ESS, a method is developed for checking incoming and outgoing goods in terms of quality. Suppliers could learn from this by looking into the working method of ESS. The knowledge of performing a good quality control is in fact present within ESS and the organization could benefit from it if this knowledge is shared with their suppliers. In short, the bottom line is that ESS generally needs to strengthen its ties with its suppliers. Intensifying cooperation should create benefits for efficiency in the supply chain for both parties.

4.5 Obtaining qualitative and quantitative data in order to design a new supplier evaluation scheme

In this chapter, the results of designing a supplier evaluation scheme are shown. First, the criteria of the supplier evaluation model are drawn up by combining the literature with the empirical results of the workshop with the business decision makers of ESS. After that, the assumptions of the pairwise comparison have been completed and the pairwise comparison process have been carried out in order to determine the importance per criteria. The design of the supplier evaluation scheme with criteria and the importance per criteria is shown in

Table 1.

The next step is to assess the supplier performance via a workshop with the business decision makers. The performance of suppliers is measured on quantitative and qualitative criteria. The quantitative data is collected through the ERP system of ESS. This data has also been verified in the workshops to check whether the data corresponds to reality. In addition, the qualitative criteria were also measured by organizing workshops with the business decision makers of ESS. Moreover, the quantitative results can be better explained by obtaining qualitative data about suppliers through workshops. The suppliers were discussed in detail on the basis of all the criteria previously drawn up in Table 18. The suppliers were assessed on all these aspects by the business decision makers of ESS.

Finally, a second dimension has been added to the supplier evaluation model to explain why certain suppliers perform in a certain way. In this second dimension, second sources are compared with each other which are the core suppliers of ESS. All suppliers in this group are specialized in a certain type of product. However, these suppliers can also produce each other's products when necessary. This comparison has been made so that the poorly performing supplier(s) can learn from the well-performing suppliers. Within the group of core suppliers, it is shown that the whole group is scoring very low on the criterion delivery. This has several causes due to the tight planning of ESS and simply the late deliveries of the supplier. Therefore, this can be improved by finding a better coordination with suppliers with regard to delivery planning. In addition, ESS should connect their core suppliers to each other so that suppliers can learn from each other. This will allow ESS to ensure better performance in the core supplier portfolio.

5. Model: design of the new supplier evaluation scheme for ESS and the implementation steps to accomplish a practical approach

5.1 Display ESS's supplier evaluation scheme based on literature and empirical results in order to measure suppliers' performances

In this chapter, the designed supplier evaluation scheme based on this research is shown in Figure 16. Figure 10 shows that only the criterion *quality* makes a huge difference in the pairwise comparison in determining the weighting factor of the criteria. The other criteria on which a supplier is assessed are reasonably close to each other in terms of importance. Also, in the newly designed supplier evaluation scheme the trend can be recognized that the criterion *costs* are considered less important as quality and delivery. However, the cost criteria remain an important decision factor when choosing to continue or stop working with a supplier. Although the green supplier evaluation criteria are rising enormously in popularity, these criteria were not included in this study due to the environment of the ESS organization. However, it is strongly recommended that similar criteria be added to a supplier evaluation or selection scheme of companies.

Criteria	*Sub criteria*	*Effective weight*	*Score (0-100)*	*Effective score*
Quality	Acceptance ratio	16.8%		
	Quality control at the supplier	25.2%		
Delivery	Lead time	10.5%		
	On time delivery	10.5%		
Support	Supplier accessibility	2.8%		
	Quality of communication	11.2%		
Costs	Price per product	14%		
Innovativeness	Technical capability	6%		
	Knowledge/patents	3%		
			Final End Score	

Figure 16. The supplier evaluation scheme for each supplier

5.2 Benefits of a supplier evaluation scheme: improvement of efficiency and collaboration between buyer and supplier

The biggest advantage of evaluating suppliers is that it provides an insightful picture of supplier performance. Based on the supplier evaluation, business decision makers can make better and well-founded decisions in the field of cooperation between buyer and supplier. By gaining in-depth insight into supplier performance, the organization can take action to improve or stop the cooperation between buyer and supplier. In addition, such an overview indicates the exact points where a supplier can or must improve. In this way, the buyer can directly manage the supplier's performance that can lead to a more efficient collaboration.

Thereby, a supplier evaluation scheme provides an advantage for current employees. By setting conditions and monitoring supplier performance, employees know better which requirements a supplier must meet. Within the organization, it is also clear which factors are important when working with suppliers. Therefore, a supplier evaluation scheme helps in creating new Key Performance Indicators (KPIs) for suppliers. A more well-founded signal is hereby sent to suppliers and concrete improvements can be made by the supplier.

5.3 Implementation: support of in-real time data to reach a more efficient supplier evaluation process

The process of designing a supplier evaluation scheme went smoothly, but improvements can still be made during the evaluation of suppliers. In this study, the group of suppliers was reduced to the top 25 suppliers of ESS. As mentioned before, one of the barriers for organizations when evaluating suppliers is the reduction of the group of suppliers to keep a clear overview of the evaluation. [87] However, the organization must strive for an evaluation in which all suppliers are included in the assessment. Therefore, the so-called "unimportant" suppliers should also be assessed.

In addition, a barrier that has not been resolved in this study is the use and creation of in-real-time data to speed up the supplier evaluation process. [88] By using in-real time data, a supplier evaluation can take place at any time. At the moment this is not yet possible within the ESS organization because the ERP systems have not yet been adapted to this. Nowadays, little or no supplier evaluation takes place to monitor performance. As a result, it is important that the systems are better adapted to each other to enable in-time supplier evaluation. This will ensure that ESS can have an efficient supplier evaluation at any time.

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[87] See (Sundtoft Hald & Ellegaard, 2011) p.5.
[88] See (Sundtoft Hald & Ellegaard, 2011) p.6.

Finally, the use of in-real-time data will reduce the time of evaluating suppliers. The process is in fact accelerated and simplified by the use of in-real-time data. Therefore, it is strongly recommended to generate in-real-time data in the future for evaluating suppliers to make this process more efficient and effective.

5.4 Evaluation of the new supplier evaluation model

After the supplier evaluation model has been designed through the use of literature and workshops with the business decision makers of ESS, it is important to evaluate the model. The criterion used in this study was determined by the business decision makers. However, 2 sub criteria have been added from the literature. Namely, *knowledge* & *quality control at the supplier*. These criterion in the model has been used because it meets the needs of ESS when it comes to measuring supplier performance.

The active role of ESS business decision makers is due to the fact that they know best which criteria suit ESS. The literature shows that criterion as *quality* & *delivery* play a major role in evaluating suppliers. However, the importance of each criteria is different for each organization. This has to do with the environment, industry and strategy of the company. For example, a company with a cost strategy has a different understanding of supplier assessment than a company that strives for high quality products.

Furthermore, the designed supplier evaluation model is unfortunately not universally applicable for other organizations. Lessons can be learned from the importance of different criterion. ESS trades with suppliers in the same environment, so there is little focus for CSR. It is assumed that suppliers operates in a sensible manner, for another company as ESS located in a different environment, they may find this very important to measure. This makes the model not universally applicable for other companies. In addition, ESS will also have to evaluate the criterion once every 2 years to see whether these criterion are still applicable to ESS. Because of the growth phase of ESS, it may be that the considerations in evaluating suppliers may change over the years. In the future, research could be done on the impact of a company's strategy on supplier assessment. In order to research this impact, the following hypothesis could be used: Do different companies focus on different supplier assessment criteria when there are different strategies among these companies?

To conclude, the model to assess suppliers has a good effect on ESS. However, this model is not universally applicable due to different environments of companies. In addition, the model takes the growth phase into account in which ESS finds itself, but here a review of the used and weighted criterion must take place in a few years' time.

5.5 A new design with a second dimension for evaluating suppliers

In this chapter, the model is shown on which suppliers are assessed in this study. The criteria that have been drawn up by the business decision makers confirm the literature. Namely, an equal ranking is indicated in the literature in the importance of the criteria. After that, the benefits are indicated from an evaluation schedule for ESS. A new supplier evaluation scheme provides an insightful picture of the supplier performance of ESS. In addition, ESS can better manage suppliers on KPIs that are set up on data. Finally, the implementation of the supplier evaluation scheme was discussed. By using and creating in-real-time data within the organization, the process of supplier evaluation can be a lot more efficient and effective. In this way, the process can be carried out at any time with the entire set of suppliers instead of assessing a small selection of suppliers.

6. Discussion: limitations in this study and possible future influences on supplier evaluating schemes for manufacturing companies

6.1 Contribution to the literature: Comparing multiple suppliers in the second dimension

Currently, there is a lot of written about the process of supplier evaluation. In almost all articles in the literature, the process of supplier evaluation is about defining criteria, importance and the method of calculating supplier performances.[89] However, there was a lack of comparing the performance of suppliers with each other.

In this research a second dimension has been added whereby second sources are compared with each other. Second sources are suppliers who can supply the same type of material / products. Moreover, this small group of suppliers is magnified to gain a better understanding between the ratio of the most important suppliers. Furthermore, this better understanding must lead to a good supplier development plan in order to improve the performance of suppliers who supply the most important equipment to ESS.

The reason why no dimension was added based on the preferred customer status[90] of ESS at suppliers is as follows; for a company that has the preferred customer status by many suppliers, it is not relevant to compare the performance of suppliers, where you are a preferred customer with one supplier and not with the other. In the situation of ESS, many suppliers are largely dependent on ESS. Especially, the suppliers that supply the core material are dependent on ESS and are therefore forbidden to supply to ESS's competitors. Therefore, the situation of ESS is unique in the literature where the most important suppliers are dependent on ESS.

6.2 Managerial implications: an update of the criteria in the supplier evaluation process according to the AHP method

Firstly, this research provides information about performing a supplier evaluation process according to the AHP method. This research was conducted by organizing workshops with business decision makers who collaborate with suppliers from different perspectives. By holding these workshops, the criteria were determined and the importance of these criteria was identified. Furthermore, this study has measured the popularity of criteria on which suppliers must be assessed according to practice and literature. As a result, this study shows, the criteria *support* making a slow rise in popularity and importance. This is probably due to

[89] See (Ho, Xu & Dey, 2010), p.3.
[90] See (Schiele, Calvi & Gibber, 2012) p.16.

the fact that relationships between buying firms and suppliers are becoming increasingly important.[91]

Secondly, the implementation process of a supplier evaluation scheme is shown. It is indicated how certain barriers can be overcome. After that, the results of the supplier evaluation process are displayed. Based on the results, an action plan has been defined as what actions a purchasing organization needs to take regarding the supplier. Therefore, the supplier is subdivided into three groups; poorly performing suppliers, suppliers that need improvement, and well-performing suppliers.

Finally, this research has implications for other companies that are willing to implement a supplier evaluation scheme. However, such a company needs to have similar characteristics as Easy Sanitary Solutions. Such a company can use the supplier evaluation scheme to assess supplier performance. However, such a company will have to assess the performance in a workshop with their business decision makers. This research provides the supplier evaluation scheme where suppliers should be assessed on.

6.3 Limitations and future research: Internet of Things and Industry 4.0 can improve supplier evaluation schemes efficiency

In the future, it could be investigated whether the *Internet of Things* (IoT) & *Industry 4.0* leads to a more efficient and effective way of supplier evaluation. Mainly connecting different links in the supply chain can increase the speed of supplier evaluation. As a result, this will allow a faster and better in-real time supplier evaluation.

At the moment, there are already several studies that support that IoT can contribute to a more efficient supply chain management. Therefore, these IoT technologies and sensors are often used to measure actual events within the supply chain.[92] However, it has not yet been investigated how these applications can contribute to a more efficient and effective supplier evaluation model. The IoT applications already generate data from actual events on which a supplier is assessed. However, there are no researches about supplier evaluation schemes that present these applications in one overview.

In addition, Shrouf & Miragliotta (2015) mentioned that through the use of smart meters (IoT) more accurate KPIs can be drawn up so that performance evaluation can be

[91] See (Krause, Handfield & Tyler, 2007) p.528.
[92] See (Abdel-Basset, Manogaran & Mohamed, 2018) p.13.

improved.[93] A better visualization of actual performance means that the results are measured more accurately, which increases the reliability and validity of supplier evaluation.

Moreover, Industry 4.0 can make supplier evaluation more efficient on the fact that fewer people are needed to collect information. Industry 4.0 offers various solutions in the field of Just in Time (JIT) delivery by suppliers. This research has shown that JIT delivery is extremely important in the assessment of suppliers. The application of Industry 4.0 results in *wireless tracking of goods, smart reallocation of orders & item tagging*. [94] The consequences of applying Industry 4.0 ensures that suppliers perform better on the criteria Delivery. However, this requires a good cooperation in the buyer supplier relationship. Therefore, it is important to investigate how a buyer-supplier relationship should be set up to ensure that both parties can benefit from the application of Industry 4.0.

The limitation of such an investigation is that such research must be carried out at large enterprises. At present, SMEs make little or no use of applications such as IoT and Industry 4.0. In order to investigate such an effect or how an organization can best use these applications to improve supplier evaluation, a study must be carried out at several large enterprises. In this study, the limitations lie primarily in the use of criteria described in the literature. Most literature about criteria on which a supplier must be assessed dates from 2010 or earlier. In recent years, only green supplier evaluation has been written and the traditional criteria have been omitted by multiple researchers. Also, the company where the supplier evaluation process is investigated, is an SME. By conducting the research in a large enterprise, the research will be able to focus more on the use of *Industry 4.0* & *Internet of Things* during the preparation of the supplier evaluation process.

[93] See (Shrouf & Miragliotta, 2015) p.8.
[94] See (Sanders, Elangeswaran & Wulfsberg, 2016) p.828.

7. Conclusion: The supplier evaluation scheme will help ESS to improve the efficiency and reliability of their supply chain

In this chapter, an answer to the following central research question will be given;

> *"How should Easy Sanitary Solutions design and implement a supplier evaluation scheme in order to monitor the performance of suppliers?"*

In order to answer the central research question, firstly a literature review was performed to create a better understanding about designing a supplier evaluation scheme. *Supplier evaluation* is a part of the *supplier management* process as shown in Figure 4. Supplier evaluation is a process whereby the performance of suppliers is monitored in order to gain a better insight into the supplier portfolio. Therefore, the ultimate goal is to make the supply chain more efficient and to raise the supplier portfolio to a higher level. Moreover, the designed supplier evaluation model based on this study is shown in Appendix I. The top 25 suppliers of ESS are assessed on the following criteria; Quality, Delivery, Price, Support & Innovativeness. However, a second qualitative dimension has also been added to the supplier evaluation scheme. This second dimension provides a better explanation of why suppliers perform in a certain way. In addition, comparable suppliers are compared with each other in order to allow suppliers to learn from each other. In this way, it is also possible to manage the supplier development process in a better manner.

Next to this, a good supplier development program is required to raise the supplier portfolio to a higher level. After the evaluation, suppliers are divided into groups that determine whether to say goodbye to the supplier or a development plan is drawn up to improve the performance of suppliers. A supplier development plan identifies the issues that emerged from the evaluation, showing why a supplier is performing that way. Subsequently, action points are given so that the supplier can improve. Furthermore, there will not be a development plan for high-performance suppliers, however, as far as possible, small improvement points will be looked at in a supplier development process to improve the relationship and performance between supplier and buyer.

In the future, new technologies will have to be implemented in the evaluation process to perform a supplier evaluation at any time. In addition, these technologies as IoT & Industry 4.0 give the advantage that these technologies make the supplier evaluation process more efficient and can be more accurately measure the actual performance of suppliers.

To conclude, the implementation of a supplier evaluation scheme will result in a higher level of the supplier portfolio for ESS. For this, it is important that the performance for suppliers is properly monitored in order to provide a clear picture of the state of supplier performance. In addition, it is important that much attention is paid to supplier development to jointly improve performance in the supply chain. This results in a more efficient supply chain for the company ESS. In order to improve the supplier evaluation scheme in the future, this research will have to be carried out again in 3 years. Reason for this, the company ESS is now in a growth phase, which means that the weighting factors of the current criteria can be different than in the future. Therefore, it must be taken into account in which phase the company is located.

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Appendix I

Criteria	Subcriteria	Question	Observed	Points	Weights	Score
Quality	***Acceptance ratio***	What is the number of products from the supplier that are accepted by Quality department?		0	16,8%	0
	Quality control at the supplier	In which extent does the supplier ensure their quality in their process? Where and when is the supplier controlling the quality in their process?		0	25,2%	0
				Total score for the criteria Quality		**0**
Costs	***Price per product***	What are the costs per product in comparison with other suppliers in the market?		0	14%	0
				Total score for the criteria Price		**0**
Support	***Supplier accessibility***	In which extent can a supplier be reached to communicate for questions or remarks?		0	2,8%	0
	Quality of communication	In which extent is the communication with the experienced as useful and helpful?		0	11,2%	0
				Total score for the criteria Support		**0**
Delivery	***Lead time***	What is the timeframe between placing an order and receiving the goods from the supplier? The extent of extremely long to extremely fast delivery depends on the average delivery time in the market of the supplier.		0	10,5%	0
	On time delivery (Reliability)	What is the number of products that are delivered on time by the supplier?		0	10,5%	0
				Total score for the criteria Delivery		**0**
Innovativeness	***Technical capability***	What is the technical capability to innovate for the supplier?			6%	
	Knowledge/patents	Does the supplier has unique patents and the knowledge to create innovate solutions/products which lead to a better NPD?			3%	
				Total score for the criteria Innovativeness		**0**

0 – 2 (1-20 points)	3 – 4 (21-40 points)	5 – 6 (41-60 points)	7 – 8 (61-80 points)	9 – 10 (81-100 points)
The percentage of accepted product is between 0 and 20%. So, there are a very few amount of products accepted by the Quality department of ESS.	The percentage of accepted product is between 21 and 40%. So, there are a few amount of products accepted by the Quality department of ESS.	The percentage of accepted product is between 41 and 60%. So, there are an acceptable amount of products accepted by the Quality department of ESS.	The percentage of accepted product is between 61 and 80%. So, there are a many amount of products accepted by the Quality department of ESS.	The percentage of accepted product is between 0 and 20%. So, there are an excellent amount of products accepted by the Quality department of ESS.
The supplier does not check the quality of their products at all. So, there is no control and insight of the quality at all.	The supplier ensure the quality of their products before the products are send to the customer.	The supplier ensure the quality of their products at the start and the end of their production process. So, the quality of products can be controlled towards the supplier of the supplier	The supplier ensure the quality of their products at the start and the end of their production process. Also, the supplier has certifcates to ensure the quality of their products	The supplier ensure the quality of their products at the start and the end of their production process and ensure quality with certificates. Thereby, the supplier works with local suppliers to mitigate risk.
The supplier is more than 2% more expensive than the competition in the market.	The supplier is 0-2% more expensive than the competition in the market.	The supplier has a acceptable price per product in comparison with the competition	The supplier is 0-2% cheaper than the competition in the market.	The supplier is more than 2% cheaper than the competition in the market.
The supplier is very poorly accessible which makes the supplier very difficult to reach. They are not only in emergence situations poorly to reach but also in standard situations	The supplier is poorly accessible during emergence situations. However, in standard situations the accessibility of the supplier is acceptable.	The supplier is an acceptable amount of time accessible in standard and emergence situations.	The supplier easily accessible in emergence and standard situations via at least 1 channel (phone or email).	The supplier is always to reach via multiple channels (phone and email). The response time for emails is quick and the supplier is always accessible via the phone.
The quality of communication with the supplier is experienced as very poor and not helpful/useful. So, there is a lack of knowledge and/or during the communication people do not understand each other.	The quality of communication is experienced as poor and not helpful. There is not a great intention to improve the relationship by the supplier.	The quality of communication with the supplier is acceptable and sometimes useful. However, there is room for improvement in the quality for advices.	The quality of communication with the supplier is experienced as excellent and helpful. The knowledge is acceptable and the supplier is keen to share their information.	The quality of communication with the supplier is experienced as excellent and very helpful. So, the suppliers has a lot of knowledge about the process and are willing to share information.
There is a extremely long delivery time by the supplier in comparison with the average delivery time of their competition.	There is a long delivery time of the supplier in comparison with the average delivery time of their competition.	The supplier ensures an acceptable delivery time which is comparable with the average market delivery time.	The suppliers' delivery time is slightly shorter than the average market delivery time.	The supplier delivery time is shorter than the average market delivery time and performs above expectation.
The percentage of products delivered on time by the supplier is between 0 and 20%. So, a very few amount of products are delivered on time by the supplier.	The percentage of products delivered on time by the supplier is between 21 and 40%. So, a few amount of products are delivered on time by the supplier.	The percentage of products delivered on time by the supplier is between 41 and 60%. So, an acceptable amount of products are delivered on time by the supplier.	The percentage of products delivered on time by the supplier is between 61 and 80%. So, a many amount of products are delivered on time by the supplier.	The percentage of products delivered on time by the supplier is between 81 and 100%. So, almost all products are delivered on time by the supplier. If the score reach 100%, all products are delivered on time.
The technical capability of the supplier is extremely low.	The technical capability of the supplier is low.	The technical capability of the supplier is extremely high.	The technical capability of the supplier is high.	The technical capability of the supplier is extremely high.
The unique patents/knowledge does not contribute to a better NPD.	The unique patents/knowledge has a little contribution to a better NPD.	The unique patents/knowledge has an accceptable impact in order to achieve a better NPD.	The unique patents/knowledge of the supplier has a high contribution in order to achieve a better NPD.	The unique patents/knowledge of the supplier has an extremely high contribution in order to achieve a better NPD.

Appendix II

1. Acceptance ratio

Name	Totaal	Geretourneerd	Waarde	% return	% acceptance
Supplier 1	196.313	4.948	€ 77.709	3%	97%
Supplier 2	1.172.480	10.085	€ 137.461	1%	99%
Supplier 3	597.342	-00	€ -00	0%	100%
Supplier 4	400	-00	€ -00	0%	100%
Supplier 5	4.503.628	12.826	€ 13.387	0%	100%
Supplier 6	702.365	-00	€ -00	0%	100%
Supplier 7	6.732	-00	€ -00	0%	100%
Supplier 8	110.802	7	€ 7	0%	100%
Supplier 9	23.000	-00	€ -00	0%	100%
Supplier 10	171.600	-00	€ -00	0%	100%
Supplier 11	334.184	-00	€ -00	0%	100%
Supplier 12	1.800.000	-00	€ -00	0%	100%
Supplier 13	10.422.770	325.258	€ 1.627	3%	97%
Supplier 14	7.224	421	€ 2.947	6%	94%
Supplier 15	240.000	-00	€ -00	0%	100%
Supplier 16	24	12	€ 1.080	50%	50%
Supplier 17	149.609	7.771	€ 31.758	5%	95%
Supplier 18	104.200	-00	€ -00	0%	100%
Supplier 19	20.048	-00	€ -00	0%	100%
Supplier 20	15.200	-00	€ -00	0%	100%
Supplier 21	81.600	-00	€ -00	0%	100%
Supplier 22	3.619.076	27.860	€ 2.946	1%	99%
Supplier 23	55	-00	€ -00	0%	100%
Supplier 24	692.042	7.385	€ 77.754	1%	99%
Supplier 25	67.200	38.200	€ 372	57%	43%
Supplier 26	640.000	-00	€ -00	0%	100%
Supplier 27	2.077.514	-00	€ -00	0%	100%
Supplier 28	7.500	-00	€ -00	0%	100%
Supplier 29	91.676.893	14.307.066	€ 267.408	16%	84%
Supplier 30	110.000	-00	€ -00	0%	100%
Supplier 31	154	-00	€ -00	0%	100%
Supplier 32	3.160.062	14.348	€ 16.413	0%	100%
Supplier 33	100	-00	€ -00	0%	100%
Supplier 34	971	92	€ 6.334	9%	91%
Supplier 35	5.328	488	€ 6.495	9%	91%
Supplier 36	1.000	747	€ 190	75%	25%
Supplier 37	2.200	-00	€ -00	0%	100%
Supplier 38	2.500	-00	€ -00	0%	100%
Supplier 39	9.000	-00	€ -00	0%	100%
Supplier 40	249.300	-00	€ -00	0%	100%
Supplier 41	15.000	-00	€ -00	0%	100%

Supplier 42	261.170	3.058	€ 11.111	1%	99%
Supplier 43	87.050	-00	€ -00	0%	100%
Supplier 44	225.000	1.000	€ 257	0%	100%
Supplier 45	26.420	94	€ 435	0%	100%
Supplier 46	6	6	€ 307	100%	0%
Supplier 47	364.500	-00	€ -00	0%	100%
Supplier 48	3.200	-00	€ -00	0%	100%
Supplier 49	200	-00	€ -00	0%	100%
Supplier 50	2.629	240	€ 24.000	9%	91%
Supplier 51	12.000	-00	€ -00	0%	100%
Supplier 52	260	-00	€ -00	0%	100%
Supplier 53	500	-00	€ -00	0%	100%
Supplier 54	16	-00	€ -00	0%	100%
Supplier 55	400	-00	€ -00	0%	100%
Supplier 56	1.000	31	€ 130	3%	97%
Supplier 57	100	-00	€ -00	0%	100%
Supplier 58	21.511	-00	€ -00	0%	100%
Supplier 59	30	-00	€ -00	0%	100%
Supplier 60	5.000	-00	€ -00	0%	100%
Supplier 61	10.250	-00	€ -00	0%	100%
Supplier 62	16	-00	€ -00	0%	100%
Supplier 63	6.000	-00	€ -00	0%	100%
Supplier 64	1.152	-00	€ -00	0%	100%
Supplier 65	10.710	152	€ 1.649	1%	99%
Supplier 66	5.000	-00	€ -00	0%	100%
Supplier 67	5.000	-00	€ -00	0%	100%
Supplier 68	2.000	-00	€ -00	0%	100%
Supplier 69	8.500	-00	€ -00	0%	100%
Supplier 70	5.057	712	€ 14.848	14%	86%
Supplier 71	2.600	-00	€ -00	0%	100%
Supplier 72	2.250	15	€ 293	1%	99%
Supplier 73	16.725	-00	€ -00	0%	100%
Supplier 74	38.021	847	€ 15.429	2%	98%
Supplier 75	60.000	-00	€ -00	0%	100%
Supplier 76	820	-00	€ -00	0%	100%
Supplier 77	4.200	-00	€ -00	0%	100%
Supplier 78	810	-00	€ -00	0%	100%
Supplier 79	470	32	€ 192	7%	93%
Supplier 80	1.000	-00	€ -00	0%	100%
Supplier 81	22.000	-00	€ -00	0%	100%
Supplier 82	1.000	-00	€ -00	0%	100%
Supplier 83	40	-00	€ -00	0%	100%
Supplier 84	134	-00	€ -00	0%	100%
Supplier 85	3.000	-00	€ -00	0%	100%
Supplier 86	200	-00	€ -00	0%	100%
Supplier 87	2.000	-00	€ -00	0%	100%

2. On time delivery

Name	Total deliveries	Total products	Late deliveries	Late products	% late deliveries	% on time deliveries
Supplier 1	1.638	196.313	1.236	137.795	70%	30%
Supplier 2	3.121	1.172.480	1.682	786.196	67%	33%
Supplier 3	306	597.342	122	167.602	28%	72%
Supplier 4	2	400	1	200	50%	50%
Supplier 5	644	4.503.628	206	1.028.588	23%	77%
Supplier 6	39	702.365	36	439.338	63%	37%
Supplier 7	1	6.732	1	6.732	100%	0%
Supplier 8	181	110.802	157	46.696	42%	58%
Supplier 9	10	23.000	5	10.600	46%	54%
Supplier 10	10	171.600	4	150.400	88%	12%
Supplier 11	15	334.184	6	69.848	21%	79%
Supplier 12	5	1.800.000	2	456.000	25%	75%
Supplier 13	78	10.422.770	67	7.715.714	74%	26%
Supplier 14	10	7.224	10	7.224	100%	0%
Supplier 15	6	240.000	2	60.000	25%	75%
Supplier 16	1	24	0	0	0%	100%
Supplier 17	217	149.609	150	110.479	74%	26%
Supplier 18	18	104.200	12	56.200	54%	46%
Supplier 19	9	20.048	5	10.000	50%	50%
Supplier 20	5	15.200	4	13.200	87%	13%
Supplier 21	4	81.600	2	27.840	34%	66%
Supplier 22	175	3.619.076	143	2.616.076	72%	28%
Supplier 23	2	55	2	55	100%	0%
Supplier 24	1.029	692.042	548	307.904	44%	56%
Supplier 25	2	67.200	1	33.600	50%	50%
Supplier 26	16	640.000	12	440.000	69%	31%
Supplier 27	50	2.077.514	33	1.130.248	54%	46%
Supplier 28	3	7.500	0	0	0%	100%
Supplier 29	495	91.676.893	285	41.195.565	45%	55%
Supplier 30	7	110.000	6	60.000	55%	45%
Supplier 31	3	154	2	102	66%	34%
Supplier 32	766	3.160.062	747	3.078.209	97%	3%
Supplier 33	1	100	1	100	100%	0%
Supplier 34	25	971	23	919	95%	5%
Supplier 35	5	5.328	2	1.200	23%	77%
Supplier 36	2	1.000	2	1.000	100%	0%
Supplier 37	1	2.200	1	2.200	100%	0%
Supplier 38	1	2.500	1	2.500	100%	0%
Supplier 39	2	9.000	2	6.000	67%	33%
Supplier 40	17	249.300	8	110.300	44%	56%
Supplier 41	3	15.000	1	2.000	13%	87%

Supplier 42	112	261.170	106	218.070	83%	17%
Supplier 43	14	87.050	7	34.050	39%	61%
Supplier 44	9	225.000	7	175.000	78%	22%
Supplier 45	42	26.420	42	26.420	100%	0%
Supplier 46	1	6	0	0	0%	100%
Supplier 47	40	364.500	28	231.000	63%	37%
Supplier 48	3	3.200	3	3.200	100%	0%
Supplier 49	1	200	1	200	100%	0%
Supplier 50	20	2.629	16	2.129	81%	19%
Supplier 51	3	12.000	3	12.000	100%	0%
Supplier 52	6	260	6	260	100%	0%
Supplier 53	5	500	4	400	80%	20%
Supplier 54	10	16	10	15	94%	6%
Supplier 55	2	400	1	200	50%	50%
Supplier 56	10	1.000	4	500	50%	50%
Supplier 57	1	100	0	0	0%	100%
Supplier 58	159	21.511	108	16.504	77%	23%
Supplier 59	1	30	0	0	0%	100%
Supplier 60	1	5.000	1	5.000	100%	0%
Supplier 61	2	10.250	0	0	0%	100%
Supplier 62	3	16	3	16	100%	0%
Supplier 63	2	6.000	1	2.000	33%	67%
Supplier 64	4	1.152	2	576	50%	50%
Supplier 65	85	10.710	40	4.535	42%	58%
Supplier 66	1	5.000	1	5.000	100%	0%
Supplier 67	1	5.000	1	5.000	100%	0%
Supplier 68	1	2.000	1	1.000	50%	50%
Supplier 69	12	8.500	7	4.500	53%	47%
Supplier 70	43	5.057	36	4.627	91%	9%
Supplier 71	1	2.600	0	0	0%	100%
Supplier 72	5	2.250	4	1.250	56%	44%
Supplier 73	3	16.725	3	16.725	100%	0%
Supplier 74	257	38.021	200	26.262	69%	31%
Supplier 75	6	60.000	6	60.000	100%	0%
Supplier 76	14	820	13	800	98%	2%
Supplier 77	8	4.200	7	4.000	95%	5%
Supplier 78	5	810	1	30	4%	96%
Supplier 79	22	470	11	230	49%	51%
Supplier 80	2	1.000	2	1.000	100%	0%
Supplier 81	3	22.000	0	0	0%	100%
Supplier 82	1	1.000	1	1.000	100%	0%
Supplier 83	1	40	1	40	100%	0%
Supplier 84	2	134	1	84	63%	37%
Supplier 85	2	3.000	1	1.000	33%	67%
Supplier 86	2	200	0	0	0%	100%
Supplier 87	1	2.000	1	2.000	100%	0%

3. Lead time

Name	Leadtime
Supplier 1	35
Supplier 2	21
Supplier 3	8
Supplier 4	10
Supplier 5	17
Supplier 6	9
Supplier 7	45
Supplier 8	10
Supplier 9	6
Supplier 10	20
Supplier 11	14
Supplier 12	8
Supplier 13	11
Supplier 14	63
Supplier 15	10
Supplier 16	6
Supplier 17	26
Supplier 18	14
Supplier 19	30
Supplier 20	48
Supplier 21	10
Supplier 22	32
Supplier 23	28
Supplier 24	23
Supplier 25	19
Supplier 26	12
Supplier 27	32
Supplier 28	13
Supplier 29	36
Supplier 30	26
Supplier 31	15
Supplier 32	101
Supplier 33	7
Supplier 34	25
Supplier 35	22
Supplier 36	27
Supplier 37	35
Supplier 38	138
Supplier 39	47
Supplier 40	12
Supplier 41	9
Supplier 42	17

Supplier 43	21
Supplier 44	38
Supplier 45	31
Supplier 46	1
Supplier 47	14
Supplier 48	24
Supplier 49	35
Supplier 50	32
Supplier 51	20
Supplier 52	31
Supplier 53	27
Supplier 54	61
Supplier 55	12
Supplier 56	10
Supplier 57	41
Supplier 58	21
Supplier 59	5
Supplier 60	32
Supplier 61	15
Supplier 62	32
Supplier 63	5
Supplier 64	21
Supplier 65	18
Supplier 66	28
Supplier 67	29
Supplier 68	32
Supplier 69	14
Supplier 70	51
Supplier 71	8
Supplier 72	28
Supplier 73	34
Supplier 74	25
Supplier 75	28
Supplier 76	9
Supplier 77	16
Supplier 78	9
Supplier 79	18
Supplier 80	60
Supplier 81	5
Supplier 82	1
Supplier 83	8
Supplier 84	7
Supplier 85	18
Supplier 86	1
Supplier 87	28

Appendix III

Supplier	Acceptance ratio	EW1	Quality control at the supplier	EW2	Price per product	EW3	Supplier accessibility	EW4	Quality of communication	EW5	Lead Time	EW6	On time delivery	EW7	Technicalcapability	EW8	Knowledge/patents	EW9	Final score
Supplier 1	97%	0,16	85%	0,2142	70%	0,098	30%	0,0084	39%	0,04368	55%	0,06	30%	0,03	90%	0,054	95%	0,0285	**70,0%**
Supplier 2	99%	0,17	70%	0,1764	80%	0,112	95%	0,0266	95%	0,1064	90%	0,09	33%	0,03	90%	0,054	85%	0,0255	**79,7%**
Supplier 3	100%	0,17	90%	0,2268	60%	0,084	90%	0,0252	95%	0,1064	85%	0,09	72%	0,08	50%	0,03	50%	0,015	**82,0%**
Supplier 5	100%	0,17	75%	0,189	80%	0,112	80%	0,0224	90%	0,1008	70%	0,07	77%	0,08	85%	0,051	95%	0,0285	**82,6%**
Supplier 6	100%	0,17	90%	0,2268	90%	0,126	90%	0,0252	90%	0,1008	90%	0,09	37%	0,04	50%	0,03	50%	0,015	**82,6%**
Supplier 8	100%	0,17	95%	0,2394	90%	0,126	85%	0,0238	85%	0,0952	95%	0,10	58%	0,06	50%	0,03	50%	0,015	**85,8%**
Supplier 10	100%	0,17	100%	0,252	100%	0,14	100%	0,028	100%	0,112	100%	0,11	12%	0,01	100%	0,06	100%	0,03	**90,8%**
Supplier 11	100%	0,17	90%	0,2268	70%	0,098	90%	0,0252	90%	0,1008	80%	0,08	79%	0,08	90%	0,054	90%	0,027	**86,7%**
Supplier 12	100%	0,17	90%	0,2268	90%	0,126	80%	0,0224	80%	0,0896	80%	0,08	75%	0,08	50%	0,03	50%	0,015	**84,0%**
Supplier 13	97%	0,16	95%	0,2394	70%	0,098	85%	0,0238	85%	0,0952	80%	0,08	26%	0,03	50%	0,03	50%	0,015	**77,5%**
Supplier 14	94%	0,16	60%	0,1512	80%	0,112	60%	0,0168	60%	0,0672	70%	0,07	0%	0,00	95%	0,057	85%	0,0255	**66,1%**
Supplier 15	100%	0,17	95%	0,2394	60%	0,084	60%	0,0168	60%	0,0672	70%	0,07	75%	0,08	50%	0,03	50%	0,015	**77,3%**
Supplier 17	95%	0,16	55%	0,1386	85%	0,119	55%	0,0154	55%	0,0616	55%	0,06	26%	0,03	90%	0,054	95%	0,0285	**66,2%**
Supplier 18	100%	0,17	95%	0,2394	70%	0,098	80%	0,0224	70%	0,0784	85%	0,09	46%	0,05	95%	0,057	95%	0,0285	**82,9%**
Supplier 19	100%	0,17	90%	0,2268	70%	0,098	90%	0,0252	90%	0,1008	75%	0,08	50%	0,05	50%	0,03	50%	0,015	**79,5%**
Supplier 22	99%	0,17	75%	0,189	85%	0,119	90%	0,0252	65%	0,0728	60%	0,06	28%	0,03	80%	0,048	60%	0,018	**73,1%**
Supplier 24	99%	0,17	85%	0,2142	90%	0,126	90%	0,0252	80%	0,0896	60%	0,06	56%	0,06	95%	0,057	95%	0,0285	**82,8%**
Supplier 26	100%	0,17	95%	0,2394	80%	0,112	85%	0,0238	85%	0,0952	85%	0,09	31%	0,03	50%	0,03	50%	0,015	**80,5%**
Supplier 27	100%	0,17	90%	0,2268	60%	0,084	90%	0,0252	75%	0,084	80%	0,08	46%	0,05	70%	0,042	80%	0,024	**78,6%**
Supplier 29	84%	0,14	85%	0,2142	85%	0,119	90%	0,0252	78%	0,08736	55%	0,06	55%	0,06	95%	0,057	95%	0,0285	**78,9%**
Supplier 30	100%	0,17	90%	0,2268	90%	0,126	90%	0,0252	90%	0,1008	80%	0,08	45%	0,05	50%	0,03	50%	0,015	**82,4%**
Supplier 32	100%	0,17	95%	0,2394	75%	0,105	90%	0,0252	65%	0,0728	60%	0,06	3%	0,00	50%	0,03	50%	0,015	**72,0%**
Supplier 34	91%	0,15	80%	0,2016	40%	0,056	90%	0,0252	60%	0,0672	75%	0,08	5%	0,01	90%	0,054	80%	0,024	**66,4%**
Supplier 35	91%	0,15	90%	0,2268	75%	0,105	85%	0,0238	85%	0,0952	75%	0,08	77%	0,08	50%	0,03	50%	0,015	**80,9%**
Supplier 40	100%	0,17	90%	0,2268	90%	0,126	90%	0,0252	85%	0,0952	90%	0,09	56%	0,06	50%	0,03	50%	0,015	**83,9%**
Supplier 42	99%	0,17	90%	0,2268	85%	0,119	85%	0,0238	85%	0,0952	80%	0,08	17%	0,02	50%	0,03	50%	0,015	**77,7%**
Supplier 43	100%	0,17	90%	0,2268	55%	0,077	80%	0,0224	75%	0,084	65%	0,07	61%	0,06	90%	0,054	85%	0,0255	**79,0%**
Supplier 44	100%	0,17	90%	0,2268	90%	0,126	90%	0,0252	90%	0,1008	90%	0,09	22%	0,02	50%	0,03	50%	0,015	**80,9%**
Supplier 45	100%	0,17	90%	0,2268	85%	0,119	90%	0,0252	90%	0,1008	80%	0,08	0%	0,00	95%	0,057	90%	0,027	**80,7%**
Supplier 47	100%	0,17	90%	0,2268	90%	0,126	90%	0,0252	90%	0,1008	90%	0,09	37%	0,04	95%	0,057	95%	0,0285	**86,5%**
Supplier 50	91%	0,15	90%	0,2268	60%	0,084	90%	0,0252	85%	0,0952	80%	0,08	19%	0,02	60%	0,036	80%	0,024	**74,8%**
Supplier 58	100%	0,17	90%	0,2268	60%	0,084	90%	0,0252	75%	0,084	80%	0,08	23%	0,02	95%	0,057	90%	0,027	**78,0%**
Supplier 65	99%	0,17	80%	0,2016	90%	0,126	90%	0,0252	40%	0,0448	85%	0,09	58%	0,06	80%	0,048	80%	0,024	**78,5%**
Supplier 70	86%	0,14	55%	0,1386	60%	0,084	65%	0,0182	40%	0,0448	55%	0,06	9%	0,01	70%	0,042	70%	0,021	**56,0%**
Supplier 74	98%	0,16	85%	0,2142	90%	0,126	90%	0,0252	80%	0,0896	78%	0,08	31%	0,03	85%	0,051	90%	0,027	**81,2%**
Weights	**16,80%**		**25,20%**		**14%**		**2,80%**		**11,20%**		**10,50%**		**10,50%**		**6%**		**3%**		**100,00%**

Appendix IV

Keywords	Initial Hits	Limit to 1990-2018	Hits only in relevant subject areas	Usable and assessed papers	Search Key
Supplier evaluation	6542	5894	1276	16	TITLE-ABS KEY (supplier AND evaluation) AND (LIMIT-TO (SUBJAREA , "BUSI"))
Supplier development	21858	19864	5440	8	TITLE-ABS KEY (supplier AND development) AND (LIMIT-TO (SUBJAREA , "BUSI"))
Supplier portfolio management	393	372	175	6	TITLE-ABS-KEY (supplier AND portfolio AND management) AND (LIMIT-TO (SUBJAREA , "BUSI"))
Analytical Hierarchical Process for supplier evaluation	68	64	20	8	TITLE-ABS-KEY (analytical AND hierarchical AND process AND supplier AND evaluation) AND (LIMIT-TO (SUBJAREA , "BUSI"))
Multi criteria decision making for supplier evaluation	404	351	101	6	TITLE-ABS-KEY (multi AND criteria AND decision AND making AND supplier AND evaluation) AND (LIMIT-TO (SUBJAREA , "BUSI"))
Research reliability & validity	31446	21024	1491	7	TITLE-ABS-KEY (research AND reliability AND validity) AND (LIMIT-TO (SUBJAREA , "BUSI"))

Journal	**Papers in Period (2016-2018)**	**Papers relevant according to abstract**	**Usable and assessed papers**	**Keywords**
Journal of Supply Chain Management	8	5	2	*"Supplier performance management" "Supplier evaluation" "fuzzy approach" "Analytical hierarchical process"*
Journal of Cleaner Production	32	11	3	*"CSR for supply chain management" "Supplier sustainability performance evaluation" "Supplier development" "Sustainable supplier selection" "multi-criteria decision making"*
International journal of production and Operations management	2	1	1	"*Supplier innovation evaluation*"
Journal of purchasing and supply management	3	1	0	*"Buyer-supplier relationship"*