MODERN MANAGEMENT REVIEW **2022**
MMR, Vol. 27, No. 3(2022), pp 49-57 **July-September**

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METHOD OF PROCESSING CUSTOMERS' EXPECTATIONS TO IMPROVE THE QUALITY OF PRODUCTS

Obtaining and processing customers' expectations for products is a problem in view of the dynamic changes of these expectations. It refers to precisely determining the most important requirements of customers to improve the product in a standardized way. The purpose of the article was to develop a method to process customers' expectations to improve the quality of products. The motivation for developing this method was to reduce uncertainty in expressing customer expectations. Using the SMART(-ER) method, the goal of the analysis was determined. Then, during brainstorming (BM), the product and the analysis criteria were selected. Next, by using a survey with the Likert scale, the customer expectations were obtained. Later, these expectations were processed by the fuzzy analytic hierarchy process (FAHP). Based on processed weights, the choice of important criteria was compiled. The choice was made according to the Pareto-Lorenz Rule. The originality of the article is based on a method, which simultaneously combines quality management tools with the method in a fuzzy decision environment. This method can be used to verify customers' expectations for any product.

Keywords: multi-criteria decision making; quality; production engineering; FAHP method; mechanical engineering.

1. INTRODUCTION

Improving a product is a challenge. Organizations obtain customers' expectations, but it is still a problem to process them in a precise way (Ostasz, Siwiec, Pacana, 2022; Pacana, Siwiec, 2021). It results from changes in these requirements over time and from the subjective character of these expectations (Siwiec, Pacana, 2021). After obtaining expectations, it is necessary to use the methods, which allow one to reduce this subjective approach. The most often used is the fuzzy multi-criteria decision method (FMCDM) and the relatively frequently used method is the Fuzzy Analytic Hierarchy Process/FAHP (Laarhoven, Pedrycz, 1983). The FMCDM method is used to determine the relative weights of criteria (Torfi, Farahani, Rezapour, 2010) and the FAHP (Saad, Kunhu, Mohamed, 2015)

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which was used to verify orders in the automotive industry. The main idea was to determine the order for using the different methods. The next example is an article (Putra, Andryana, Gunaryati, 2018), in which the quality of gems was analyzed. The FAHP method was used to choose and assess the quality of gems. Additionally, an analysis of the effectiveness of this method was performed in the work of Lima-Junior, Carpinetti (2019). As a result, it was concluded that this method can be used as an effective tool to eliminate the zero weight of criteria and points of the alternative without impact on coherent results. The next examples of the application of these methods were in the analysis of the future sea sector including criteria such as human factors, management and environmental aspects (Ozdemir, Altinpinar, Demirel, 2018) as well as political issues taking into account , political, economic and social criteria (Oguztimur, 2011), or verification of car parts (Shukla, Garg, Agarwal, 2014). In addition, Siwiec and Pacana (2021), developed a model supporting making decisions in the development of a product considering sustainable development. The model was based on combined decision methods, i.e., FAHP and the fuzzy technique for order of preference by similarity to the ideal solution (FTOPSIS). Ulewicz, Siwiec, Pacana, Tutak, Brodny (2021) developed a method to verify renewable energy sources (RES). The method was combined FAHP, TOPSIS, and qualitative-cost analysis (AKJ).

After reviewing the selected works, the authors tried to reduce the uncertainty of the customer' expectations. The fuzzy multi-criteria decision method (FMCDM) was used for that purpose. This method was combined with other techniques, for example, the FTOPSIS method. However, this method was not combined with quality management tools to improve the quality of the product when considering customer expectations. Hence, it was concluded that the right approach is to develop a method to process customers' expectations as part of the FAHP method and quality management tools. The concept was to reduce uncertainty in determining customer expectations while improving the quality of the product. The purpose of the article was to develop a method for processing customer's' expectations to improve the quality of products. The method was used for the development of a more customer-friendly vacuum cleaner.

2. METHOD

The proposed method was developed using integrated quality management tools and the fuzzy multi-criteria decision method. Those methods included SMART(-ER) method, brainstorming (BM), survey on the Likert scale, FAHP method, and Pareto-Lorenz analysis (rule 20/80). The general scheme of the stages of the method is shown in Figure 1.

Figure 1. Scheme of integrated stages of the proposed method to process customers' expectations

Source: Own study.

A short description of the proposed method is shown in the next part of the study.

Stage 1. Determining the purpose of the analysis

The purpose is determined by the entity using the proposed method. To determine the desired outcome, it is adequate to use the SMART(-ER) method (Lawlor, Hornyak, 2012). It was assumed that the purpose is to determine the precise criteria for the product. This precise criterion is what is important for the customers.

Stage 2. Choice of product for verification

The choice is done by the entity applying proposed method. In this approach, this refers to the choice the product we are planning to improve. It results from the concept of method, where in the first order we are making improvement decisions for important criteria. Therefore, it can be a product in the maturity phase or the declining phase.

Stage 3. Determining product criteria

Step 3 refers to the determination of criteria for which importance (weights) will be calculated. Therefore, it should be a criterion that generates a quality product. Mainly, there are technical criteria, so-called quantitative (measurable) criteria. Therefore, it is preferred to determine criteria in this category group. It is necessary to determine from fourteen to twenty-five criteria (Hansen, Bush, 1999; Huang, 1999; Roder, Heidl, Birkhofer, 2013). In the proposed approach, the criteria are defined by a team of experts brainstorming (BM) according to the product catalog (specification). The criteria are defined for the product selected in Step 2 of the method.

Stage 4. Obtaining customer expectations

The purpose is to obtain assessments of importance of criteria according to customer expectations. To obtain customers' expectations, it is proposed to use the popular tool, survey with the Likert scale (Alexandrov, 2010), where 1 = practically irrelevant criterion to 5 = the most important criterion. The survey considers all criteria specified in the third stage of the method. The method presented in the paper (Siwiec, Pacana, 2021) is used to estimate the required number of customers from whom expectations will be obtained.

Stage 5. Determining the weights of the criteria

The idea of Stage 5 is to process all assessments of criteria weights (from the fourth stage) into precision estimated weights of criteria. It means to reduce inconsistencies and uncertainties in the assessments of weights of criteria determined by customers. It was assumed that it is effective to use the FAHP method. Initially, the processing of assessment of weights from the Likert scale into the fuzzy Saaty scale is done. This means replacing grades on the traditional five-point scale with grades on a fuzzy scale, as shown in Table 1.

Table 1. Processing assessments in the Likert scale into a fuzzy Saaty assessment

Description Assessments of Importance	Assessments in the Likert Scale	Fuzzy Assessment in Likert Scale
Practically unimportant	1	1; 1; 1
Not important	2	1,5; 2; 2,5
Important	3	2,5; 3; 3,5
Very important	4	3,5; 4; 4,5
Absolutely the most important	5	4,5; 5; 5,5

Source: Own study based on (Siwiec, Pacana, 2021).

After processing the assessments, it is necessary to develop a combined fuzzy decision matrix as shown in Formula 1 (Ulewicz et. al., 2021).

$$\tilde{x}_{ij}=\left(a_{ij}, b_{ij}, c_{ij}\right)$$
$$where: \quad a_{ij}=\min_{k}\left\{a_{ij}^{k}\right\}, \quad b_{ij}=\frac{1}{K}\sum_{k=1}^{K} b_{ij}^{k}, \quad c_{ij}=\max_{k}\left\{c_{ij}^{k}\right\}, \tag{1}$$

where: a – fuzzy rating, left, b – fuzzy middle rating, c – fuzzy rating on the right, K – customer, i, j = 1, 2, …, n.

Then, it is necessary to follow the FAHP method, as is shown in the literature on the subject (Oguztimur, 2011; Ozdemir et al., 2018; Ulewicz et al., 2021; Shukla et al., 2014; Siwiec, Pacana, 2021).

Stage 6. Choice of the importance of criteria

At this stage, it is necessary to determine the criteria that are important to customers.

The choice is made based on weights of criteria in the fifth stage. In the proposed approach, the Pareto-Lorenz analysis was used (Hoła, Sawicki, Szóstak, 2018). As a result, 20% of the weight of criteria are the most important criteria for customers. For these criteria, improvement actions should be taken in the first place. After their introduction, customer satisfaction should be verified, and the next criteria should be improved.

3. RESULTS

A test of the proposed integrated method was carried out for a domestic vacuum cleaner. This product was manufactured in a Polish company located in Podkarpacie.

In the first stage, the purpose of the analysis was determined. In this approach, the purpose was to precisely determine the criteria for the product that were important to the customers.

In the second stage, the product for verification was selected. As part of the method test, the vacuum cleaner was the choice. The choice resulted from the preferences of the entity in which the analysis was performed. The verification product was in the maturity phase. It was subjected to improvement activities by changing the design of the vacuum cleaner. However, there was still a search for a way to increase customer satisfaction with this product. Therefore, it was considered justified to analyze it.

As part of the third stage of the method, the criteria for the vacuum cleaner were determined. Based on the assumptions, these criteria were determined during brainstorming (BM). There were fourteen technical criteria, which were selected based on the catalog (specification) of the vacuum cleaner, i.e.: motor power, cable length, winding system, dimensions, weight, filter type, width of the suction hose, length of the suction hose, possibility of vacuum control, type of road wheels, on / off type, electric brush socket, number of accessories in the set, and rubber protectors to protect against bumping.

During the fourth stage of the method, the customers' expectations were obtained. As part of the pilot research carried out in 2020, the expectations of twenty-four customers were obtained. A survey based on Likert Scale was used to obtain assessments of the weights of criteria for the vacuum cleaner. All fourteen vacuum cleaner criteria that were identified in Step Three of the method were considered in the survey. The weights of the criteria weights were processed in the next step by the weightings of the vacuum cleaner criteria.

At the fifth stage of the method, the weights of the criteria were calculated.

According to the proposed approach, the FAHP method was used for that. Initially, customers' expectations were processed from the Likert scale into the fuzzy Saaty scale. Then the combined matrix was created. The results are shown in Table 2.

Table 2. Fragment of a combination of assessments of vacuum cleaner criteria

Criteria	Mark	a	b	c
Vacuum cleaner motor power	C1	2,5	3,72	5,5
Length of the power cord	C2	1,5	3,8	5,5
Power cord winding system	C3	1	3,04	5,5
Dimensions of the vacuum cleaner	C4	1	2,72	5,5
Weight of the vacuum cleaner	C5	1	2,64	5,5
Type of vacuum cleaner dust filter	C6	1	2,84	5,5
…				
Rubber protectors to protect furniture against knocking	C14	1	3,08	5,5

Source: Own study.

Then a pairwise comparison matrix was developed. The matrix was developed according to the ratings of the connected customers. A fragment of the results of comparisons with pairs of criteria is presented in the Table 3.

Table 3. Fragment of results of comparison by pairs of criteria

M_{ij}	C1	C2	C3	C4	C5	C6
C1	1,00;1,00;1,00	1,67;0,98;1,00	2,50;1,22;1,00	2,50;1,37;1,00	2,50;1,41;1,00	2,50;1,31;1,00
C2	0,60;1,02;1,00	1,00;1,00;1,00	1,50;1,25;1,00	1,50;1,40;1,00	1,50;1,44;1,00	1,50;1,34;1,00
C3	0,40;0,82;1,00	0,67;0,80;1,00	1,00;1,00;1,00	1,00;1,12;1,00	1,00;1,15;1,00	1,00;1,07;1,00
C4	0,40;0,73;1,00	0,67;0,72;1,00	1,00;0,89;1,00	1,00;1,00;1,00	1,00;1,03;1,00	1,00;0,96;1,00
C5	0,40;0,71;1,00	0,67;0,69;1,00	1,00;0,87;1,00	1,00;0,97;1,00	1,00;1,00;1,00	1,00;0,93;1,00
C6	0,40;0,76;1,00	0,67;0,75;1,00	1,00;1,00;0,93	1,00;1,04;1,00	1,00;1,08;1,00	1,00;1,00;1,00
where: C1 – motor power, C2 – length of the power cord, C3 – power cord winding system, C4 – dimensions, C5 – weight, C6 – type of vacuum cleaner dust filter						

Source: Own study.

A fuzzy geometric average value for each criterion, fuzzy weights, and weights in terms of decimals were calculated and are shown in Table 4. (Oguztimur, 2011; Ozdemir et al., 2018; Ulewicz et al., 2021; Shukla et al., 2014; Siwiec, Pacana, 2021).

The sum of weights for all criteria was equal to 1. Therefore, the correctness of the calculations was confirmed.

As part of the sixth stage of the method, the most important criteria were selected. The choice was made according to the weights of the criteria and by using the Pareto-Lorenz analysis (Table 5.).

Table 4. Results from the FAHP method

Criteria	Mark	Fuzzy Geometric Average Value	Fuzzy Weight	Weight
Vacuum cleaner motor power	C1	2,21;1,33;1,03	0,16;0,09;0,07	0,11
Length of the power cord	C2	1,33;1,36;1,03	0,09;0,10;0,07	0,09
Power cord winding system	C3	0,88;1,09;1,03	0,06;0,09;0,07	0,07
Dimensions of the vacuum cleaner	C4	0,88;0,86;1,03	0,06;0,07;0,07	0,07
Weight of the vacuum cleaner	C5	0,88;0,94;1,03	0,06;0,07;0,07	0,07
Type of vacuum cleaner dust filter	C6	0,88;1,02;1,03	0,06;0,07;0,07	0,07
Suction hose width	C7	0,88;0,77;1,03	0,06;0,05;0,07	0,06
Length of the suction pipe (suction pipe)	C8	0,88;0,99;1,03	0,06;0,07;0,07	0,07
Possibility to control the vacuum of the vacuum cleaner in the working handle	C9	0,88;0,87;1,03	0,06;0,07;0,07	0,07
Type of road wheels of the vacuum cleaner	C10	0,88;0,86;1,03	0,06;0,06;0,07	0,06
Type of vacuum cleaner on / off	C11	0,88;0,76;0,84	0,06;0,05;0,06	0,06
Electric brush socket	C12	0,88;0,92;1,01	0,06;0,07;0,07	0,07
Number of accessories included with the vacuum cleaner (suction tubes and nozzles)	C13	1,33;1,10;0,84	0,09;0,08;0,06	0,08
Rubber protectors to protect furniture against knocking	C14	0,83;1,09;1,03	0,06;0,08;0,07	0,07

Source: Own study.

Table 5. Pareto-Lorenz analysis to select important criteria

Criteria	Mark	Weight	Cumulative Value	Cumulative Value [%]
Vacuum cleaner motor power	C1	0,11	0,11	10,74
Length of the power cord	C2	0,09	0,19	19,45
Number of accessories included with the vacuum cleaner	C13	0,08	0,27	27,12
(suction tubes and nozzles)	C3	0,07	0,34	34,14
Power cord winding system	C14	0,07	0,41	41,02
Rubber protectors to protect furniture against knocking	C6	0,07	0,48	47,87
Type of vacuum cleaner dust filter	C8	0,07	0,55	54,65
Length of the suction pipe (suction pipe)	C4	0,07	0,61	61,40
Dimensions of the vacuum cleaner	C9	0,07	0,68	68,15
Possibility to control the vacuum of the vacuum cleaner	C5	0,07	0,75	74,83
in the workholding	C12	0,07	0,81	81,43
Weight of the vacuum cleaner	C10	0,06	0,88	87,91
Electric brush socket	C7	0,06	0,94	94,18
Type of road wheels of the vacuum cleaner	C11	0,06	1,00	100,00

Source: Own study.

It was concluded that the criteria, i.e., the power of the vacuum cleaner motor and the length of the power cord, constitute 20% of the most important criteria. For these criteria, improvement actions were given the highest priority. After their implementation, customer satisfaction should be verified, and the next criteria should be considered.

4. DISCUSSION AND CONCLUSION

Customers' expectations are necessary considerations during the improvement of the quality of products. Therefore, the adequate obtaining of data and processing the improvement of products are problems. There are different methods supporting this process. However, it is still difficult to avoid changing these requirements in time to reduce the uncertainty and concerns of customers. Therefore, the method to support this process was proposed. The purpose of the article was to develop a method to process customer expectations to improve the quality of the products. The method was integrated with methods of quality management tools and fuzzy multi-criteria decision method, i.e.: SMART(-ER) method, brainstorming (BM), survey with the Likert scale, FAHP method, and Pareto-Lorenz analysis. As part of the method test, a household vacuum cleaner was selected. As part of the SMART(-ER) method, the objective was determined as well as precise criteria of the product, which will be important to customers. During brainstorming (BM), fourteen criteria were determined. For these criteria, a Likert scale-based survey was developed. With its use, the expectations of twenty-four customers were met. These expectations were related to the validity of the product criteria. Criteria weighting assessments were processed using the FAHP method. Then, using the Pareto-Lorenz method, important criteria were selected, i.e., motor power and cable length. It was decided that for these criteria and improvement actions should be performed first.

It was considered that benefits of the proposed method are, e.g.: obtaining customers' expectations as part of the popular Likert scale, and then processing these expectations in a fuzzy decision environment. It reduced the subjective assessments by customers and uncertainty during their determination. Additionally, the originality of the method combines quality management tools with the FMCDM method to sequentially improve the quality of the product.

A limitation of this research is a lack of information about requirements because of changes in the product. Therefore, future research will be referred to extensions of the proposed method about additional elements to help identify the necessary changes to important product criteria.

The proposed method can be used for any product. The method can assist the entity (e.g., a manufacturing company) in determining the order of criteria to be changed and considering customer expectations. Therefore, it can be a useful tool to process customer expectations as part of product quality improvement sometimes known as continuous quality improvement (CQI).

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DOI: 10.7862/rz.2022.mmr.16

The text was submitted to the editorial office: April 2022.
The text was accepted for publication: September 2022.