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Supplier selection in the fashion industry

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List of Abbreviations

AHP	Analytic Hierarchy Process
KPI	Key Performance Indicators
MACBETH	Measuring Attractiveness by a Categorical Based Evaluation Technique
MADM	Multi-Attribute Decision-Making
MAUT	Multiple Attributes Utility Theory
MCDM	Multi-Criteria Decision-Making
MODM	Multi-Objective Decision-Making
PROMETHEE	Preference Ranking Organization Method for Enrichment Evaluations
SMART	Simple Multi-Attribute Rating Technique
SMARTER	Simple Multi-Attribute Rating Technique Exploiting Ranks

1 Introduction

Supplier selection is of particular importance within the field of logistics. It is seen as an essential success factor for every manufacturing company and its entire supply chain network (Chan et al., 2008, p. 3826; Marufuzzaman et al., 2009, p. 224). The choice of the most appropriate supplier can be made by using different processes, which aim to increase the overall benefit, increase customer satisfaction and minimize the product supplier risks (Chan et al., 2008, p. 3826).

This is also a frequently discussed topic within the fashion industry. The fashion industry is characterized by a constantly changing product range, almost complete dependence on consumers and rising labor costs in emerging countries (Macchion et al., 2014, pp.1-2; Mondragon et al., 2019, pp. 1-2). Therefore, flexibility and reliability as well as technological conditions play a decisive role in the selection and evaluation of the supplier (Mondragon et al., 2019, pp. 1-2; Pishchulov et al., 2019, p. 167). Due to the changing preferences of customers new decision-making factors are gaining importance. Besides the economic aspect, the focus is now also on ecological and social aspects (Jia et al., 2015, p. 1604; Guarnieri and Trojan, 2019, pp. 347-348; Pishchulov et al., 2019, p. 167; Winter and Lasch, 2016, pp. 175-181). If suppliers do not comply with human rights or ecological standards, this is usually attributed to the company and often causes damage to its image. Therefore, the consideration of environmental and social issues in supplier evaluation plays an important role in the fashion industry (Pishchulov et al., 2019, p. 167). Besides the challenges already mentioned many companies in the fashion industry have found that a supplier who produces cheaply but is far away and difficult to reach has more disadvantages than advantages. Within the last few years, it became clear that for this reason more money had to be spent on quality control, as different standards prevailed in supplier countries (Guercini and Runfola, 2010, pp. 913-914; Macchion et al., 2014, p. 4). Therefore, they now try to find a balance between local and global procurement and production (Abecassis-Moedas, 2007, pp. 300-301; Danese, 2013, p. 1038).

In the following paper, this basic information given above will be used to answer the question of which decision-making process for choosing a supplier in the fashion industry leads to the most promising result, taking into account economic, ecological and social goals. In the first step, different processes are presented and analyzed. These processes are SMART and SMARTER, Even Swaps, AHP, MACBETH, MAUT and PROMETHEE, which have been chosen due to their established usage in logistics decision-making. Based on this, a process is selected and implemented. For this purpose, the four stages of supplier selection are carried out: initial supplier qualification, agreement of measurement criteria, obtainment of relevant information and decision (Pishchulov et al., 2019 p. 167 quoted from Cousins et al., 2008, n.p.). The result is then critically analyzed and a conclusion will be formulated.

2 Multi-criteria decision-making

Within this chapter, different methods for solving the Multi-Criteria Decision-Making (MCDM) problem are evaluated. The MCDM aims to quantify the trade-offs between different aspects, in this case economic, environmental and social. Within MCDM, a distinction can be made between two approaches in particular (Banasik et al., 2018, p. 372). On one hand, there is the Multi Attribute Decision-Making (MADM) method. In general, MADM is used when a finite set of alternatives is involved, which can be evaluated on the basis of several attributes. Secondly, the Multi-Objectives Decision-Making (MODM) method can be used. The MODM is applied to identify a Pareto optimal solution to a problem which fulfills the desires of the decision-maker (Banasik et al., 2018, p. 372; Thies et al., 2019, p. 9). Therefore, the solution is more likely to be considered as subjective as it does not produce a mathematical optimum as a result (Weistroffer and Narula, 1997, p. 300). These solutions are identified on an efficiency frontier of a mathematically constrained solution space (Banasik et al., 2018, p. 372; Thies et al., 2019, p. 9). Within this paper, we will focus on MADM methods.

2.1 MAUT

The Multiple Attributes Utility Theory (MAUT) is a mathematically sound multi-criteria decision analysis for supplier selection, developed by Keeney and Raiffa in 1976. The aim is to structure a complex choice problem and to evaluate the alternatives according to previously selected criteria in order to facilitate the decision-making process for the decision maker (Sanayei et al., 2008, p. 734).

At the beginning of the method, a value tree is created. This consists of a hierarchical arrangement of four levels. In the first level, the overall goal is defined, in this case the selection of the best supplier. Below this, the previously selected criteria for assessing the alternatives are listed, for example the criterion "cost". In the third level, the criteria are broken down into individual factors, in this case "transport costs" and "product costs". The various alternatives, the suppliers, are then shown on the lowest level (Min, 1994, pp. 26-27). The decision maker's assessment of the individual suppliers based on the individual criteria is determined by an interview-based procedure. This can be done by a human analyst or by a MAUT computer program (Huang and Keskar, 2007, pp. 517-518). Ratings are assigned a utility value on a range scale of 0-1, where 0 is the worst possible rating and 1 is the best possible rating. The same method is used to assess the relative importance of the criteria. The processes are repeated for each criterion (Canbolat et al., 2007, p. 318). Afterwards the utility function of the decision maker is developed. For this purpose, the functional relationship between the criteria and the utility scores is established (Min, 1994, p. 26). The total utility value is then calculated for each alternative. The ranking of the decision alternatives can be determined from the total utility scores. In the last step, sensitivity analyzes are conducted. These serve to find the weaknesses of the best alternative. From this determination, the decision maker is then able to weight up whether to possibly use resources to improve the individual criteria. This could be, for example, the expansion of the transport infrastructure to enable greater flexibility (Canbolat et al., 2007, p. 323).

A general advantage of MAUT is its ease of use and the possibility to map a complex problem into a simple hierarchy. Moreover, it can be applied with both qualitative and quantitative factors, and also in uncertain decision environments (Sanayei et al., 2008, p. 741; Min, 1994, pp. 24-25). The evaluation of alternatives on an absolute scale makes it easier for the decision maker to assess whether the investment of money and time is worth the effort to remedy weaknesses. A special feature of MAUT is its aim to leave the final decision to the decision maker. The MAUT-Software should only serve as a support for the decision-making process (Canbolat et al., 2007, p. 323). Since this multi-criteria decision method does not use pairwise comparison, it is also applicable to decision problems with a large number of alternatives (Min, 1994, p. 31; Huang and Keskar, 2007, p. 518). However, it should be noted that checking the consistencies, as well as refining the results, requires some repetition, which could make the method time-consuming and complicated. Extracting the decision maker's evaluations is also conditional. In order to translate the decision maker's preferences as accurately as possible into a nominal scale, the analyst is required to have a high level of expertise, as well as skill and commitment on the part of the interviewing analyst, or detailed programming of the software to match the selected criteria (Sanayei et al., 2008, p. 741; Canbolat et al., 2007, p. 318).

2.2 SMART and SMARTER

The Simple Multi-Attribute Rating Technique (SMART) was invented by Edwards in 1977 and later on advanced to SMARTER by Edwards and Barron (Barfod et al., 2016, p. 5). SMART is the simplest form of the Multi-Attribute Utility Theory (MAUT) and requires two assumptions: utility independence and preferential independence. It is often used in specific areas like construction, transportation, logistics and manufacturing problems (Velasquez and Hester, 2013, p. 6). SMART evaluates a limited amount of decision alternatives on the basis of a limited amount of performance criteria. The purpose of this analysis is to classify the criteria in a subjective order of preference and assign numerical weights to these (Barfod et al., 2016, p. 5). SMARTER basically has the same functionality as SMART, with the difference that it uses the Rank Order Centroid (ROC) technique to assign weight to each criterion (Tangkesalu and Suseno, 2018, p. 2).

The first step of conducting a SMART analysis is identifying the decision maker and the problem. Afterwards, other alternatives with their corresponding attributes have to be identified to rank the corresponding attributes according to their importance. The attributes are given values in order to measure the performance of the alternatives, whereas the least important attribute is given a 10 and the most important is given a 100. In the next step, the normalized weights have to be calculated. Therefore, the value for each attribute divided by the sum of the value of all attributes (Olson, 1996, p. 35). Hereafter, the location of each alternative has to be measured by evaluating their respective attributes for each alternative. The value of each alternative can be scaled from 0 to 100. The utility for each alternative is being calculated by multiplying the normalized weight with the scaled value for the respective alternative (Olson, 1996, pp. 35-36). Lastly, it has to be decided which alternative is the better one out of all. If only a single alternative has to be chosen, the best alternative would be the one where the utility of the value is the highest (Olson, 1996, p. 36).

One advantage of SMART is that it is possible for every decision maker to apply the technique because it is simple to use and very transparent (Velasquez and Hester, 2013, p. 61). Furthermore, it also illuminates important aspects concerning the problem and how every aspect is connected to the problem (Goodwin and Wright, 2014, p. 37). Besides, the technique is not restricted to only one weight assignment technique. It allows any type of weight assignment technique to be used for example relative and absolute weight assignment (Velasquez and Hester, 2013, p. 61). Nevertheless, a major critique of SMART is regarding the use of numerical weights and assigning them to attributes, which could be a difficult task for decision makers. It could lead to a decrease in the confidence level and at the same time is more vulnerable to uncertainty. In addition, it tends to oversimplify the problem and because of that the method may not capture all the detail and complexities of the real problem (Barfod et al., 2016, p. 5).

2.3 Even Swaps

Even Swap was developed by Hammond, Keeney and Raiffa in 1998 based on the idea of Benjamin Franklin, who compared two alternatives by weighing the pros and cons of several alternatives (Altun and Dereli, 2014, p. 1). The word “Even” represents equivalence and “Swap” implies exchange. Therefore, the method is about making trade-offs by hypothetically changing one consequence of an alternative and compensating the same consequence for another one (Altun et al., 2016, p. 33). Out of a set of alternatives the Evan Swap method helps decision makers to identify the ‘best’ one (Lahtinen and Hämäläinen, 2016, p. 891).

Firstly, a consequence table has to be created including all alternatives and their consequences for each objective, which leads to a better structure. Furthermore, it allows a better comparison between alternatives and gives a clearer framework for making trade-offs. It is important that all consequences are described in the same terminology otherwise it is not possible to perform a rational swap between objectives (Hammond et al., 1998, p. 4). This is followed by the elimination of dominated alternatives. Within this step alternatives are identified which can be eliminated. Therefore, the decision maker has to review all alternatives to identify the one that performs the worst on a particular performance criterion. In addition, this alternative also needs to be rated at maximum equal with the other alternatives in all other areas (Hammond et al., 1998, p. 5; Altun and Dereli, 2014, p. 1). After the dominated alternatives are eliminated, trade-offs within the remaining alternatives are performed (Hammond et al., 1998, p. 6). Within this step, the decision maker has to decide what objective he wants to adjust. Afterwards it is necessary to decide how to compensate the change in another objective. The next step is the conduction of the Even Swap, to eliminate the irrelevant objective. This is repeated until the decision maker is able to select the dominant alternative (Hammond et al., 1998, pp. 6-7).

One advantage of the Even Swap method is that it is easy to apply and less complicated than other multi-criteria decision analysis methods (Lahtinen and Hämäläinen, 2016, p. 891). Furthermore, the method uses defined paths, which provides the decision makers with a reliable framework for performing trade-offs (Lahtinen and Hämäläinen, 2016, p. 891; Hammond et al., 1998, pp. 1-2). However, a critique of this method is that it only provides the 'best' alternative but not the second or third preferred alternative. In addition, the Even Swap method has no mechanism to check whether the trade-offs are consistent with each other. Moreover, similarities between alternatives are not regarded even though decision makers are keen about the differences and similarities among alternatives and not only about which alternative is the best (Altun et al., 2016, p. 34).

2.4 AHP

The analytic hierarchy process (AHP) was developed by Thomas Saaty in the 1970s. The main field of application is multi-criteria decision-making. It was developed to deal with the need to measure and compare both physical (related to the objective reality) and psychological (related to subjective ideas and beliefs) events.

Prior to the comparison process, the decision hierarchy, comprising all relevant criteria and sub-criteria, has to be constructed. The first step comprises the determination of the focus, as the overall objective of the decision problem must be clear. This is followed by the definition of the main criteria and the subsequent decomposition into hierarchically structured sub-criteria to identify the relevant factors for the decision problem. Finally, the available alternatives are defined to enable the measurement of each alternative's performance on the criteria. The definition of decision-relevant factors is a crucial task. The hierarchy needs to represent the problem as precise as possible but not too precise, as this can lead to a loss of sensitivity (Saaty, 1987, pp. 161-163).

After all relevant factors have been detected and decomposed into sub-criteria, they are weighted in terms of their relevance for the decision problem. This is achieved by constructing a pairwise comparison matrix. The matrix allows a judgement of the relative importance of the criteria with respect to the overall decision goal. Saaty 1990 uses a specific 1-9 scale which allows the formulation of questions that translate the decision maker's perception of the importance into numbers. The result of this process is a priority vector. After rating the relative importance of each criterion, the performance of the alternatives on these criteria is assessed. Therefore, pairwise comparison matrices are enabled again. The last step is the calculation of the composite performance of every alternative. The performance on each criterion is multiplied by the relevance of that criterion and the results are subsequently added up to represent the overall performance of the considered alternative. Comparing the scores of the alternatives reveals the most favorable option (Saaty, 1990, pp. 12-17).

The strength of AHP lies in its ability to include quantitative as well as qualitative data and criteria (Chan and Chan, 2009, p. 1196). The criteria can also be changed and adjusted along the iterative process of identifying relevant factors and decomposition into sub-criteria. This provides the required flexibility for decision-makers to gain a more in depth understanding of the problem. The pairwise comparisons, showing the performance of each alternative on each main and sub criterion, reduce the complexity of multi-criteria decision problems. The process is easily comprehensible, which allows for high transparency and involvement of the decision maker, leading to higher acceptance of results (Govindan et al., 2015, p. 70). However, it should be mentioned that especially in the early years of the method, critique has been voiced by several authors (Watson and Freeling, 1982, n.p.; Watson and Freeling, 1983, n.p.; Dyer, 1990, n.p.). The most frequently criticized flaw of the AHP is “rank reversal”. This implies that adding an alternative considered irrelevant, results in a change of ranks in the remaining alternatives. Pérez et al. (2006) argue that not only the addition of irrelevant alternatives leads to the observed rank reversal problem. Adding criteria that each alternative performs homogeneously on, leads to the same result (Pérez et al., 2006, p. 99). More recent literature dismisses the AHP as outdated. Asadabadi et al. (2019) claim that AHP frequently leads to rankings that are not acceptable for rational thinking persons. The result is a discrepancy between the application in scientific case studies and the exploitation in practice (Asadabadi et al., 2019, p. 2).

2.5 PROMETHEE

The Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE) was developed by Brans in 1982 and further extended by Brans and Vincke (1985) and Brans and Mareschal (1994). PROMETHEE is a well-established outranking method, which deals with the ranking and selection of a set of alternative options on the basis of several criteria. The objective of this method is to identify the pros and cons of the alternatives and to achieve a ranking among them (Behzadian et al., 2010, pp. 198-199).

Several versions of the PROMETHEE methods were developed. However, the most common applications in practice are PROMETHEE I for partial ranking of the alternatives and PROMETHEE II for complete ranking of the alternatives (Behzadian et al., 2010, p. 199). The following part will only focus on the application of these two versions.

The starting point of this method is the evaluation matrix, which presents the performance of each alternative in relation to each criterion. Based on this matrix, preference functions for each pair of options are determined. They can range from 0 to 1. Whereas 0 implies that there is no difference between the pair of options and 1 indicates a big difference (Brans and Vincke, 1985, pp. 648-649). In the next step, the decision maker has to weight the criteria and choose a preference function. PROMETHEE does not provide specific guidelines for determining the weights, so each weighting remains subjective and is restricted only to the evaluated alternatives. Therefore, sensitivity analyses, which clarify how far the chosen weights influence the output, can be used to limit the subjectivity in the criteria weighting. Afterwards, the outranking degree of the alternatives is estimated. The preferences are multiplied by the criteria's weights from which a matrix of global preferences is created in which the sum of the row expresses the strength of an alternative (dominance) and the sum of the column expresses how much an alternative is dominated by the other ones (subdominance) (Brans and Vincke, 1985, pp. 648-649: Macharis et al., 2004, pp. 308-309).

One strength of PROMETHEE lies in its user-friendliness which enables a simple application, and the process is well comprehensible for other parties involved which leads to a higher acceptance of final results. In addition, the decision maker does not have to be exactly aware of his preferences and their expression. The expression of preferences in this method is made possible by the design of preference functions (Ulengin et al., 2001, p. 186). PROMETHEE can also deal with qualitative and quantitative criteria as criteria scores can be expressed in their own units (De Keyser and Peeters, 1996, p. 458). Nonetheless, a widespread critique of PROMETHEE is that it does not provide a clear method by which to assign weights to the different criteria. Consequently, the weighting remains subjective and is not comprehensible for everybody. Therefore, for all criteria the difference between evaluations must be meaningful. Furthermore, PROMETHEE does not provide the possibility to effectively structure the decision problem, as there is no 'classical' decision tree or decision hierarchy constructed. For a problem containing many alternatives and criteria, it could become difficult to maintain a clear view of the problem and to evaluate the results. Besides, PROMETHEE also suffers from the "rank reversal" problem when a new alternative is introduced. This problem was already identified for the AHP method where adding a new alternative or criteria results in a change of ranks in the remaining alternatives (Macharis et al., 2004, pp. 311-312).

2.6 MACBETH

The Measuring Attractiveness by a Categorical Based Evaluation Technique (MACBETH) is a multi-criteria decision aid developed in the early 1990s by Bana e Costa and Vansnick. It is based on the software M-MACBETH, an algorithm founded on linear programming models. By the interaction between decision maker and software, the performance of several alternatives is evaluated on the basis of different decision criteria (Karande and Chakraborty, 2013, p. 280).

Firstly, the decision maker has to select suitable criteria for evaluating the alternatives. These are then categorized and visualized in the form of a value tree (Bana e Costa, 2012, p. 429). In the second step, performance descriptors have to be defined in the M-MACBETH software. On this basis the criteria are evaluated (Karande and Chakraborty, 2013, p. 260). At least two reference levels have to be defined, an upper reference level, also known as "good", which identifies the highest possible performance score, and a lower reference level, denoted as "neutral", which represents the lowest performance score. These are important for the construction of quantitative interval scales and serve as a reference for the decision maker during pairwise comparisons. The highest reference level is declared in the MACBETH scale with the value 100, while the lowest reference level is assigned the value 0 (Bana e Costa, 2004, pp. 324-325). Numerical value functions must then be defined. These are created by the decision maker's pairwise comparison of the performance levels with respect to one criterion each (Karande and Chakraborty, 2013, p. 263). In this step, the difference in the attractiveness of the individual alternatives is evaluated. This is conducted using ordinal ratings from "Null": alternatives A and B are equally attractive, to "Extreme": alternative A is extremely attractive over alternative B (0: "Null"; 1: "Very weak", 2: "Weak"; 3: "Moderate"; 4: "Strong"; 5: "Very strong"; 6: "Extreme"). In this procedure, the order of comparison has to be observed; this starts between the most attractive performance level and the lowest performance level in order of increasing attractiveness. From the ordinal evaluations, the software creates an evaluation matrix of the alternatives. At the same time, the consistency of the evaluation is checked. Afterwards the decision maker is then able to eliminate any inconsistencies and makes limited adjustments to the calculated values. On this basis, the software creates a numerical value function (Bana e Costa, 2004, p. 325). To determine the weighting, a similar process is followed. The decision maker is asked how he would qualify the improvement of the performance level of a criterion from "neutral" to "good". Possible answers are "very weak", "weak", "moderate", "strong" and "very strong". This questioning process is also carried out for each criterion. Parallel to the weighting evaluation, the software again checks the consistency of the answers, points out possible inconsistencies to the decision maker and suggests potential solutions (Karande and Chakraborty, 2013, p. 263)

The most common advantage of MACBETH is that it can be used with both quantitative and qualitative data (Karande and Chakraborty, 2013, p. 262). The technical application of the software is clear and simple (Bana e Costa, 2012, p. 425). In addition, the software determines the numerical value functions from the ordinal valuation (Bana e Costa, 2004, pp. 333-334). This prevents the decision maker from being forced to convert his evaluations into a numerical scale. The systematic inconsistency controls also prevent faulty judgements (Bana e Costa, 2004, p. 329). Nevertheless, the method is criticized for its scope for interpretation. For example, a "strong" difference is defined and interpreted differently by different decision makers or even by the same person in a different context. In addition, the order of the question might have an impact on the decision maker's evaluation. In summary, there is a risk of relatively high subjectivity (Bana e Costa, 2004, p. 328).

2.7 Method selection

After presenting the different MADM methods, it will be now evaluated which method is most appropriate to solve the problem of the supplier selection in the fashion industry. In this context, all methods are evaluated on the basis of several performance criteria considering the characteristics of this problem.

Firstly, it should be noted that each of the models presented is suitable for both qualitative and quantitative data. SMART evaluates a limited amount of decision alternatives on the basis of a limited amount of performance criteria and with its simplicity it may not capture all the detail and complexities of the real problem (Barfod et al., 2016, p. 5). Even Swaps only provides the 'best' alternative but not the second or third preferred alternative and similarities between alternatives are not regarded which makes a final decision more difficult (Altun et al., 2016, p. 34). Considering the complexity of the problem SMART and Even Swaps can be excluded on the basis of the arguments mentioned above. Secondly, when having a supplier selection problem with multiple performance criteria an important requirement is a comprehensible decision process with the possibility to effectively structure the decision problem. This seems crucial since the decision maker has to maintain a clear view of the problem and to evaluate the results as well as to make the result comprehensible for outsiders. This criterion is met by AHP through its easily comprehensible process which allows for high transparency and involvement of the decision maker and by its decision hierarchy, comprising all relevant criteria and sub-criteria to structure the problem (Govindan et al., 2015, p. 70). Nevertheless, it should be noted that one weakness of the AHP is rank reversal. This could lead to a significant change in the result when adding another alternative (Pérez et al., 2006, p. 99). MAUT and MACBETH both provide a clear structure through a creation of a value tree (Min, 1994, pp. 26-27; Bana e Costa, 2012, p. 429). However, when using MAUT, in order to translate the decision maker's preferences as accurately as possible into a nominal scale, the analyst is required to have a high level of expertise, as well as skill and commitment on the part of the interviewing analyst, or detailed programming of the software (Sanayei et al., 2008, p. 741; Canbolat et al., 2007, p. 318). Therefore, this method is more complicated than AHP with its pairwise comparisons. When using MACBETH, a risk of relatively high subjectivity occurs, because of its scope for interpretation when evaluating the differences between performance levels. In addition, another problem is that the order of the question might have an impact on the decision maker's evaluation (Bana e Costa, 2004, p. 328). While evaluating the comprehensibility and the ability to structure the problem, PROMETHEE has some shortcomings too as there is no 'classical' decision tree or decision hierarchy constructed to structure the problem. Furthermore, PROMETHEE does not provide a clear method for assigning weights to the different criteria, so the weighting remains subjective. As a conclusion, it may not be understood by external observers (Macharis et al., 2004, pp. 311-312).

Concluding the analysis of the methods and considering the problem, it could be argued that none of the methods will give a flawless solution. Nevertheless, some methods seem to be more suitable than others. In the following paper, the AHP method will be used, as it is a comprehensive and structured method that reduces the complexity of the problem through pairwise comparisons (Govindan et al., 2015, p. 70). Even though AHP, like PROMETHEE, suffers from the "rank reversal" problem, it appears to be the most appropriate choice when directly compared with the other five options.

3 Case study: Supplier selection for Italian trouser manufacturer

3.1 AHP software introduction

To ensure the correct structure and error free execution of the AHP process, the free web based AHP solution "AHP-OS" was used. The tool was developed by Klaus D. Goepel and the current version was introduced by his article in the International Journal of the Analytic Hierarchy Process. His intention was to provide a complete and free software tool that guides the AHP process and enables the documentation of input data and results in an open format. A special feature is the possibility to use group input. The group members register and participate in the project by answering the AHP-typical questions for weighting of objectives and alternatives. The software subsequently calculates the group consensus. Apart from group input, the software performs sensitivity analysis and ensures that the answers to the weighting questions are consistent. In case of inconsistencies in judgements, the participant is provided with suggestions to immediately solve the problem (Goepel, 2018, p. 469).

3.2 Implementation of AHP

The first step when solving a decision problem with AHP is to formulate the objective. In this paper, supplier selection in the fashion industry is considered from the perspective of an Italian trouser manufacturer, where the decision maker is the company's procurement manager. As already mentioned in the introduction, social and environmental factors are considered in addition to economic factors. The next step is to select the factors that are relevant for the decision and subsequent decomposition into a hierarchic structure. Based on a literature review, objectives for the three dimensions (economic, social, environmental) were determined as well as the corresponding key performance indicators (KPI). The hierarchy structure (Figure 1) contains the selected objectives and KPIs.

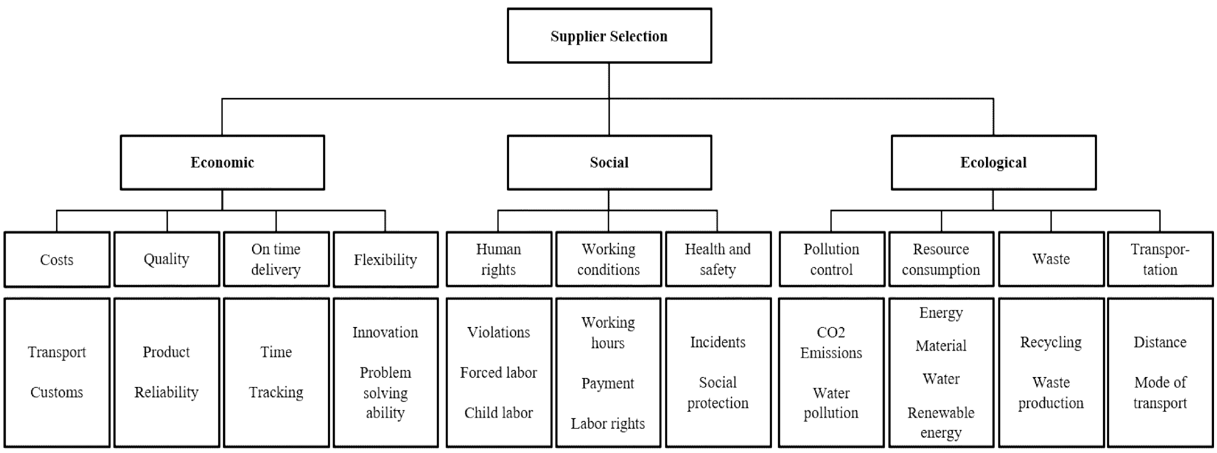

Figure 1: Hierarchy template for supplier selection in fashion industry

It is important to note that the product costs have been omitted from the costs, as these can vary greatly within a country and are therefore not comparable at country level.

Since this decision problem is a hypothetical case, no specific suppliers can be considered, instead four countries are selected as alternatives. Germany, China, Bangladesh and Turkey represent the four alternatives. The countries were chosen due to their high export numbers for textiles and because of the current development that companies try to find a balance between local and global procurement and production (Abecassis-Moedas, 2007, pp. 300-301; Danese, 2013, p. 1038). Germany and Turkey represent local alternatives. Based on the selected KPIs and countries, the next step is to obtain the relevant information for the measurement of each alternative's performance on the criteria. Various data sources and indicators were used for this purpose, although information could not be found for all KPIs at country level because some are company-specific factors. Examples are the reliability or problem-solving ability of a supplier. The data sources for all individual KPIs are listed in appendix 1. Table 1 shows the data sources for the KPIs of the economic dimension.

Table 1: Data sources for KPIs of economic dimension

Objective	KPI	Data Source/Indicator
Economic factors		
Costs	Transport (Pishchulov et al., 2019)	*Hamburg-Container (2021)*
	Customs (Pishchulov et al., 2019)	*Import.de (2021), Zoll (2021)*
Quality	Product quality (Jia et al., 2015)	*Made-In-Country Index (Statista Survey, 2017)*
	Reliability (Pishchulov et al., 2019)	*No data available*
On time delivery	Delivery time (Jia et al., 2015; Pishchulov et al., 2019)	*Lead time to export, median case (days) (World Bank, 2018)*
	Tracking (Pishchulov et al., 2019)	*LPI (Tracking and Tracing) (World Bank, 2018)*
Flexibility	Innovation (Pishchulov et al., 2019)	*Global Innovation Index 2020 (INSEAD WIPO, 2010)*
	Problem solving ability (Pishchulov et al., 2019)	*No data available*

The AHP-OS software was used for the further implementation of the AHP process. First, a hierarchy template was created containing the three dimensions economic, social and environmental as well as the objectives of the individual dimensions and the corresponding KPIs. Based on this template all three dimensions and the objectives were weighted in terms of their relevance for the decision problem. This was done by pairwise comparison. For this step the software asks the user to compare each factor with the other ones which are on the same level of the hierarchy template. The program uses a Likert scale where the user has to decide which criterion is more important, and how much more on a scale 1 to 9. This allows the assignment of a weight for each factor at each level. After rating the relative importance of each criterion, the performance of the alternatives on these criteria is assessed. Here the obtained information for each KPI from the last step weas used. Again, pairwise comparison was used, and the user had to rate how much better one country is compared to another with respect to one KPI on a scale of 1 to 9. As mentioned at the beginning, a special feature of the software is the possibility to use group input for the rating of all criteria. However, this function was not used and the pairwise comparison was done together as a group to encourage group discussion and to clarify that each group member had the same information base for the decision since no one is an expert on the KPIs for each country. The software created a final hierarchy template including all weights that were assigned (Appendix 2). Based on this template the software calculated the composite performance of each alternative. Table 2 shows the results of the AHP process. The alternative with the highest score and therefore the most favorable option is Germany. The rankings of the other three alternatives are significantly lower.

Table 2: Final results of AHP

Country	Germany	Turkey	China	Bangladesh
Ranking	0.600624	0.176167	0.157447	0.065761

To examine how robust the choice of the alternative Germany is, sensitivity analysis was used. The analysis was also performed by the software and proved that the solution for the top alternative Germany is robust. Nevertheless, it should be noted that "problem solving ability" represents a critical performance criterion where a change in the weighting can change the ranking between Turkey and China.

3.3 Discussion

As already described in a previous analysis, the AHP method was very well suited for organizing the process in a structured way. This is also identified in the literature as one of its greatest strengths (Govindan et al. 2015, p. 70; Suriyanti et al., 2020, p. 223). It was possible to compare qualitative as well as quantitative parameters and achieve a clear result.

In addition, the use of software could be seen as an advantage, so that the process is further clarified and mathematical errors in the calculations can be avoided. Nevertheless, the software indicates any inconsistencies in the evaluation within the ranking to the user. While this can have the advantage of making the result more representative, scores were also increasingly awarded in the course of the process so that the software did not detect any discrepancies that were too large. Consequently, the use of software could lead to different results than if it had not been used (Dotoli et al., 2020, p. 4). It is important to critically question this aspect when considering the results, as other authors describe the possibility of consistency control through the reliability aspect of the AHP method as an elementary aspect (Azarnivand and Chitsaz, 2015, p. 23; Marttunen et al., 2017, p. 7; Li et al., 2015, pp. 103-104). In addition, the ranking process allowed for many different perspectives to be discussed within the groups and thus all participants agreed with the result. Based on the supplier selection according to the AHP methodology Germany achieved the highest ranking. The further the analysis progressed, it became more and more obvious that countries like Germany are not really comparable to countries like Bangladesh or China. This became apparent due to several factors, especially in the social and environmental areas. However, since no product price was included as an attribute in the economic aspect, the low-wage countries did not have the possibility to gain an advantage in this area. In retrospect, it can be stated that AHP seems to be best suited when the selected countries are also largely similar within the criteria. Moreover, one can assume that the countries which were compared would be more similar under real conditions, for example due to cost restrictions imposed by the company management. A major problem associated with this method, or with evaluation methods in general, is the collection of representative data in order to be able to provide a ranking. Especially in the area of social aspects, only very few data are available in countries like China or Bangladesh. It is often pointed out that there are basically legal requirements in several areas, compliance for these is not controlled in some countries. In the context of relevant data, some indices also appear to be more a point of reference, as common sense tends not to attach great importance to these statements. In addition, many indices also refer to the country as a whole and not exclusively to the manufactures. This was particularly noticeable in the case of the index on water consumption. According to the data, Bangladesh should have the best use of this resource, but in the course of the discussion within the group, it became clear that this is probably due to the sparse supply of fresh water to private homes. In these cases, it was necessary to rely on personal knowledge. Moreover, it should be noted that the analysis was not carried out by experts. In addition, several data are not well-founded, which is partly due to the fact that no real suppliers were examined. Similar problems emerged for the economic KPIs. Furthermore, only a few companies in the sea freight sector quote costs of about 30 cents per a pair of trousers (Hamburg-Container, 2021, n.p.). The exact production costs are difficult to estimate without obtaining quotes. This caused major challenges in certain points, which is why the implementation of AHP turned out to be relatively complex and time-consuming. Nevertheless, according to the literature, AHP is one of the fastest and most straightforward applications (Mastrocinque et al., 2020, p. 14). In conclusion, it should be mentioned that no method for selecting the objectives and the corresponding KPIs for AHP are given. In this case, a literature analysis was used to identify important decision criteria for supplier selection in the fashion industry. However, the final selection of the individual criteria was made at the decision makers own discretion, which means that important criteria can be missed. A possible method for selecting the right KPIs is presented by Kibira et al. (2017). Here, the KPIs are selected in a 4-step process based on certain KPI criteria. In addition, it should be remembered that even if a quantitative result is obtained, it is still a subjective mathematical optimum. As already confirmed in this paper, as well as by several authors, almost all indicators used, as well as their scores, depend on the decision-makers (Banasik et al., 2018, p. 377).

4 Conclusion

4.1 Resume

The aim of this paper was to choose a suitable method for selecting a supplier in the fashion industry. In addition to economic goals, ecological and social goals of the company should also be taken into account, as these are becoming increasingly important for consumers. For this purpose, a total of six MADM methods were presented and weighed against each other with their advantages and disadvantages. In order to be able to carry out the selected method as an example, a scenario of a trouser manufacturer based in Italy was constructed, which had to select a supplier from China, Bangladesh, Turkey or Germany.

When weighing up the methods, AHP emerged as the most promising decision-making method for a supplier selection problem in the fashion industry. The main advantage of AHP lies in the structuring of the decision problem, the ease of implementation, as well as the high level of transparency and the associated high level of comprehensibility of the processes. In addition, the possibility of weighting the main objectives, plus the individual weighting of the subordinate KPIs, also allows the complexity of the real problem to be depicted very well. As far as the implementation of AHP using the AHP-OS software is concerned, it was found that the evaluation process of the individual KPIs is very time-consuming. It was also noticeable that consistent weighting of the KPIs in relation to each other was difficult even if these inconsistencies were marked by the software. The incomplete data situation also caused difficulties. However, this problem is not especially due to the AHP decision-making method.

Using AHP in the hypothetical scenario, the decision makers came to the conclusion that a supplier from Germany would best fit the company's goals. This result is due to the significantly better ecological and social evaluation of the country compared to the alternatives and contradicts the significantly higher weighting of the economic goal (economic: 0.540; ecological: 0.163; social: 0.297). However, if a supplier from Germany is chosen, the economic aspects are significantly worse, e.g. associated with higher costs, than with the alternatives China, Bangladesh and Turkey, and this, although the economic goal should be prioritized in the consideration. This leads to the conclusion that AHP is better suited for comparing similar countries or suppliers. Therefore, it is recommended to pre-select suppliers that are rated similarly in the criteria in order to avoid an unintentional shift in priorities.

In order to make optimal decisions, weaknesses of the AHP process, such as "rank reversal", need to be compensated. It is suggested to combine several MCDM methods and thus to use the advantages of the individual methods and to minimize weaknesses. These combination possibilities need to be further developed and evaluated in future research.

4.2 Limitations

Although this paper aims to identify the most applicable method for supplier selections in the fashion industry, only a limited number of six MCDM methods could be included in the comparison. In addition, possible combinations of methods were not included in the analysis. Due to the limiting components of time and scope of work, the decision-making process in the exemplary scenario was conducted exclusively with the help of AHP. For better comparability, it would have been useful to conduct the process using all the methods examined.

Central limitations of the present work also result from the hypothetical nature of the scenario. Consequently, there are no concrete suppliers to decide between. Instead, countries represent the decision alternatives which resulted in incomplete data. Firstly, ecological factors in particular are usually dependent on the priorities of the individual suppliers and not on their country of origin, e.g. the choice of transport. Secondly, the data is only partially based on sources and had to be supplemented by assumptions made. The choice of a supplier is always made subjectively by the respective decision-makers. With regard to this criterion, the subjective weighting of the individual KPIs by the authors is not to be criticized, but it must be noted at this point that the authors of this paper are not professionally employed in the logistics industry and therefore do not represent experts. It can also be assumed that there are other decision-relevant KPIs for many companies in the fashion industry which are not considered. Which other performance indicators are relevant for fashion manufacturers with a focus on ecological and social goals could be the subject of further research.

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Appendix

Appendix 1: Data sources for KPIs 25

Appendix 2: Final hierarchy template including all weights 27

Appendix 1: Data sources for KPIs

Objective	KPI	Data Source/Indicator
Economic factors		
Costs	Transport (Pishchulov et al., 2019)	Hamburg-Container (2021)
	Customs (Pishchulov et al., 2019)	Import.de (2021); Zoll (2021)
Quality	Product quality (Jia et al., 2015)	Made-In-Country Index 2017 (Statista Survey, 2017)
	Reliability (Pishchulov et al., 2019)	No data available
On time delivery	Delivery time (Jia et al., 2015; Pishchulov et al., 2019)	Lead time to export, median case (days) (World Bank, 2018)
	Tracking (Pishchulov et al., 2019)	LPI (Tracking and Tracing) (World Bank, 2018)
Flexibility	Innovation (Pishchulov et al., 2019)	Global Innovation Index 2020 (INSEAD WIPO, 2010)
	Problem solving ability (Pishchulov et al., 2019)	No data available
Ecological factors		
Pollution control	CO2 Emission (Pishchulov et al., 2019; Winter & Lasch, 2016)	CO2 Emission 2014 from manufacturing and construction (World Bank, 2014)
	Water pollution (Pishchulov et al., 2019; Winter & Lasch, 2016)	Environmental Performance Index 2020: Waste water treatment (EPI, 2020)
Resource consumption	Energy (Jia et al., 2015; Winter & Lasch, 2016)	Statistical Review of World Energy (BP, 2020, p. 8)
	Material (Pishchulov et al., 2019)	Material resources (OECD, 2017)
	Water (Jia et al., 2015)	Water withdrawals (indicator) (OECD, 2021)
	Renewable energy (Pishchulov et al., 2019)	Statistical Review of World Energy (BP, 2020, p. 53)
Waste	Recycling (Pishchulov et al., 2019; Winter & Lasch, 2016)	Environment at a Glance 2020 (OECD, 2020)
	Waste production (Winter & Lasch, 2016)	Ranking of the largest waste producers worldwide by selected countries in 2018 (Statista, 2020; data collection by ISWA; World Bank;

		Website (Waste Atlas, 2014); Stern, 2018)
Transportation	Distance (Winter & Lasch, 2016)	Google Maps (2021)
	Mode of transport (Winter & Lasch, 2016)	No data available
Social factors		
Human right	Violations (Jia et al., 2015)	European Court of Human Rights (2020); Human Rights (IPSOS, 2018; United States Department of State / Bureau of Democracy, Human Rights and Labor, 2019); Peace Index (Institute for Economic and Peace, 2020)
	Forced labor (Pishchulov et al., 2019)	Global Slavery Index (Walk Free Foundation, 2018)
	Child labor (Pishchulov et al., 2019)	Publications related to child labour (Benita/Earthlink, 2018; Brinkmann, 2013; UNICEF, 2019)
Working condition	Working hours (Jia et al., 2015; Pishchulov et al., 2019; Winter & Lasch, 2016)	Ratio of weekly hours worked per population aged 16-64 (ILOSTAT, 2020b)
	Payment (Pishchulov et al., 2019; Winter & Lasch, 2016)	Statutory gross monthly minimum wages in US dollars (ILOSTAT, 2020d); Where Pay Is Lowest For Cheap Clothing Production (McCarthy, 2019)
	Labor rights (Jia et al., 2015, Winter & Lasch, 2016)	Labour Rights Index (Wageindicator.org, 2020)
Health and safety	Incidents (Jia et al., 2015; Pishchulov et al., 2019; Winter & Lasch, 2016)	Non-fatal occupational injuries per 100.000 workers (ILOSTAT, 2020a)
	Social protection (Jia et al., 2015; Pishchulov et al., 2019)	Proportion of population covered by social protection floors/system (ILOSTAT, 2020c)

Appendix 2: Final hierarchy template including all weights

Level 0	Level 1	Level 2	Level 3	China	Bang-ladesh	Tur-key	Ger-many
Supplier Selection	Economic **(0,540)**	Costs **(0,121)**	Transport **(0,80)**	0,089	0,089	0,173	0,648
			Customs **(0,20)**	0,083	0,083	0,417	0,417
		Quality **(0,254)**	Product **(0,80)**	0,071	0,071	0,184	0,674
			Reliability **(0,20)**	0,079	0,079	0,208	0,635
		On time delivery **(0,054)**	Time **(0,25)**	0,377	0,073	0,156	0,395
			Tracking **(0,75)**	0,318	0,077	0,155	0,449
		Flexibility **(0,571)**	Innovation **(0,25)**	0,283	0,054	0,145	0,518
			Problem solving ability **(0,75)**	0,260	0,066	0,117	0,557
	Ecological **(0,163)**	Pollution control **(0,376)**	CO2-Emission **(0,50)**	0,065	0,147	0,239	0,549
			Water pollution **(0,50)**	0,147	0,052	0,221	0,581
		Resource consump-tion **(0,177)**	Energy **(0,102)**	0,070	0,149	0,243	0,538
			Material **(0,054)**	0,154	0,076	0,230	0,541
			Water **(0,571)**	0,183	0,074	0,100	0,643
			Renewable energy **(0,274)**	0,293	0,054	0,102	0,551
		Waste **(0,240)**	Recycling **(0,750)**	0,206	0,050	0,076	0,668
			Waste production **(0,25)**	0,103	0,052	0,203	0,642
		Transpor-tation **(0,207)**	Distance **(0,333)**	0,070	0,070	0,322	0,538
			Mode of transport **(0,667)**	0,108	0,077	0,298	0,517
	Social **(0,297)**	Human rights **(0,413)**	Violations **(0,195)**	0,055	0,080	0,190	0,675
			Forced labor **(0,088)**	0,079	0,051	0,178	0,691
			Child labor **(0,717)**	0,113	0,049	0,202	0,637
		Working conditions **(0,327)**	Working hours **(0,143)**	0,079	0,052	0,221	0,649
			Payment **(0,429)**	0,105	0,050	0,186	0,659
			Labor rights **(0,429)**	0,092	0,049	0,239	0,620
		Health and Safety **(0,260)**	Incidents **(0,50)**	0,079	0,052	0,221	0,649
			Social protection **(0,50)**	0,082	0,053	0,191	0,674

Affidavit

We hereby declare that we have produced the present work independently and without the use of any aids other than those specified. All passages that have been taken literally or analogously from published or unpublished writings are marked as such. The paper has not yet been submitted in the same form or in extracts in the context of other examinations.

Bremen, 09.06.2021

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