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Dominika SIWIEC[1]
Andrzej PACANA[2]

AN APPROACH TO PREDICT CUSTOMER SATISFACTION WITH CURRENT PRODUCT QUALITY

Improving product quality is still a challenge; therefore, this article aims to propose an approach to predict customer satisfaction. We implemented the following techniques: the SMART(-ER) method, brainstorming (BM), a Likert-scale survey, the Pareto rule, the WSM method, and the Naive Bayes Classifier. Customer expectations were obtained as part of the survey research. Based on these, we determined customers' satisfaction with the current quality of the criteria and the weights of these criteria. We then applied the Pareto rule, the WSM method, and the Naive Bayes Classifier. In the proposed approach, it was predicted that current product quality is not very satisfactory to customers; that conditioned the need for improvement actions. The originality of the study is the ability to predict customer satisfaction while taking into account the weights of this criterion. The proposed approach can be used for any product.

Keywords: predicting of quality, product quality, customer satisfaction, decision support, Naive Bayes Classifier, Weighted Sum Model, production engineering.

1. INTRODUCTION

In well-prospering organizations, it is important to continuous product improvement (Pacana, Siwiec, 2021). To do that, it is necessary to obtain customers' expectations and market requirements. It refers not only to new products, but also existing products, where it refers to determining customers' satisfaction with current product quality. Based on the satisfaction of determined customers, it is possible to make a decision about a need to initiate improvement actions and ongoing verification of product quality and customer satisfaction. According to (Giemza, 2006), customer satisfaction is the degree (level) on which customers' expectations are achieved. Therefore, it is important to determine these expectations and the degree to which they are met. These actions also include predicting the level of product quality level (Wu, Shieh, 2006). It provides to determine product quality ahead of the competition, and this quality will satisfy the customer's requirements (Siwiec,

[1] Dominika Siwiec, Rzeszow University of Technology; e-mail: d.siwiec@prz.edu.pl. ORCID: 0000-0002-6663-6621.
[2] Andrzej Pacana, Rzeszow University of Technology; e-mail: app@prz.edu.pl (corresponding author). ORCID: 0000-0003-1121-6352.

Pacana, 2021). Therefore, modern organizations are searching for different solutions to support this process.

The literature review has shown that the HoQ method (House of Quality, or QFD – Quality Function Deployment) (Hauser, 1993; Kurniawan, Wijayanti, 2020) is the most often used tool to design and improve products. The idea of HoQ is assumed to be that products should be designed in a way that reflects customer requirements and preferences. Therefore, in HoQ, the relations between customer expectations and technical requirements are determined (Temponi, Yen, TIao, 1999). Currently, the HoQ is well known and often modified. For example, the authors (Dincer, Yuksel, Marinez, 2021) have determined criteria, dimensions, and alternatives for developing new services in the medical industry. That relied on developing a model according to the 2-tupe linguistic, Interval-Valued, and the DEMATEL extension. In turn, in this work (Temponi, Yen, Tiao, 1999), an extension of HoQ was developed by implementing fuzzy logic. The aim was to obtain imprecise customer expectations and support the team of experts in concluding implicit relations between requirements. Whereas, the author of this work (Shrivastava, 2013) presented a method of creating HoQ according to six stages, i.e.: customer expectations, technical requirements, planning matrix, matrix of interconnectedness, matrix of technical correlations, and prioritized section or patterns and goals. Another example is the work (Abdulkerim, Avvari, Cherkos, 2019), in which the HoQ and the SERVQUAL method are combined. That relied on measuring the quality of service, designing and improving products to achieve customer satisfaction. However, in this work (Xie, Qin, Jiang, 2020), the decision method was developed, which was implemented in the HoQ. This method supported the choice of technical properties, where a rough sets algorithm or correlation matrix was used. For example, the relations of customer demand and the importance of technical attributes were verified. The test was carried out for the mobile phone.

Then, in this work (Moradi, Raissi, 2015), the linear programming in HoQ was realized to determine customers' preferences in mathematical terms. Another example is the work (Erdil, Arani, 2018), in which new areas of application of the HoQ method to improve product quality were proposed. The concept consisted of determining a new framework for the implementation of the HoQ method. In turn, in this work (Miao, Liu, Chen, 2015), the two models were developed to verify different design scenarios in an uncertain environment. The models were verified by car design. In the context of predicting product quality, the Naive Bayes Classifier was often used (Piątkowski, 2014). For example, in the article (Li, Li, 2014), the stability of the product was predicted according to Bayes' theorem. The method was supported by OptumG2 programming, which allowed analysis of the reduction of endurance. The Bayesian classifier allows to determine the stability and instability of the product state. In turn, the authors (Abellán, Castellano, 2017) proposed a method based on the measure of Info-Gain, which is combined with Bayes Classifier. The purpose is to predict a large number of data, where this method is effective in selecting and choice variables. Whereas, in this article (Trovato, Chrupała, Takanishi, 2016), the method of using imprecise knowledge of the man was developed. This method is integrated with Naive Bayes Classifier and has applications in the integration of man and robots.

After a review of the literature, it was concluded that there are methods to obtain customer expectations and predict the quality of the product. For this purpose, the HoQ method and the Naïve Bayes Classifier are mainly used. However, it is still searching for a method to predict customer satisfaction according to current product quality. It refers to the need to develop approach, which will be able to determine the level of customer satisfaction from the current (existing) product and make decisions about the need to take improvement actions.

Therefore, the aim of the article was to propose an approach to predict customer satisfaction from the current product quality. As part of the analysis, the thesis was assumed to be the following.

Thesis: It is possible to estimate the current product level according to customer satisfaction from current product criteria and the weights (importance) of these criteria and then predict customer satisfaction from the current product.

The approach test was done for the domestic vacuum cleaner, which was produced in the Podkarpacie company.

2. APPROACH

The proposed approach aimed to predict customer satisfaction from the current product quality. To this aim, the seven major stages were captured in a single coherent model (Figure 1). In this approach, the selected techniques were integrated, i.e.: SMART(-ER) method (Lawlor, Hornyak, 2012), brainstorming (BM) (Putman, Paulus, 2011), questionnaire with Likert scale (Altuntas, Özsoy, Mor, 2019), Pareto rule (Hoła, Sawicki, Szóstak, 2018), Weighted Product Model (WPM) (Kumar et al., 2021), and Naïve Bayes Classifier (Abellán, Castellano, 2017).

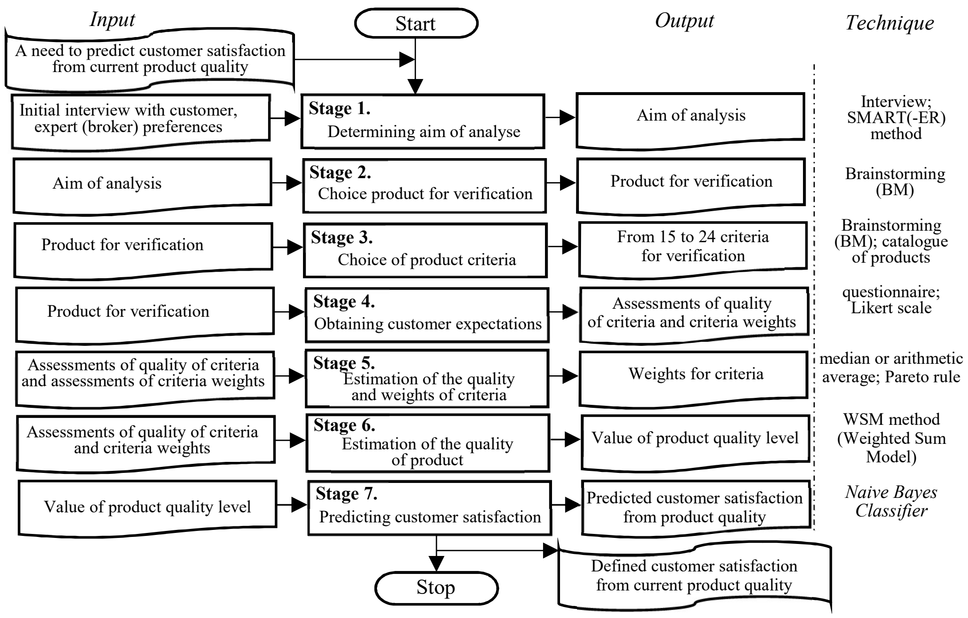

Figure 1. Model to predict product quality according to current customer satisfaction
Source:. Own study.

The short characteristic of the proposed approach is shown in the next part of the study.

Stage 1. Determining aim of analyse. It was assumed that the aim is determined by the entity (broker, expert). In the proposed approach, the aim was to determine customer expectations and then predict customer satisfaction from current product quality. To determine the aim, it is preferred to use the SMART(-ER) method (Lawlor, Hornyak, 2012).

Stage 2. Choice product for verification. At this stage, it is necessary to choose the product to analyse. The verification product for verification can be in the declining or maturity phase. The choice of product results from entity preferences using the proposed approach.

Stage 3. Choice of product criteria. It relies on determining the criteria possible to include in predicting product quality. It was assumed that these criteria are determined by group technical criteria (quantity), i.e., bases criteria determined the quality of the product. These criteria are selected according to the catalogue (specification) of products. These criteria are determined by a team of experts during brainstorming (BM) (Putman, Paulus, 2011). Following the authors (Siwiec, Pacana, 2021), it was assumed that the number of all criteria should be equal from 10 to 25 criteria. It is necessary to determine a single group of criteria that are characterized by all verified criteria.

Stage 4. Obtaining customer expectations. The aim of this stage is to determine customer satisfaction from current criteria and determine the weights (importance) of the criteria for customers. The number of customers results from the need of entity (expert, broker). The number of customers refers, e.g. obtaining expectations as part of initial research (n<100) or representative research (n>100). Following the authors (Muttaqi'in, Katias, 2021), it was assumed that to obtain customers' expectations the questionnaire was used. It was assumed that the questionnaire can be useful to customers in determining their preferences. The questionnaire should be allowed to determine customer satisfaction from the quality of the criterion and its importance (weights). The questionnaire should be allowed to determine customer satisfaction from the quality of the criterion and importance (weights) of these criteria. Therefore, the questionnaire included all product criteria that were selected in the third stage of the concept. These criteria should be characterized according to a catalogue (specification), e.g., by value or parameter. The Likert scale was used to determine customer satisfaction with the criteria for the products. The customer assessed each of the criteria by giving grades from 1 to 5, where 1 - criterion practically does not meet the client's expectations (the quality level of the criterion is unsatisfactory), 5 - criterion fully meets the client's expectations (the quality level of the criterion is satisfactory). Then, for all criteria, it is necessary to determine the weights (important criteria for customers). The weights are determined in the Likert scale, i.e., from 1 to 5, where 1 is the less important criterion, 5 is the most important criterion. Weights have to be determined for all verified criteria.

Stage 5. Estimation of the quality and weights of criteria. The quality of the criteria and weights of criteria were assumed to the be determined according to assessments from the questionnaire. The satisfaction of the customer with the quality of the current criteria and the importance of these criteria were obtained in the fourth stage. The quality of the criteria is determined by values on the Likert scale. Therefore, to estimate the importance of these criteria, it was assumed that the weights of these criteria were calculated according to weights assumed by the customers. Following the authors of the work (Siwiec, Pacana, 2021), it was assumed that for the small number of customers (n<100) the median of all evaluations of the weight of criteria is calculated. In turn, for a large number of customers (n>100), the arithmetic average of all assessments of criteria weights is calculated. Based on the weights (importance) of the criteria, it is possible to determine the most important (so-called key) product criteria. To this aim, the Pareto rule (20/80) is used, as shown in the literature (Hoła, Sawicki, Szóstak, 2018). The criteria, which weights, are 20% of all the criteria weights are criteria from which the improvement actions are taken first. The improvement of these criteria increases customer satisfaction.

Stage 6. Estimation of the quality of product. This stage relies on the estimated quality considering customers' expectations for all verified products. It was assumed that in this aim, the values (assessments) of quality of the criteria (from stage 4) are included, and then are integrated with the weights of these criteria (from stage 5). It is necessary to estimate the quality of product separately for each customer who participated in the study. To estimate the quality of product, the WSM method (Weighted Sum Model) is used (Siwiec, Pacana, 2021; Kumar et al., 2021; Keshavarz-Ghorabaee, 2021). The choice of this method was conditioned by its effectiveness in estimating product quality. Additionally, this method allows one to the quality estimate quality according to assessments of quality of criteria and the weights of these criteria. The next benefit of the WSM method is the possible estimation of quality according to different criteria measures. Therefore, there is no need to normalize of assesses. Formula (1) allows estimating product quality according to the WSM method (Kumar et al., 2021; Siwiec, Pacana, 2021):

$$A_i^{WSM} = \sum_{i=2}^{n} w_j^t x_{ij} = Q_i \tag{1}$$

where: w – weight of the criterion (from stage 5), x – quality of the criterion (from stage 4), i – customer, i, j = 1,…, n.

According to the assumption approach, the number of quality levels () should be equal to the number of customers. The quality of the product is used to predict the satisfaction of customers. It is shown in the next stage of the approach.

Stage 7. Predicting customer satisfaction. As part of predicting customer satisfaction, it was assumed that the Naïve Bayes Classifier was used (Abellán, Castellano, 2017; Piątkowski, 2014; Trovato, Chrupała, Takanishi, 2016). The idea is to use the initial satisfaction of individual customers to predict the satisfaction of the general community. The Naïve Bayesian Classifier is used for that. To this end, it is necessary to present the quality of the product (Q_i) as decimal value (2):

$$Q_i^p = \frac{Q_i}{1000} \tag{2}$$

where: Q – quality of the product, i – 1, 2, …, n.

Then, for each value of product quality, it is necessary to note the state of customer satisfaction. This state is determined according to the proportion of values for estimated product quality levels, e.g., the level is not very satisfactory, moderately satisfactory, and very satisfactory. For this purpose, formulas (3–5) are used:

$$\max_{i=1} Q_i^p = Q_i^{vs} \quad \text{and} \quad < Q_i^{vs};\ Q_i^{as}) \quad - \text{product quality very satisfactory} \tag{3}$$

$$\min_{i=1} Q_i^p = Q_i^{nvs} \quad \text{and} \quad (Q_i^{as};\ Q_i^{nvs}\rangle \quad - \text{product quality is not very satisfactory} \tag{4}$$

$$\frac{\max\limits_{i=1} Q_i^p + \min\limits_{i=1} Q_i^p}{2} = Q_i^{as} - \text{product quality is fairly satisfactory on average} \tag{5}$$

where: i = 1, 2…, n, i – customer.

Then, it is possible to predict customer satisfaction from current quality of the product. The Naïve Bayesian Classifier is used, which is the method of machine learning. It is effective in determining the category of case (Abellán, Castellano, 2017; Piątkowski, 2014; Trovato, Chrupała, Takanishi, 2016). The Classifier is not a complicated decision method, which has application to verify qualitative and quantitative data. The Bayes Classifier is also a tool of STATISTICA 13.3. Therefore, the process of predicting product quality can be more effective. In the Naïve Bayesian Classifier, the data representing customer satisfaction are considered as vectors $x = [x_1, x_2, \dots, x_r]$, whose individual components are the so-called traits or attributes (x_k), where r – number of attributes. In the case where k is conventional, then l_k takes different values. The sets of customers' expectations (so-called vectors) are separated into subsets (classes), where it is assumed that classes are separable and its sum is equal to the whole area. Hence, it is assumed, that each point belongs exactly to a single class (subset), where C – collection of all classes, c – single class, then $c \in C$. The Bayesian formula includes conditioned probability, where A and B – observation of random events, P(A) – probability of event A, whereas $P(A|B)$ – probability of A occurrence provided that B has occurred (6) (Piątkowski, 2014; Trovato, Chrupała, Takanishi, 2016):

$$P(A|B) = \frac{P(A \cap B)}{P(B)} \tag{6}$$

where: $A \cap B$ – simultaneous occurrence of A and B, therefore the probability is also referred to as (7) (Abellán, Castellano, 2017):

$$P(A|B) = \frac{P(B|A)P(B)}{P(A)} \tag{7}$$

The Bayesian formula allows expressions shown expressions for the most probable class *(np)* (8) by formula (9) (Trovato, Chrupała, Takanishi, 2016):

$$c_{np} = \arg \max_{c \in C} P(c \mid x_1, x_2, \dots, x_r) \tag{8}$$

$$c_{np} = \arg \max_{c \in C} \frac{P(x_1, x_2, \dots, x_r \mid c)\ P(c)}{P(x_1, x_2, \dots, x_r)} \tag{9}$$

In turn, the elements in the denominator are not dependent on class, therefore the result of classification is not changed (10) (Abellán, Castellano, 2017; Piątkowski, 2014; Trovato, Chrupała, Takanishi, 2016):

$$c_{np} = \arg \max_{c \in C} P(x_1, x_2, \dots, x_r \mid c)\ P(c) \tag{10}$$

In case where probability shown by formula (10) is known, or it is possible to estimate it, it is necessary for use it directly to the classification. The model, which is created based on this formula, is the so-called optimal Bayesian classifier. Predicting customer satisfaction with the product quality level is carried out depending on the estimated quality levels. The maximum probability value determines the level of customer satisfaction with the quality of the current product quality.

3. TEST OF APPROACH

The test of the approach was performed for the domestic vacuum cleaner. Research was carried out in an initial research group equal to 24 customers. The sample size was obtained in 2020.

According to the first stage, the objective of analyse was determined. It was assumed that purpose is to predict customer satisfaction from the current quality of the domestic vacuum cleaner.

As assumed in the second stage, the product for verification was selected. It was a domestic vacuum cleaner, which was produced in the Podkarpacie enterprise. This product was in the maturity phase. The choice of this product was conditioned by the need to determine customers' satisfaction and make decisions about improvement actions.

In the third stage, the product criteria for verification were selected. These criteria were selected after brainstorming (BM) was performed in a group of experts. Moreover, the choice of criteria was based on the vacuum cleaner catalog (specification). Those were technical criteria which generated the quality of the product. According to the proposed approach, ten main criteria were determined, i.e., engine power, suction power, cable length, power cord winding system, operating range, dimensions, weight, noise level, type of dust filter, and type of bag.

According to the fourth stage, the customers' expectations were obtained. To this end, the survey was carried out on the Likert scale was carried out. It was an initial research, which was performed in 2020 on 24 customers. The survey included the stage of determining the weights of the current criteria of vacuum cleaner criteria and the stage of determining the satisfaction of the quality of these criteria. The questionnaire included all criteria from the fourth stage. These criteria were characterized according to the vacuum cleaner by current values (parameters) that characterize them.

Then, as assumed in the fifth stage, the quality and weights of the criteria were estimated. The quality of the criteria was customers' assesses of their satisfaction with the current criteria. In turn, the weights of criteria were estimated as the median of all customers' assesses of importance of these criteria. It was the result of the number of customers ($n=24$, where $n<100$). According to the Pareto rule, the most important criteria for customers were selected (Figure 2).

According to rule 20/80, the most important criteria were suction power and engine power. It was concluded that these criteria should be improved at first to achieve an increase in customers satisfaction.

In the sixth stage, the quality of the vacuum cleaner was estimated. In this aim, the WSM method is used. The quality of the vacuum cleaner was estimated according to the evaluations of all customers. In this aim, the weights of the criteria (median of weights) and each assessment of customer satisfaction from these criteria were included. The result is shown in Table 1.

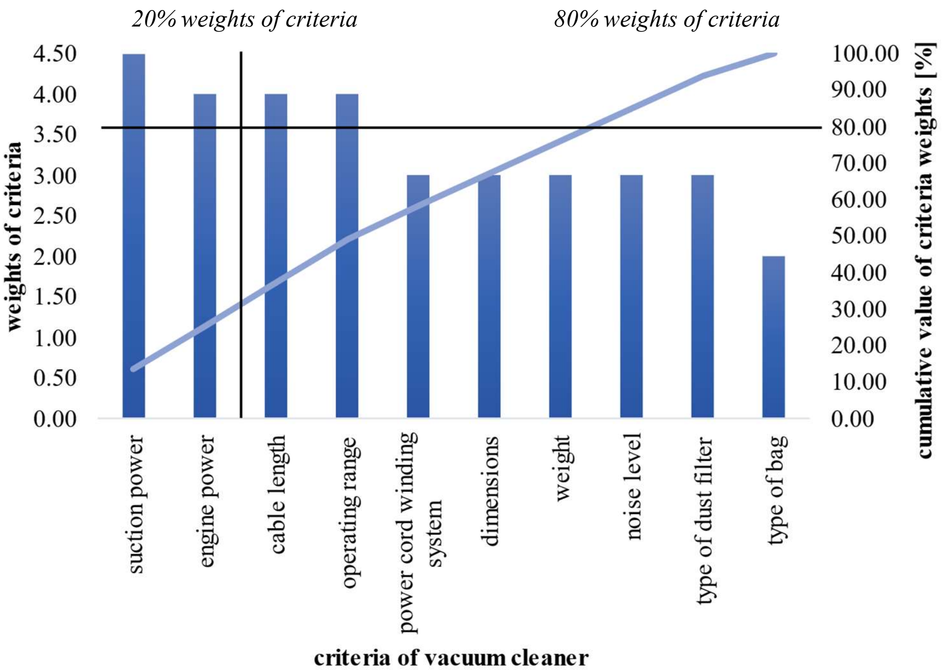

Figure 2. Pareto-Lorenz chart for weights of vacuum cleaner
Source: Own study.

Table 1. The level of quality of the vacuum cleaner according to the customers

Customer	Quality level		Customer	Quality level	
	Q_i	Q_i^p		Q_i	Q_i^p
1	106,00	0,11	13	109,50	0,11
2	90,00	0,09	14	113,50	0,11
3	100,50	0,10	15	99,50	0,10
4	101,50	0,10	16	110,00	0,11
5	132,00	0,13	17	104,00	0,10
6	89,50	0,09	18	117,00	0,12
7	102,50	0,10	19	106,50	0,11
8	105,00	0,11	20	94,50	0,09
9	92,00	0,09	21	120,50	0,12
10	107,00	0,11	22	115,00	0,12
11	126,50	0,13	23	94,50	0,09
12	92,50	0,09	24	121,00	0,12

Source: Own study.

The 24 vacuum cleaner quality levels, and that number resulted from the number of customers participating in the study. On the basis of these quality levels, the customers' satisfaction was predicted.

In the seventh stage, customers' satisfaction with the current quality level of vacuum cleaner quality was predicted. The Naïve Bayes Classifier was used for that. According to formula (2), the vacuum cleaner quality levels of vacuum cleaner were processed into decimal values (Q_i^p). Then, for these values, states of customer satisfaction were noted as states of customers satisfaction which were determined according to formulas (3-5). The results are shown by formulas (11-13):

$$\max_{i=1} Q_i^p = Q_i^{vs} = 0{,}13 \quad \text{and} \quad < 0{,}13;\ 0{,}11) \quad - \text{product quality very satisfactory} \tag{11}$$

$$\min_{i=1} Q_i^p = Q_i^{nvs} = 0{,}09 \quad \text{and} \quad (0{,}11;\ 0{,}09 > \quad - \text{product quality is not very satisfactory} \tag{12}$$

$$\frac{\max_{i=1} Q_i^p + \min_{i=1} Q_i^p}{2} = Q_i^{as} = 0{,}11 - \text{product quality is fairly satisfactory on average} \tag{13}$$

where: i = 1, 2…, n, i – customer.

Customers' satisfaction states with the current quality of the vacuum cleaner are shown in Table 2.

Table 2. Customers' satisfaction with the current quality of the vacuum cleaner

Customer	**Quality level**		**Customer**	**Quality level**	
	Q_i^p	**Satisfaction state**		Q_i^p	**Satisfaction state**
1	0,11	average satisfying	13	0,11	average satisfying
2	0,09	not very satisfying	14	0,11	average satisfying
3	0,10	not very satisfying	15	0,10	not very satisfying
4	0,10	not very satisfying	16	0,11	average satisfying
5	0,13	very satisfying	17	0,10	not very satisfying
6	0,09	not very satisfying	18	0,12	very satisfying
7	0,10	not very satisfying	19	0,11	average satisfying
8	0,11	average satisfying	20	0,09	not very satisfying
9	0,09	not very satisfying	21	0,12	very satisfying
10	0,11	average satisfying	22	0,12	very satisfying
11	0,13	very satisfying	23	0,09	not very satisfying
12	0,09	not very satisfying	24	0,12	very satisfying

Source: Own study.

According to the determined states of customers' satisfaction, the general customer satisfaction from the current quality of the vacuum cleaner was predicted. The Naive Bayes Classifier in STATISTICA 13.3. was used for that. The results are shown in Table 3.

Table 3. Predicted customer satisfaction from the current quality level of the vacuum cleaner

Class of state of customer satisfaction from current quality of vacuum cleaner	A priori value	Average value	Standard deviation
very satisfying	0,25	0,12	0,00
not very satisfying	0,46	0,10	0,00
average satisfying	0,29	0,11	0,00

Source: Own study.

After verification, it was predicted that the current quality of the vacuum cleaner is not very satisfactory (0,46) to customers. As part of an increase in customer satisfaction, it is necessary to improve the product. According to the Pareto rule, it was concluded that the suction power and engine power should be improved at first. If there is a need to improve these criteria, it is possible to achieve an increase in customer satisfaction. Subsequently, improvement actions should be taken for the remaining criteria.

4. DISCUSSION AND CONCLUSION

Improving the quality of products is the main action in well-benevolent organizations. Therefore, it is necessary to recognize customer expectations and market requirements. In this aim, it is effective to determine the current level of quality and predict customers' satisfaction with this quality. Then, it is possible to make a decision on the need to initiate improvement actions. In turn, it is also useful to determine the criteria from which these improvement actions should be realized. Therefore, the purpose of the article was to propose an approach to predict customers' satisfaction with the current product quality. In this approach, techniques were integrated, i.e.: SMART(-ER) method, brainstorming (BM), questionnaire with Likert scale, Pareto rule, WSM model, and Naïve Bayesian Classifier. An approach test was carried out for an example of a domestic vacuum cleaner. Research was carried out based on an initial sample size equal to 24 customers. This sample size was obtained in 2020. The quality of the vacuum cleaner was determined by criteria, i.e.: engine power, suction power, cable length, power cord winding system, operating range, dimensions, weight, noise level, type of dust filter, and type of bag. Customers' expectations were obtained as part of survey research on the Likert scale. The survey included the stage of determining the weights of the current criteria of vacuum cleaner criteria and the stage of determining the satisfaction of the quality of these criteria. According to Rule 20/80, the most important criteria were: engine power and suction power. It was concluded that these criteria should be improved at first to achieve an increase in customer satisfaction. Then, according to the WSM method, the current quality of the vacuum cleaner was estimated. The quality was estimated for each customer. According to quality levels, states of customer satisfaction were determined, that is, very satisfying (0,13), average satisfying (0,11), and not very satisfying (0,09). Next, general satisfaction with the current quality of the vacuum cleaner was predicted. The Naïve Bayesian Classifier in STATISTICA 13.3. was used. As a result, it was predicted that the current quality is not very satisfying for customers (0,46). It was shown that at first, it is necessary to verify satisfaction of the most important criteria (i.e., engine power and suction power). Then, it is necessary to take improvement actions for other criteria.

Main benefits of the proposed approach:

- determining customers' satisfaction with current product criteria,
- determining weights (importance) of current product criteria and important choice important criteria for customers,
- estimating the current quality of product according to assessments of satisfaction with criteria and weights of these criteria,
- predicting customer satisfaction from the current quality product level,
- possible to use the approach for any number of customers,
- useful approach to verify any products.

The disadvantages of this approach: a lack of predicting expected quality of product and also necessary changes of criteria. Therefore, future research will be based on adapting the approach to predict the expected quality of the product based on the current quality level.

It was recognized that the proposed approach may be beneficial for various organizations that strive to meet customer expectations. Additionally, this approach can be useful in predicting the quality of any product.

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