MULTIPLE CRITERIA EVALUATION OF SUPPLIERS IN COMPANY OPERATING IN CLOTHING INDUSTRY

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Abstract

The paper presents a coherent methodology of a multiple criteria evaluation of suppliers in clothing industry covering: definition of a set of variants – fabric suppliers, definition of a consistent family of criteria that allows for their comprehensive evaluation, modeling of decision maker's (DM's) preferences (including: the definition of the importance of criteria and the DM's sensitivity towards changes of criteria values), computational experiments resulting in the final ranking of suppliers and finally the selection of the most desired supplier.

The analysis of 5 suppliers namely fabric producers, operating on the Polish market, whose factories are located in Poland, have been taken into consideration. Also in the family of criteria evaluating the cooperating units (important for the DM), 9 measures have been taken into account. These have included, among others: product price/cost and payment conditions, timeliness of delivery/ supplier, reliability of delivery/ supplier, cost of delivery, accessibility of supplier. In the computational phase a selected MCDM/A ranking methods (especially Electre III/IV and AHP methods) have been applied.

Key words: Suppliers selection problem, Ranking of suppliers, Multiple Criteria Decision Making/ Aiding (MCDM/A), Electre III/IV method, AHP method

1. INTRODUCTION

Each business entity carries out its own supply process regardless of one's operating industry. Companies purchase wide range of raw materials, components, semi-finished goods or final products. They are all necessary to conduct business activity, mainly for manufacturing or service companies. Supply process, which is a key component of one's successful functioning on the market, significantly affects not only company's economic situation but also its position regard to competitors.

The selection of the desirable supplier plays a key role in the whole procurement process. As it determines a future success of the company, it ought to be well-thought and based on the set of criteria relevant from the company's point of view. In terms of suppliers selection process, a number of methods can be applied, including multiple criteria evaluation methodology.

The above mentioned method consists of the following procedures: defining the set of variants (e.g. suppliers), defining a consistent family of evaluation criteria, structuring of decision maker's preferences model in the given decision situation, carrying out computational experiments aiming at obtaining the final ranking and enabling the selection of the most desired variant. Conducting the effective process of selection may help to obtain fruitful cooperation between potential supplier and a parent company and may be a key factor of their future success.

The overall research goal of this paper is to present a universal, generic methodology of evaluating suppliers and selecting the most desirable ones regarding the considered business environments, supply conditions and external circumstances. The authors claim that the suppliers' selection problem has a multiple criteria character, and thus develop the proposed approach based on the principles of Multiple Criteria Decision Making/ Aiding. The challenge and the novelty of this work is to present the comparison of the multiple criteria evaluations of suppliers across the clothing industry, using the original methodology which is based on the previous authors' works and experience.

The hypothesis of this works indicates the way of evaluating and selecting the most desirable supplier, generating various possibilities based on the multiple criteria analysis.

The object of the research is the company operating in the clothing industry, which produces and distributes clothes for women, men and children. The company is a leading entity within others operating in East-Central Europe retail market. Its incoming collection will present clothes made of new quality of fabric with UV stabiliser. As so far the company has not purchased this kind of fabric, it has been decided to verify the potentiality of polish producers.

In terms of structure and methods used, the paper presents characteristics of 5 suppliers – manufacturers of fabric with UV stabiliser. The evaluation criteria (crucial from the company Board of Directors' perspective – acting as decision maker) include 9 main criteria and their sub-criteria which are, among others: quality of fabric, price, timeliness of shipments, safeguard supply (process) and supply flexibility. In terms of computational procedures multiple criteria ranking methods have been applied, including Electre III/IV and AHP.

2. THE PROCESS OF EVALUATION AND SELECTION OF SUPPLIERS

2.1. Nature of the Process

Cooperation with suppliers plays the crucial role in procurement management i.e. entities responsible for delivery of goods such as raw materials, components, semi-finished goods or finished products required by the manufacturers, distributors or service providers. Cooperation with the suppliers is a key component, which determines the proper functioning of the company. What is more, the effective logistics which is providing a high standard of delivery performance as well as the lowest costs and high customer's satisfaction, nowadays are believed to be more significant than product's advertising process or the final price. The supplier aims

above all to attain a high quality by participating in production and purchase process in the buyers company (Appelfeller & Buchholz, 2011, p. 71). Thus, the selection of the most desired supplier is one of the most important economic decision which determines existence and good functioning of the company. Also, operations relating to the receipt of goods, settling payments and delivery are not enough to guarantee a success. Discontinuity of supply may incur huge losses to the company i.e. loss of consumer confidence, reduction of orders, deterioration of company reputation and decline in market position (Kulińska, 2009, p. 24). Therefore, suppliers' selection is becoming a relevant factor in logistics chain of the parent company.

The selection of the desired supplier is crucial for the company since it provides for the short- and medium-term of the goods' protection. Thus, one has to create the structure of suppliers who are able to provide necessary products (Piontek, 1993, p. 103) regarding reliability and high quality of delivery performance as well as the competitive market price. The suppliers' final selection and evaluation is based on the multiple criteria methodology (thoroughly described in the next section of this paper), ensuring minimisation of the total purchase costs and maintenance of stocks. Other reasons for undertaking cooperation with suppliers are (Sudolska, 2008, p. 110-111):

- improvement of products' quality,
- increase of product assortment,
- relative flexibility in procurement,
- willingness to modernise existing technologies,
- ability to obtain modern technologies,
- continuity of deliveries in case of unexpected events,
- possibility to negotiate prices of the deliveries.

The selection of the suitable supplier is a really significant economic decision which will determine the future success of the buyer. Such decision ought to be carefully analysed and well-thought. It is also an example of multiple criteria decision problem, which means that the evaluation of the supplier should include both qualitative and quantitative criteria. Also, such approach allows to select the most desired supplier in order to guarantee a long-term, fruitful cooperation between purchaser and vendor.

2.2. Suppliers Evaluation Criteria

In order to select the accurate supplier, number of different criteria, specifying company's expectations, need to be taken into consideration. Such criteria are defined with appliance of the following rules (Krawczyk, 2001, p. 333):

- the number of criteria ought to be reasonable, regarding the importance of the issue,
- criteria ought to be complementary, allowing for assessment of all necessary selection aspects,
- criteria should be applied separately in order to avoid repetition in evaluation process,
- criteria ought to be possible to arrange in terms of their meaning and value.

Regardless of the company's operating industry, one should evaluate the supplier considering the following aspects (Mukherjee, 2017, p. 66; Piontek, 1997, p. 178;

Piontek, 1994, p. 135-136; Lührs, 2010, p. 114; Easton et al., 2014, p. 39; Piontek, 1997, p. 178):

- product's price,
- quality and variety of the raw materials, components and semi-finished goods in offer,
- deliveries' conditions (including: supplier's location, reliability of the delivery, payment terms and conditions).

Depending on the specific character of each company, its operating industry or specification and relevance of one's procurement process, more detailed criteria (including higher number of criteria) can be applied in order to evaluate potential suppliers. It was originally described by Dickson (1966, p. 15-17), who carried out extensive research in 60s of 20th century indicating 23 relevant factors used by the companies in suppliers evaluation process. Considering the value of each criterion, he indicated as the most significant: price, quality and performance of the delivery. The other researcher Burton (1988, p. 38-41) introduced 10 criteria which are: quality, delivery, production facilities and capacity, net price, technical capability, packaging ability, geographic location, training aids, management and organization, operational controls. Other researchers tried to reduce number of factors i.e. Bernard (1989, p. 1-7), who described 5 attributes (quality, delivery, net price, management and organization, service) or Chapman (1989, p. 1993-2007), indicating only 3 criteria (quality, delivery, production facilities and capacity).

Different model presented by Yücenur, Vayvay and Demirel (2011, p. 823-833) indicates 4 supplier evaluation criteria (service quality, cost, risk factors, supplier's characteristics) and 28 attributes. However, Ordoobadi (2009, p. 314-327) also describes 4 criteria (quality, delivery, service, costs), but only 12 sub-criteria. What is more, exactly the same criteria are presented by Labib (2010, p. 6287-6299). Other authors: Ertay, Kahveci and Tabanli (2011, p. 1152-1167) indicate 6 main criteria (reliability, responsiveness, flexibility, cost and financial, assets and infrastructure, environment) and 20 sub-criteria.

Most recent publication of Galińska and Żak presents the model of the supplier evaluation process with an application of the following criteria (Żak & Galińska, 2017, p. 132):

- Product Price/Cost and Payment Conditions,
- Timeliness of Delivery/ Supplier,
- Reliability of Delivery/ Supplier,
- Cost of Delivery,
- Accessibility of Supplier,
- Customer Service Quality (during the supply process),
- Market Position of the Supplier,
- Performance of the Supplier,
- Modernity of the Supplier.

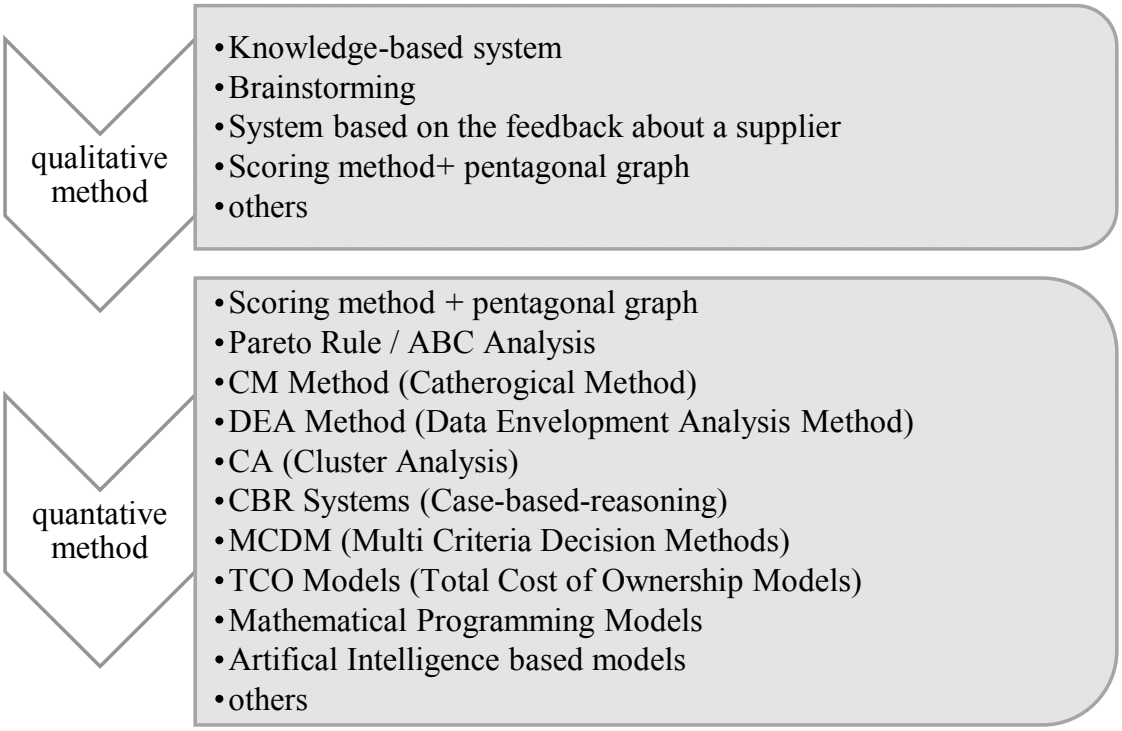
This article presents the case study of suppliers evaluation process based on the above mentioned criteria. All these aspects are thoroughly described in section 4, whereas the computational experiments, carried out with the application of these criteria, are presented in section 5 of this paper.

2.3. Methodology in the Suppliers Evaluation and Selection Process

Suppliers evaluation considers one's ability to safeguard supply sources, develop a trustworthy relationship with the supplier, reliability and trustworthiness in their partnership, introduction of the clear selection process and maintenance of a sustainable advantage over competitors.Within the scope of procurement process, the final selection of the most desired supplier is the last stage of a decision process. It also forecasts the profits for the company from establishing cooperation with the potential supplier. Then, the parent company commissions the execution of some services to the counterparty. Finally, the results of supplier's evaluation criteria and their potential to build long-term cooperation with the customer should be taken into consideration in the whole selection process[5].

In addition, evaluation and selection process can be carried out with an application of both qualitative and quantitative methods and procedures. The most common are (Figure 1):

Figure 1. Ranking of suppliers' evaluation and selection methods



Source: self-study based on Nowakowski & Werbińska- Wojciechowska, 2012, p. 34

Modern literature provides a lot of tools, methods and procedures used in suppliers evaluation and selection process. Recently however, Multiple Criteria Evaluation Method has been becoming increasingly important. Next section of this paper presents detailed description of the above mentioned method.

[5]http://www.ebz-beratungszentrum.de[access June 27,2016]

3. MULTIPLE CRITERIA DECISION MAKING/AIDING METHODOLOGY (MCDM/A)

3.1. Methodological Background of MCDM/A

Multiple Criteria Decision Making methodology, which derived from the operational research, is a mathematical method supporting the decision making process. It is applied to evaluate different aspects of the considerate variants (hardly comparable) in order to select the best alternative. Such method supports decision maker (DM) (person who defines decision problem) with rules, tools and methods in solving complex decision problems, considering several – often contradictory – points if view (Figueira et al., 2005, p. 21; Vincke, 1992, p. 33). Multiple criteria analysis facilitates decision making process, starting with defining the objectives, creation of the variants and finally, selection of the most desired one (Walentynowicz & Jankowska-Mihułowicz, 2012, p. 207). It provides thorough analysis of all the criteria defined by the decision maker in search for the most desired alternative (Roy, 1990, p. 324-331; Roy, 1990, p. 71).

MCDM/A is a methodology in which, having defined a set of actions (variants/ solutions) A and a consistent family of criteria F, it tends to (Galińska et al., 2015, p. 140-144):

- determine the subset of actions (variants, solutions) considered as the most desired in aspect of family of criteria (choosing problem),
- divide A into subsets according to concrete classification rules (sorting problem),
- rank actions (variants, solutions) from the best to the worst (ranking problem).

The set of A can be defined as set of objects, decisions, solutions, variants or actions, which are analysed in decision process. The consistent family of criteria F should be characterized by the following features (Żak, 2014, p. 7141-7153):

- it should provide a comprehensive and complete evaluation of all considered variants,
- it should have a specific direction of DM's preferences,
- the domain of each criterion should be disjoint with the domains of other criteria.

Each criterion in the family of criteria F is used to evaluate the A set and represents the DM's preferences in relations to a proper aspect of a decision problem.

Various methods and tools are used to solve the multiple criteria decision problems. In general, they can be divided into three groups:

1. Methods derived from the multi-attribute utility theory e.g. UTA (Figueira et al., 2005, p. 34), AHP (Saaty, 1980, p. 66; Saaty, 1995, p. 81-126),
2. Methods based on the outranking relation e.g. Electre I–IV (Roy, 1990, p. 324-331; Roy, 1990, p. 127), Promethee (Figueira et al., 2005, p. 213), Oreste,
3. Interactive methods called multiple objective local evaluation methods based on the trial and error approach implemented in the specific interactions e.g. Light Beam Search – LBS) (Książek, 2001, p. 555-561).

In this article, the computational experiments have been carried out with the application of two multiple criteria analysis methods i.e.: Electre III/IV and AHP method. From a methodological point of view they represent two alternative schools of MCDM/A. AHP method belongs to the American school of MCDM/A and it is based on the multi-attribute utility theory (Keeney & Raiffa, 1993, p. 76). Electre III/IV represents the MCDM/A method of the European/French originand is based on the binary outranking relation. However, both methods can be used to solve the multiple criteria decision problem of choosing the supplier for the manufacturing company.

3.2. Characteristics of Electre III/IV Method

Electre III/IV method is the multiple criteria method of ranking the finite set of variants which are evaluated with the application of the set of criteria. The method is one of the universal multiple criteria ranking methods based upon the outranking relation (Figueira et al., 2005, p. 33; Roy, 1990, p. 48; Vincke, 1992, p. 71; Żak, 2005, p. 89). The procedures carried out with the application of Electre III/IV method aim at the construction of preference model on the basis of pairwise comparisons of all decision variants taking into account the thresholds which define the relation between these variants (Stachowiak, 2002, p. 132).

Computational algorithm of Electre III/IV comprises of three stages: (Galińska et al., 2015, p. 140-144)

I. matrix evaluation construction and definition of the DM's preference model,
II. outranking relation construction,
III. outranking relation implementation.

First stage starts from the definition of the set of solutions (variants) A and the consistent family of criteria F. Then, it is necessary to specify the value of particular criterion functions and wage indexes for the each of criterion (criterion wages). Finally, the DM's preference model is defined via the thresholds of indifference qj', preference pj' and veto vj' as well as the importance indexes. It is bound by a principle as follows: qj'<pj'<vj'.

On the second stage of the method, the consistency indexes C(a,b) are computed for every pair of variants (a,b). These are presented in the form of a consistency matrix. Their values indicate to what extent the a and b are consistent with the statement that a outranks b in relation to all other criteria. Then, the inconsistency index Dj(a,b) is computed for every criterion j. The inconsistency index contradicts the statement that a outranks b. Finally, the outranking relation S(a,b) is structured which is defined as the outranking degree d(a,b) that is the aggregated measure of variants evaluation based on the consistency C(a,b) and inconsistency Dj(a,b) indexes. S(a,b) is an overall measure which specifies to what degree a outranks b. Outranking/Reliability degrees construct the reliability matrix.

On the third stage of Electre III/IV algorithm, the variants are ranked on the basis of the outranking degrees S(a,b). First it is a preliminary ranking structured with the application of descending and ascending distillations which rank the variants form the best to the worst. Afterward, the final ranking is structured on the basis of descending and ascending preorders. As the result, the variants are finally ranked. Between the

variants the following relations may occur: indifference “I”, preference “>”, non-preference “<” and incomparability “R”.

3.3. Characteristics of AHP Method

Analytic Hierarchy Process Method (AHP) is based on hierarchical analysis of decision problems. Using the method, it is possible to decompose a complex decision problem and make the final ranking for the definite set of variants. AHP method facilitates the process of choosing the decision variants which can be either some physical objects (machines, goods) or some states which are represented by the defined variants. The method encompasses the multiple criteria approach which is based on the strategy of modeling the DM’s preferences and on the assumption that the variants are comparable. Since the multiple criteria approach presumes that preferences are natural in the process of evaluation carried out by a person, the method takes into account the DM’s preferences which gives the evaluation a subjective character (Downarowicz et al., 2000, p. 7).

The AHP method was formulated by Thomas L. Saaty (1990, p. 9-26; Saaty, 1980, p. 55) who claimed that human judgements are always relative and depend on the DM’s characteristic, his role and his system of values. As the result, one may observe various approaches to the decision problem (the object of evaluation) which manifest itself in different importance wages of partial utilities of specific variants which are the same with the criteria of evaluation. The above statement indicates that the AHP method is in line with the utility theory (Downarowicz et al., 2000, p. 8).

The algorithm of the AHP method consists of four phases (Saaty, 1980, p. 55; Żak, 2011):

I. the making of the hierarchical structure of the decision process, so firstly the overall description of the problem and secondly the deconstruction of the problem to the simple parts which are the elements of the hierarchy; in particular the definition of the aim of the decision process, criteria and sub-criteria of the evaluation and evaluated variants;
II. the naming of the DM’s preferences in the form of the preferences matrix expressed on the 1 to 9 point scale (implemented by Saaty) and calculation of normalized absolute importance evaluation of all elements of the hierarchy;
III. the examination of the global consistency of the preferences matrix on the all levels of the hierarchy through calculation of the matrix consistency index CI and comparison of it with the limit value (CI< 0.1);
IV. generation of the final ranking of variants based on the aggregated utility measure Ui of each of the variants. The measure is represented by a utility function.

Ranking, which is the final result of the algorithm of the AHP method, ranks the variants from the best to the worst in accordance with calculated utility values Ui starting from the highest to the lowest value.

3.4. The proposed methodology of selecting the suppliers in clothing industry

Based on the literature review and the previous authors' works they propose the universal procedure for evaluation and selection of the most desirable supplier. The proposed an approach which based on the universal procedure of solving the multiple criteria decision problems and customized to specific features of the suppliers' selection problem. It includes the following stages (Żak & Galińska, 2017, p. 131-132):

I. Investigation of the decision situation and its verbal description.
II. The suppliers' selection problem structuring and mathematical modeling. Formulating the suppliers' selection problem as a multiple criteria ranking problem. Definition of variants A and a consistent family of criteria F.
III. Analyzing, modeling and aggregating the Decision Maker's preferences.
IV. Review, evaluation and selection of the appropriate multiple criteria methods (computational procedures, algorithms) to rank the suppliers from the best to the worst.
V. Carrying out a series of computational experiments. Solving the suppliers' selection problem with an application of the global model of preferences and selected MCDM/A methods.
VI. Selection of the most desired variant – supplier, the winner in the generated rankings and the compromises solution that best matches the trade-offs and expectations of the Decision Maker.

The stages have a universal/ generic character and can be applied to solve any category of the multiple criteria decision problems, further formulated as ranking problems. Also, the presented methodology can be used to analyse and select the suppliers operating in various industries, which is further analyzed and confirmed in previous works' of the authors.

4. DESCRIPTION OF THE DECISION SITUATION

4.1. Verbal Characteristic of the Decision Problem

The issue considered in this paper is evaluation and selection of a supplier of goods for a company operating in the clothing industry which specializes in manufacturing and distribution of clothing, shoes and accessories to variety of clients in different age groups. The company is one of the leading business entities in retail clothing market operating in the Central and Eastern Europe.

Company's business activity is divided into fashion and discount sector which are substantially different. 700 entities operate within both sectors.

Discount sector comprises the chain of shops with cloths and accessories for women, men and kids. The collection is complemented with household textiles and shoes. Good relation of cloths' quality to their price and broad network of distribution (400 stores in Poland and abroad on the Romanian, Czech and Slovak markets) are the most important advantages of the chain. In the stores often are available known and branded goods of Polish manufacturers and importers. Moreover, the company, in a dynamic way, develops e-commerce channel by selling its products online in the biggest discount clothing store.

In the sector of fashion, the company develops, promotes and distributes its three well-known clothing brands created by designers who work for the company. The sample collection is manufactured in the parent's company factory whereas the final collection is manufactured in over 100 factories in Poland and abroad, especially in China, India, Bangladesh, Turkey, Hong Kong and Pakistan, which is in line with outsourcing rules. The goods are distributed in the retail stores and online. The chain of shops in fashion sector comprises about 300 entities in Poland and abroad.

The company is going to produce for the autumn-winter collection cloths made of the fabric which contains the UV stabiliser. The fabric is light, breathable and does not stretch out. Taking into consideration that the company has not used this kind of fabric yet, the Board of Directors (acting as the Decision Maker (DM) in the decision situation described) has decided to purchase the fabric from the local producer. Afterward, the clothing with the UV stabiliser, being the sample collection, would be manufactured in the parent's company factory and not in a company of an external supplier which is in accordance with the company's policy. It allows the full control over the process of production and guarantees fair quality of the manufactured clothing. Such approach stands the company out of the competition and is highlighted in many advertising campaigns in which the main focus is not only the fact that the collections are fashionable but also that they are made of high-quality fabrics and with the best technologies.

4.2. Definition of Variants

The following autumn-winter collection of clothing is going to be based on the new fabric which contains the UV stabiliser. Taking into consideration the company's policy, the decision has been made that the fabric would be purchased from the local/national manufacturers and the sample collection would be manufactured in the parent company's factory. The company decided to verify in detail, possibilities of Polish manufacturers due to the fact that this type of the fabric has been never before purchased by the company. Besides, the Board of Directors (the DM) decided to take into consideration only local manufacturers who operate in the maximum proximity of 150 km from the company's main office. Such criteria for selection of the suppliers are supposed to reduce the time of delivery and ensure the possiblity to supply relatively often small batches of the fabric which directly enters the production process. Moreover, it facilitates the usage of modern management strategies including Just-in-Time concept. Another advantages of purchaising the fabric from the local suppliers are: reduction of storage costs, improvement of the logistics and overall economic profits. Finally, the location of the company's main office enhances the cooperation with local suppliers since in the lodzkie voivodship are located offices of many successful companies from the clothing industry.

The company needs to cooperate with the trusted suppliers so that the implementation of the Just-in-Time concept would be possible. The problem of selection of the suppliers is defined as the multiple criteria task of ranking the variants. Variants taken into consideration in the case study from D1 to D5 stand for the suppliers of the fabric which contains the UV, what is described in Table 1.

Table 1. Characteristic of variants – fabric suppliers – in the case study

SUPPLIERS	CHARACTERISTIC
D1	Large production and service undertaking, located 30 km from the customer, existing 25 years on the market.
D2	Medium production undertaking, located 15 km from the customer, existing 30 years on the market.
D3	Large production undertaking, located 70 km from the customer, existing 22 years on the market.
D4	Small production and service undertaking, located 50 km from the customer, existing 9 years on the market.
D5	Medium production undertaking, located 35 km from the customer, existing 17 years on the market.

The DM has not cooperated yet with the manufactures who offer fabric with the UV stabiliser so the selection of the supplier has to be well-thought and based on the detailed analysis. The multiple criteria would be taken into consideration to carry out the analysis. The criteria, which are believed by the DM to be the most important, are e.g.: the quality of the fabric delivered, timeliness of the supply, its security and flexibility.

4.3. Definition of the Consistent Family of Criteria

The decision process related to selection of supplier of the fabric with the UV filter has been based on the evaluation of 5 suppliers. To verify them, the model proposed by Galińska and Żak has been used (Żak & Galińska, 2017, p. 135-137). The model points to 9 evaluation criteria. The importance wages of the criteria were formulated on the basis of the interview with the DM, his preferences and aspirations. Criteria K1-K9 are described in detail in the Table 2.

Table 2. Description of criteria on the basis of which the variants – fabric suppliers – have been evaluated in the case study

CRITERIA	SUB-CRITERIA	DESCRIPTION
K1 Product price and payment conditions	K1.1: Unit cost of the product delivered	The sub-criterion specifies the total unit cost of purchasing of 1 linear metre of the product – fabric with the UV stabiliser, expressed in PLN. The sub-criterion is minimized.
	K1.2: Payment conditions	The sub-criterion specifies the payment date, expressed in the number of days. This sub-criterion is maximized.
K2 Timeliness of delivery/ supplier		The criterion specifies the share of the deliveries completed in the due date. It is the maximized criterion, expressed in percentage.

K3 Reliability of delivery	K3.1: Share of deliveries of products in appropriate quantity and conditions (undamaged)	This sub-criterion stands for the delivery of the right product in the proper quantity and quality. The sub-criterion is maximized and expressed in percentage.
	K3.2: Share of deliveries carried out as agreed	The sub-criterion specifies the percentage of deliveries performed in accordance with the timetable and agreement. It is expressed in percentage and equals to the share of applicable agreement performance. This sub-criterion is maximized.
	K3.3: Quality of the product delivered	The sub-criterion specifies the percentage of products delivered in the expected and demanded quality. This sub-criterion is maximized and expressed in percentage.
K4 Cost of delivery		The criterion specifies the delivery cost, expressed in PLN. It is the minimized criterion.
K5 Accessibility of supplier	K5.1: Time-oriented accessibility	The sub-criterion specifies the frequency of product delivery possible to perform in the period of one week, expressed in days. The sub-criterion is maximized.
	K5.2: Geographical accessibility	The sub-criterion specifies the spatial distance/ the length of road to the nearest warehouse of the supplier. It is expressed in the number of kilometers. The sub-criterion is minimized.
K6 Customer Service Quality (during the supply process)	K6.1: Level of customer support (info, monitoring, problem solving, reaction)	The sub-criterion comprises such elements as: constant monitoring of the supply and giving the information about the supply to the customer, ability of solving the problems which occur during the process of delivery, immediate response to the existing situation. The sub-criterion is maximized, expressed in 1-5 point scale.

	K6.2: Flexibility of the supplier (in changing the order)	The sub-criterion enables the measurement of the supplier's responsiveness to the unexpected/ additional order. The sub-criterion is expressed in the number of days that the supplier needs to complete an unexpected order made by the company. The sub-criterion is minimized.
K7 Market position of the supplier	K7.1: Market experience of the supplier	The sub-criterion specifies the number of years that the supplier exists on the market. It is the maximized sub-criterion, expressed in the number of years.
	K7.2: Market share	The sub-criterion specifies the supplier's share in the market. This sub-criterion is maximized, expressed in the percentage.
K8 Performance of the supplier	K8.1: Efficiency of human resources (sales/ employee)	The sub-criterion is expressed as the index: sale per the worker. The sub-criterion is maximized, expressed in PLN.
	K8.2: Assets turnover	The sub-criterion specifies the company's effectiveness of the fixed assets management. It is expressed as the relation between the value of annual sale to the value of assets of the particular supplier. The sub-criterion is maximized.
K9 Modernity of the supplier		The criterion indicates to the supplier's technological and organizational advantages. It comprises such elements as: technological know-how, availability of advanced machines and devices, their quality and modernity, the implementation of modern management concepts (lean management, JiT), the implementation of methods and technics related to environment protection. The criterion is maximized, expressed in 1-5 point scale.

The criteria listed and discribed in the Table 2 would be neccessary in evaluation of the suppliers taken into account in the case study. The DM indicated the following criteria as the most important (the highest wage of the criterion): the quality of the

delivered product, delivery timeliness, delivery security, price of the product and flexibility of the delivery process.

The evaluation matrix has been constructed (Table 3) on the basis of the nine suppliers evaluation criteria defined above and the original raw data.

Table 3. The evaluation matrix based on raw data in the case study

CRITERIA		SUPPLIERS				
		D1	D2	D3	D4	D5
K1	K1.1 [PLN]	24,1	24,5	23,5	25	25,5
	K1.2 [Days]	30	21	21	14	30
K2 [%]		0,95	0,98	0,85	0,9	0,95
K3	K3.1 [%]	0,99	0,95	0,9	1	0,95
	K3.2 [%]	0,9	0,95	1	0,85	0,98
	K3.3 [%]	0,99	0,95	0,95	0,90	0,99
K4[PLN]		174	87	406	290	203
K5	K5.1 [Days]	5	4	5	3	5
	K5.2 [KM]	30	15	70	50	35
K6	K6.1 [Points]	5	4	3	4	2
	K6.2 [Days]	1	2	1	3	2
K7	K7.1 [Years]	25	30	22	9	17
	K7.2 [%]	0,083	0,061	0,092	0,012	0,056
K8	K8.1 [PLN]	48000	37000	53000	20000	35000
	K8.2 [-]	8,3	4,9	7,5	3,1	8,9
K9 [Points]		5	4	4	3	3

In the case study described the raw data have been properly processed. Computational experiments are presented in detail in the following section of the paper.

5. COMPUTATIONAL EXPERIMENTS

5.1. The Supplier's Ranking Based on the Electre III/IV Method

In accordance with the Electre III/IV method algorithm, the evaluation matrix has been constructed (Table 3), which contains the all variants' evaluation – suppliers of the fabric with the UV stabiliser (D1, D2,…D5) in relation to all criteria (K1, K2,…K9). The data from the evaluation matrix have been processed in the computer programme MCDM ToolKit, which is the computer implementation of this method.

Afterward, the DM's preference model has been defined in the process of naming the wages of criteria and thresholds: indifference threshold q, preference threshold p and veto threshold v, which are the mode of expression the DM's sensitivity to the changing value of criteria. The model has been presented in Table 4, which is the screenshot of the MCDM ToolKit programme.

Table 4. The DM's preference model in the case study

Preference information					
Criterion	Preference direction	Weight	Indifference threshold	Preference threshold	Veto threshold
K1.1	Decreasing (Cost)	8,000	0,5	1	2
K1.2	Increasing (Gain)	2,000	0	9	30
K2	Increasing (Gain)	9,000	0,03	0,1	0,3
K3.1	Increasing (Gain)	7,000	0,03	0,1	0,3
K3.2	Increasing (Gain)	8,000	0,03	0,1	0,3
K3.3	Increasing (Gain)	10,000	0,03	0,1	0,3
K4	Decreasing (Cost)	3,000	50	200	500
K5.1	Increasing (Gain)	7,000	0	1	3
K5.2	Decreasing (Cost)	3,000	20	50	150
K6.1	Increasing (Gain)	2,000	0	1	3
K6.2	Decreasing (Cost)	8,000	0	1	3
K7.1	Increasing (Gain)	4,000	5	10	30
K7.2	Increasing (Gain)	5,000	0,005	0,02	0,1
K8.1	Increasing (Gain)	7,000	2000	10000	30000
K8.2	Increasing (Gain)	6,000	1	3	8
K9	Increasing (Gain)	5,000	0	1	3

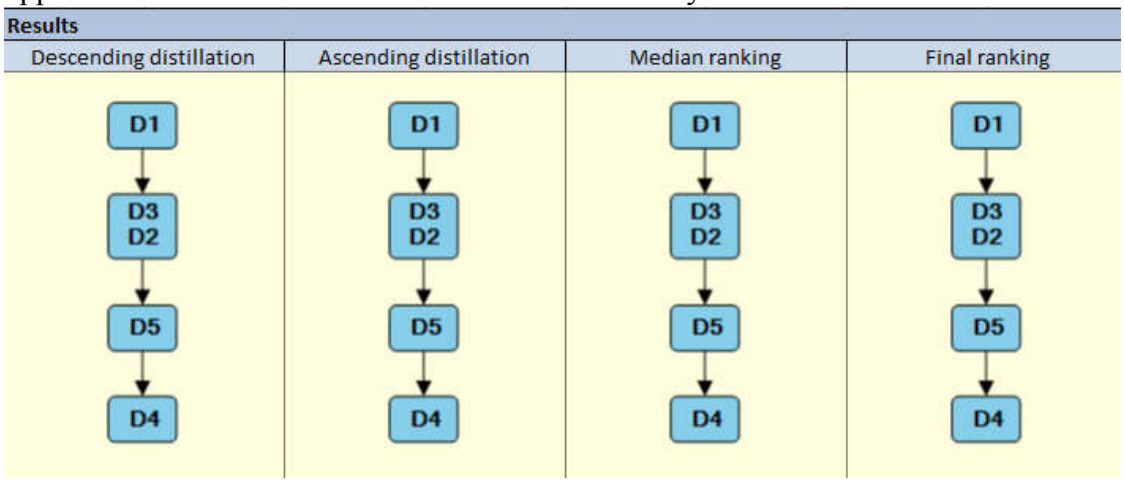
In the second stage of the algorithm of Electre III/IV method, the outranking relation has been constructed. To build the outranking relation, the matrix of concordance and discordance were generated. The concordance matrix comprises concordance indexes C(a,b) and the discordance matrix comprises the discordance indexes Dj(a,b). On that basis, the credibility matrix has been obtained which is presented in Table 5. The matrix contains the outranking and credibility degrees d(a,b), which are the aggregated measure of the variants evaluation and representation of the outranking relation S(a,b). Each credibility degree specifies the extent to which globally 'a outranks b'.

Table 5. Credibility matrix in the case study

Credibility matrix					
Alternative	D1	D2	D3	D4	D5
D1	1,000	0,968	0,856	1,000	0,939
D2	0,449	1,000	0,333	0,979	0,660
D3	0,302	0,376	1,000	0,863	0,778
D4	0,000	0,063	0,000	1,000	0,026
D5	0,000	0,333	0,000	0,479	1,000

The outranking relation S(a,b) has been used on the third stage of the algorithm. As the result of the ascending and descending distillations carried out, the complete preorders were structured. Then, they have been averaged into the median ranking and the intersection of preorders resulted in the final ranking – Figure 2.

Figure 2. Final results of the computational experiments carried out with the application of Electre III/IV method in the case study



Graphical final ranking is presented in the tabular form as the so called outranking matrix which is also known as the final relation matrix, depicted in Table 6. The matrix includes final relation of the variants – suppliers of the fabric with the UV stabiliser, expressed in the following form: indifference (I), preference (>), inverse of preference (<) and incomparability (R).

Table 6. The outranking matrix (final relation) in the case study

Relation matrix					
Alternative	D1	D2	D3	D4	D5
D1	I	>	>	>	>
D2	<	I	I	>	>
D3	<	I	I	>	>
D4	<	<	<	I	<
D5	<	<	<	>	I

The final ranking and the outranking matrix point to the D1 supplier, which is the definite leader of the ranking, as the most preferable variant. Its most important advantages are: delivery timeliness (K2) and supplier's reliability (K3.1). Moreover, the supplier offers outstanding quality of the fabric (K3.3), which is particularly important for the DM – Board of Directors of the manufacturing company. Variant D1 has at the same time few disadvantages. What is really interesting, this supplier does not offer the cheapest fabric which means that positive features of the variant compensate for that disadvantage.

The least desired variant is D4, which is presented as the one with many disadvantages. It is the small production and service undertaking which offers the fabric for high unit price (K1.1) and average quality (K3.3). Besides, the undertaking does not guarantee enough security (K3.2) of the supply which is, together with the quality of the fabric, one of the most important characteristic for the DM. Finally, the D4 variant characterizes the least effectiveness of the supply (the supply frequency which is possible to ensure within one week; K5.1).

5.2. The Ranking of Suppliers with the Application of AHP Method

The variant and criteria for evaluation have been defined on the first stage of the AHP method algorithm. Then, the authors of the paper set about forming the DM's preference model.

Forming the DM's preference model (second phase of the algorithm), the pairwise comparison has been used which is characteristic for the AHP method. Each element of the hierarchy has been compared with another one and labeled with a proper importance/preference degree on 1 to 9 point scale. Each number on that scale corresponds to the preference strength of one element in relation to the other. All of the indexes have compensatory nature which means that the evaluation value of less important element is reversal to the evaluation value of the more important one. The pairwise comparisons have been carried out for the criteria, sub-criteria and evaluated variants – suppliers of the fabric with the UV stabiliser. The absolute and normalized wage of criteria/sub-criteria/variants has been generated for each matrix.

Pursuant to the computational scheme of the AHP method, the consistency indexes CI for each matrix of relative weights at each level of the hierarchy (criteria, sub-criteria and variants) have been calculated in the third phase of the algorithm. In the analyzed case study 23 CI-s have been computed, including 1 for criteria level, 6 for the sub-criteria levels and 16 for variants compared against each criterion.

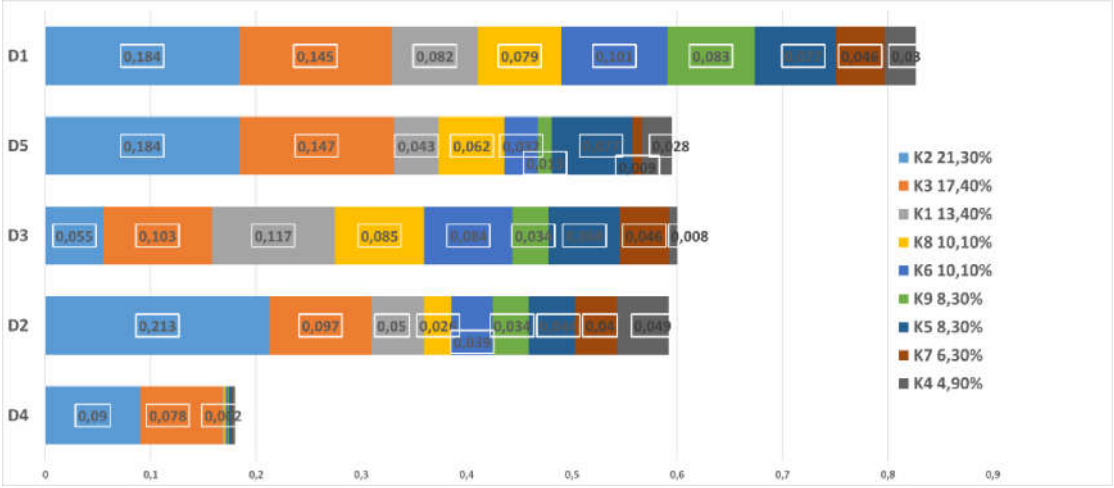
In the fourth phase of the algorithm, absolute and normalized importance wages of the elements of the hierarchy have been aggregated by means of the utility function Ui. On this basis, the final rankings of the variants have been constructed and depicted in the Table 7 and Figure 3.

Table 7. The values of utility of each variant generated in the computational procedure based on the application of AHP method in the case study

	Alternative	Score
☑	D1	0.827
☑	D5	0.605
☑	D3	0.601
☑	D2	0.592
☑	D4	0.286

Table 7 presents the computed utilities Ui of each variant – supplier, with its absolute values. Figure 3 shows the classification of variants based on their generated utilities in the form of graph. Each variant, presented on the graph, is featured by the level of computed utility (from 0.286 – D4 to 0.827 – D1 in the absolute values). The winner of the ranking generated with the application of AHP method is supplier D1. The weakest variant that occupies the bottom position of the ranking is D4.

Figure 3. Graphical representation of the final ranking generated with the application of AHP method in the case study



The results generated with the application of two different methods of multiple criteria analysis i.e. Electre III/IV and AHP are fast identical. Both methods clearly indicate that the best supplier in the described situation for the examined company is D1 variant which substantially outranks all other variants. The authors of this paper recommend to choose D1 supplier as the most universal and desired from the perspective of many different evaluation criteria.

6. CONCLUSION

This paper presents the universal methodology for solving the problem of choosing the supplier of fabric with the UV stabiliser. In the presented methodology, the rules of multiple criteria decision making/aiding (MCDM/A) are implemented, as well as the traditional algorithm of proceedings in the situation of solving the multiple criteria decision problem. The decision problem was formulated as the multiple criteria problem of ranking variants. To construct the final ranking of suppliers, the methods Electre III/IV and AHP have been used.

The paper has methodological and utilitarian values. It indicates how the complex analyses and evaluation of the suppliers should be carried out to construct the final ranking of the variants from the best to the worst in the multiple criteria sense.

On the methodological grounds, the most important author's achievement is presentation of the all stages of proceedings applied in solving the multiple criteria decision problem (ranking of variants), which is, in the described case study, selection of the fabric supplier for the company operating in the clothing industry. The authors present the procedure of defining the variants (suppliers), specify the consistent family of criteria and their evaluation, identify and model the DM's preferences, carry out computational experiments using two different methods of multiple criteria analyses, generate solutions and choose the most desired supplier. Moreover, the authors show the advantages of Electre III/IV and AHP methods as the universal tools of multiple criteria analysis which are ideal for the process of evaluation of fabric suppliers.

This paper can be used in practice since the authors demonstrate that the best solution is supplier D1, who in terms of multiple criteria evaluation is characterized by many advantages, offering at the same time not the lowest price for the product. The authors of the article recommend this variant as the most desired solution of the decision problem.

In the authors' opinion further research should be carried out in two directions:

I. Application of alternative MCDM/A methods (Promethee, ANP, UTA) to the evaluation of different categories of suppliers and in-depth analysis of their suitability, strengths and weaknesses.
II. Further analysis of suppliers' selection processes in different industries. Comparison of evaluation criteria, aspects considered and interests of various stakeholders. This research should finally confirm the consistency and universality of the proposed family of criteria.

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