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Development of Quality Function Deployment Tool for Improved Customer Service in Cosmetics Manufacturing Company

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ABSTRACT

Quality Function Deployment (QFD) is a systematic process used to integrate customer requirements into every aspect of the production and development process. This paper examines the application of QFD in manufacturing companies, highlighting its benefits, challenges, and practical implementation strategies, using a case analysis of EBI cosmetics manufacturing firm that successfully utilized QFD to improve product quality and customer satisfaction. The study aims to develop a quality function deployment tool for improved customer service in a cosmetics manufacturing company. In line with the study objectives, a unique software application named "Cosmeticsqfd", which is designed to receive feedback from customers of EBI Nigeria Limited was developed and used to analyze consumer responses to a set of structured survey questions in real-time, using the QFD approach which was derived from the house of quality (HOQ) matrix. The software encoding was done using JavaScript programming language, the framework for the software was developed using React Native, while Firebase Firestore, was used to carry out data synchronization of consumer responses in real-time. The results obtained from the analysis, led to a rejection of the Null hypothesis and it revealed "price" to be the main influencing factor for customer purchase, as well as consumer satisfaction. A reliability test on the survey questions and client responses, revealed a Spearman's correlation of 0.631 and this also validated the result, as it implies the existence of a significant relationship between the factor affecting customer purchase decision, as well as their level of satisfaction. In terms of long term benefits, the developed Cosmeticsqfd software is capable of identifying technical areas of improvement in a business and is therefore recommended for use in any enterprise where quality performance is required.

Keywords: House of Quality; Quality; Quality Assurance,; Technical requirement.

1. Introduction

As businesses aim to improve customer satisfaction and drive sales, they have to plan and implement strategies that will not only allow their business to thrive, but also provide them with capabilities to be more competitive and become leaders. In order to achieve this goal, they make strategic decisions, which in most cases involve risks and conflicts. To overcome such difficulties,

the organizations can use one or more relevant methodologies, which are cost effective to deploy and efficient enough to achieve their aim and objectives. An example of one such approach is the 'Quality Function Deployment' approach.

In today's competitive market, understanding and fulfilling customer requirements is crucial for the success of manufacturing firms. Quality Function Deployment (QFD) is a powerful tool that helps organizations to translate customer needs into specific technical requirements. Itis a structured approach to define customer needs or requirements and translate them into specific plans for the products or the services to meet those needs(Panneerselvam, 2021). QFD originated from Japan in the 1970s. Since then, it has been applied successfully by many Japanese, American and European companies for their product development.

The founder of the quality function deployment approach - Dr. YojiAkao described QFD as "a method for developing a design quality aimed at satisfying the customer, and then translates the customer's demand into design targets and major quality assurance points to be used throughout the production phase" (Akao, 2004). In other words, it is a customer-driven quality management system which incorporates the Voice of the Customer (VOC) into appropriate company requirements at each product development stage; from product planning and process design to manufacturing and delivery, in order to create higher customer satisfaction for the product.

Competitions in manufacturing companies are required to provide the best customer services. Companies give proper attention to the needs and desires of customers, both of product quality and service delivery. QFD is applied to improve services by studying the customer's expectation and conducting feedback in order to improve the customer service (Chusaeni et al., 2020). QFD can also be described in simple terms as a system which ensures that customer needs drive the product design, the production process and the service delivery (Chan and Wu, 2002).

The implementation requires that the organizations gather and integrate the VOC into the design and manufacture of their products. It has been used successfully by many world-class organizations in automobile, ship building, electronics, aerospace, utilities, leisure and entertainment, financial, software and other industries (Kiran, 2017). The implementation of QFD approach in a manufacturing firm is well understood to enhance products' quality, customer satisfaction, development time, inventory, as well as scraps and defects reduction.

According to (Chan and Wu, 2002), the cosmetics industry has experienced drastic changes in production process, supplies, management approaches, products, technology and customer demand for their products. The global market has become highly competitive and cosmetic companies are finding it very difficult to handle the competitions and consumers' expectations. For them to meet up with customer's expectations there is the need for effective products' quality management and improved customer service delivery. In order to effectively complete this research, a Nigerian Cosmetic manufacturing company - Emos Best Industries (EBI) Limited has been selected as a case study.

2. Materials and Methods

In line with the study's objective to:

1. Obtain the VOC for the company products of EBI Nigeria Limited used as a case study
2. Develop a software which will utilize the QFD approach to analyze consumer feedback

3. Display the results obtained from the analysis in real-time, which will identify factors that drive consumer purchase, for quality improvement,

A unique software application named "Cosmeticsqfd", which is tailor made to receive feedback from customers of EBI Nigeria Limited is developed from scratch and used to analyze responses to a set of structured survey questions. The results obtained from this analysis, indicate the factors responsible for influencing consumer purchase which in turn will identify areas for quality improvement.

2.1.Software Design Considerations

The design considerations for the QFD software, primarily utilizes the HOQ matrix in determining customer requirements. An appropriate methodological structure of QFD originally proposed by (Maguad, 2009) which involves seven steps listed in figure 1are followed to build the house of quality.

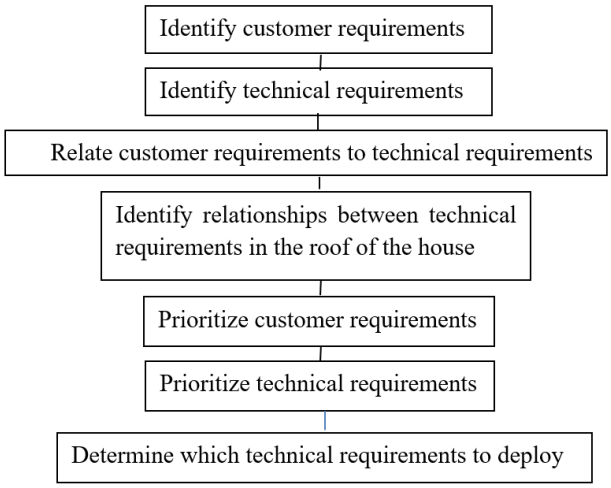


Figure 1: Showing House of Quality (HOQ) matrix (Hussain et al., 2011)

In order to determine the customer requirements, a number of closed ended survey questions are created for this study, which are also integrated into the software application, for customers to use in providing their feedback on the various products offered by EBI Nigeria Limited.

The designed software then utilizes a number of statistical formulas which include (the mean, mode, variance and standard deviation), to quantitatively determine the significance of the responses to each question. The quantitative analysis of the response to each question, will indicate the driving factors of consumer purchase, which can be used to improve customer service.

2.2 Survey Questions

The survey questions are constructed to be closed ended, so as to allow the participants to respond to a series of four (4) point scale questions.

2.2. Study Participants/Population

The study participants consist of 20 individuals who purchase EBI Nigeria Limited products (Acrofresh). After purchase, only 11 who could install the software in their phones were prompted using the software application, to provide answers to the survey questions provided.

2.3.Study Methods

The developed software is used to carry out a statistical method of analysis in order to determine the level of significance of the responses obtained from the study participants. Depending on the responses (VOC) obtained, the software is able to reveal the level of satisfaction or dissatisfaction of the study participants which are the customers of EBI Nigeria Limited in this case study.

2.4.Determining Customer and Technical Requirements

The quantitative method is used to analyze the VOC, so as to determine the customer and technical requirements, which are parts of the HOQ matrix. Under this method, a series of calculations are carried out to determine the: mean, mode and standard deviation of the responses.

The calculated standard deviation indicates how much, individual data points deviate from the mean (average) of the dataset. A higher standard deviation suggests that the data points are spread out over a wider range, while a lower standard deviation indicates that the data points are closer to the mean. In terms of quality improvement, a smaller standard deviation indicates more consistent product quality (Karras et al., 2020).

Mean (Average):

The mean is calculated from the responses using the formula provided in equation 1 as follows:

$$\overline{X} = \frac{\sum x}{n} \quad (1)$$

Where: $\overline{X}$is the mean

$\sum$x is the sum of all individual data points and

n is the total number of data points.

Mode:

The mode is a statistical measure that represents the value or values that occur most frequently in a dataset. In other words, it is the data point that appears with the highest frequency and it is particularly useful for identifying the most common or typical value in the dataset which will be obtained from the responses,

Variance:

In order to determine the standard deviation from the results, it is necessary to evaluate the variance which is a measure of the dispersion or spread of a set of data points around the mean (average) of the dataset. It quantifies how much the individual data points differ from the mean. A higher variance indicates that the data points are spread out over a wider range, while a lower variance suggests that the data points are closer to the mean. The mathematical expression for the variance is presented in equation 2 as follows:

$$\sigma^2 = \frac{\sum(x-\overline{X})^2}{n} \quad (2)$$

Where: $\sigma^2$is the variance and x represent each data point,

$\overline{X}$is the mean of the dataset, and n is the total number of data points.

Standard Deviation:

The mathematical expression for the standard deviation is presented in equation 3 as follows:

$$\sigma = \sqrt{\frac{\sum(x-\overline{X})^2}{n}} \quad (3)$$

Where: $\sigma$is the standard deviation

The results obtained using these analytical expressions, specifically determine the factors which influence the customer and technical requirements of the products.

2.5.Relationship Between the Customer and Technical Requirement

In order to determine the relationship between the customer and technical requirements, a null hypothesis test is required, to identify the existence of a significance between the two requirements. In this case, factors influencing customer purchase (technical requirement) are tested against the level of satisfaction (customer requirement).

The null hypothesis (H_0) in this case, states that, there is no significance between the factors influencing customer purchase and the level of satisfaction of the customer, after purchasing the product. This can be expressed as:

> H_0: There is no significance between the factors influencing customer purchase and the level of satisfaction of the customer

An alternate hypothesis (H_1) states that there is a significance between the factors influencing customer purchase and the level of satisfaction of the customer. So therefore:

> H_1: There is significance between the factors influencing customer purchase and the level of satisfaction of the customer

In order to carry out this analysis using the designed software, a chi-square test for testing levels of significance is used to test the significance of responses between answers to the survey questions.

To determine the significance between the factors influencing purchase and the factors influencing product satisfaction, the following steps were carried out:

1. Create a contingency table.
2. Calculate expected frequencies.
3. Compute the chi-square statistic.
4. Determine degrees of freedom.
5. Find the critical value.
6. Compare the chi-square statistic with the critical value.

2.6.Creating a Contingency Table:

The first step in carrying out the chi-square test, is the cross tabulation of the responses into a contingency table, also known as a cross-tabulation table. As shown in table 1, it presents the response to the level of satisfaction as row variables and response to the factors influencing customer purchase as column variables.

Table 1: Showing contingency table to be used for the significance test

Factors Influencing Customer Purchase	Level of customer satisfaction				
	FACTORS	Very satisfied	Somewhat satisfied	Neutral	Dissatisfied
	Price				
	Ingredients				
	Brand Reputation				

	Product Reviews				

2.7.Calculating Expected Frequencies

Expected frequencies are calculated as row total multiplied by column total divided by the overall total. Mathematically, this is represented in equation 4 as follows:

$$E_i = \frac{(Row\ Total)(Column\ Total)}{Grand\ Total} \quad (4)$$

This calculation is then carried out for each of the cells in the contingency table and used to create an expected frequency table.

2.8.Computing the Chi-Square Statistics

The chi-square statistic (χ^2) is a measure used in statistics to assess the association or independence between categorical variables in a contingency table. It is commonly used in hypothesis testing to determine whether there is a significant relationship between the variables being studied.

This is calculated using the formula provided in equation 5 as follows:

$$x^2 = \sum \frac{O_i - {E_i}^2}{E_i} \quad (5)$$

By calculating for all cells and summing them up, the chi-square statistic can be obtained.

2.9.Determining the Degrees of Freedom

The degree of freedom is a concept that represents the number of independent pieces of information available in a sample or a dataset. In this case, it is used to determine the critical value with which the null hypothesis can be tested. Mathematically, it is expressed in equation 6 as follows:

$$df = (r-1) \times (c-1) \quad (6)$$

Where: $r$is the number of rows in the contingency table and $c$is the number of columns.

2.10. Finding the Critical Value

The critical value can then be determined using the degree of freedom and a significance level of $\alpha = 0.05$.

2.11.Comparing Chi-Square Statistic with Critical Value

The last step requires a comparison between the chi-square statistic and the critical value.

If the calculated chi-square statistic is greater than the critical value, we reject the null hypothesis; or otherwise, fail to reject the null hypothesis.

The designed software is encoded with the afore-mentioned formulas for performing statistical analysis after which the results obtained from the sample population responses are represented and interpreted.

The software encoding is carried out using JavaScript programming language for developing both the front end and back end interface of the Cosmeticsqfd software. The framework for the software is developed using React Native, which is an open-source framework developed by Facebook for building cross-platform mobile applications using JavaScript and React. It allows developers to use React, a popular JavaScript library for building user interfaces, to create native mobile applications for iOS and Android platforms.

In order to carry out data synchronization of the software during use in real-time, the Firebase Firestore, also known as Cloud Firestore, which is a flexible, scalable database for mobile, web, and server development from Firebase and Google Cloud Platform, is used. An added advantage to using this database, is that Firestoresupports offline access to data and as such, users can read and write data locally, and changes are synchronized with the server once the device is back online, providing a seamless user experience.

The Cosmeticsqfd software is programmed to carry out the statistical analysis on consumer responses, after receiving prompts from the admin operating the backend of the software. In this case, the admin can decide based on the required quality function objectives, to determine the level of significance between consumers response to the survey questions. For ease of use, only responses to two questions can be selected at a time, after which the software will compute and determine the existence of a significance between responses to the selected questions. The results determined by the software, can then be used to identify which customer/technical requirement is necessary, so as to satisfy the specific quality objective of the company.

For the sake of this study, consumer response to the factors influencing their purchase of the Acofresh product of EBI Nig. Ltd, are compared to the level of their satisfaction with the product, so as to determine if there is existence of a statistical significance between both responses. The result identifies the specific factor which drives consumer purchase and is also influential to the level of customer satisfaction.

2.12.Reliability of the Qfd Software

It is necessary to validate the results obtained from the QFD software application for reliability purposes. In order to carry out this validation, IBM SPSS statistics software is used to carry out Spearman's correlation test. The Spearman correlation coefficient, denoted as (ρ) (rho), measures the strength and direction of the association between two ranked variables.

3. Results and Discussion

3.1.Cosmeticsqfd Software Application Interface

The Cosmeticsqfd software application interface (shown in figure 2), is one result of the software programming carried out using the QFD approach in analyzing the quality performance of the products of Emos Best Industries Limited. The software development was carried out using Javascript language for programming, and with a React Native open-source framework developed by Facebook for building cross-platform mobile applications.

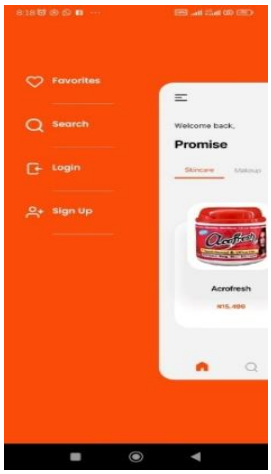


Figure 2: Showing the general interface of the cosmeticsqfd software

The Cosmeticsqfd software application has two interface, with one for the customers of Emos Best Industries Limited and one for the administrative department of the company.

3.2.Customer Interface

From the customer interface (shown in figure 3), each study participant will be directed to the homepage after successfully signing in with their username and password. The homepage contains a list of cosmetics products in various categories for which the study participants can provide a review for after purchase.

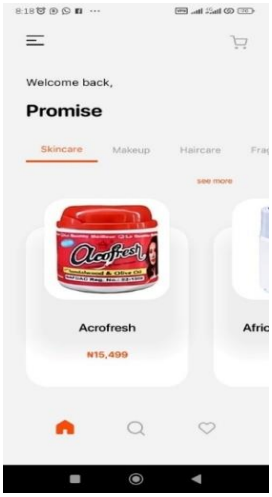


Figure 3: Showing Customer interface, including pictures and price of the company's products

The study participant can then select the product he or she wishes to provide a review for, by clicking on it. Clicking on each product, directs the individual where they are prompted to take a survey, as shown in figure 4.



Figure 4: Showing information about the product and a link to the survey questions

3.3.Administrative Interface

The administrative interface (shown in figure 5) directs the admins from Emos Best Industries Limited (after signing up), to a page for visualizing the quantity and content of responses to the survey questions provided by the respondents.

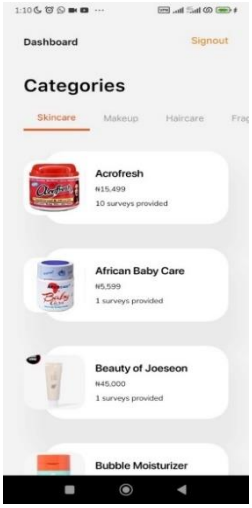
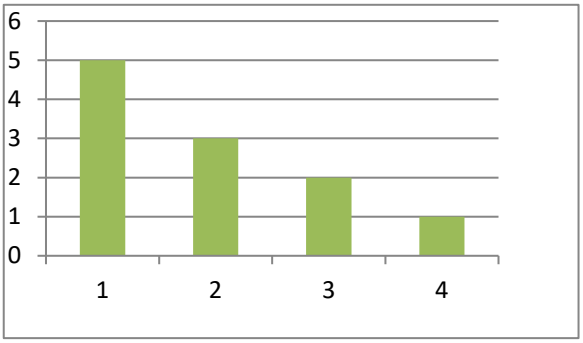


Figure 5: Showing information on the number of respondents to the survey questions from the admin interface

3.4.Participant Response to Survey Questions on Acofresh Skin Care Product

A total of 11 individuals made up of males and females from different age groups and occupations, who are customers of Emos Best Limited, responded to the survey questions on the Acofresh skin care products. The results of the analysis of their responses using the Cosmeticsqfd software are presented in the following subsections.

1. Have you used this product before?
    - I have used the product in the past one week (1)
    - I have used the product in the past one month (2)
    - I have used the product in the past six months (3)
    - I have not used the product before (4)



Mean = 1.90909

Mode = 1

Median = 2

Standard deviation = 0.996

2. What factors influenced your decision to purpose this product?
   - Price (1)
   - Ingredients (2)
   - Brand reputation (3)
   - Product reviews (4)

Keys	Percentage response
Price	20%
ingredients	0%
Brand reputation	40%
Products reviews	40%

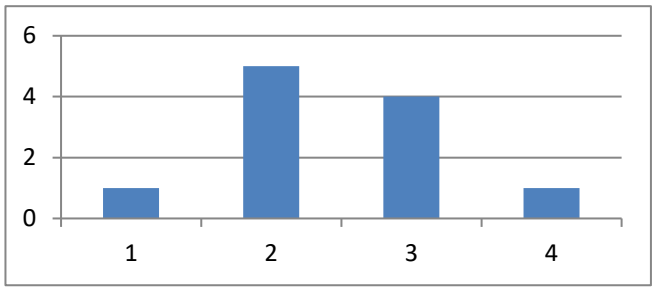
Mean = 3

Mode = 3.5

Median = 3

Standard deviation = 1.10

3. How often are you likely to buy this product?
   - Weekly (1)
   - Monthly (2)
   - Bi-monthly (3)
   - Occasionally (4)



Mean = 2.4545

Mode = 2

Median = 2

Standard deviation = 0.782

4. What type of products do you prefer?
   - Natural/organic (1)
   - Scented (2)
   - Anti-aging (3)
   - Hydrating (4)

Keys	Percentage response
Natural/organic	36%
Scented	36%
Anti-aging	18%
hydrating	9%

Mean = 2

Mode = 1.5

Median = 2

Standard deviation = 0.953

5. What specific skin concerns or needs do you look to address with body creams?
    - Dryness (1)
    - Sensitivity (2)
    - Aging (3)
    - Uneven skin tone (4)

Keys	Percentage response
dryness	27%
sensitivity	45%
Aging	18%
Uneven skin tone	9%

Mean = 2.0909

Mode = 2

Median = 2

Standard deviation = 0.900

6. Would you recommend this product to your family or friends?
    - Strongly agree (1)
    - Agree (2)
    - Maybe (3))
    - Never (4)

Keys	Percentage response
Strongly agree	9%
Agree	55%
Disagree	27%
Strongly disagree	9%

Mean = 2.3636

Mode = 2

Median = 2

Standard deviation = 0.771

7. How satisfied are you with this product?
    - Very satisfied (1)
    - Somewhat satisfied (2)
    - Neutral (3)
    - Dissatisfied (4)

Keys	Percentage response
Very satisfied	27%
Somewhat satisfied	18%
Neutral	36%
Dissatisfied	18%

Mean = 2.4545

Mode = 3

Median = 3

Standard deviation = 1.08

8. Are you willing to pay more for body creams with organic or natural ingredients?
    - Yes, significantly more (1)
    - Yes, slightly more (2)
    - No, not willing to pay more (3)
    - No preference (4)

Keys	Percentage response
Yes, significantly more	18%
Yes, slightly more	45%
No, not willing to pay more	27%
No preference	9%

Mean = 2.27272

Mode = 2

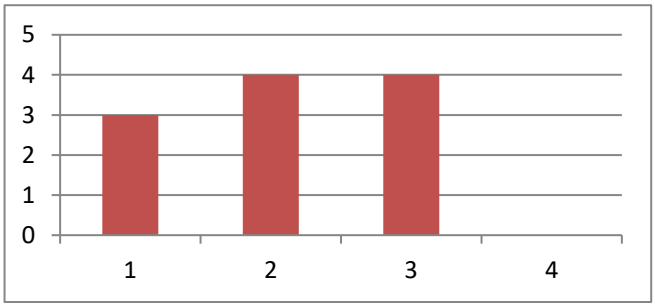
Median = 2

Standard deviation = 0.862

9. Have you ever switched brands or tried a new body cream product? If so, what motivated this change?
   - Ingredient preferences (2)
   - Price (1)
   - Recommendation from friend/family (3)
   - Advertisement/marketing campaign (4)

Keys	Percentage response	
Price	18%	Mean = 2.3636
Ingredients preference	36%	Mode = 2.5
Recommendation from friends/family	36%	Median = 2
Advertisement/marketing campaign	9%	Standard deviation = 0.881

10. Do you think the price of this product is worth the quality of the product?
    - Strongly agree (1)
    - Agree (2)
    - Maybe (3)
    - Never (4)



Mean = 2.090

Mode = 2.5

Median = 2

Standard deviation = 0.793

3.5.Results for Factors Influencing Purchase Decision

The results obtained from the participant responses to the survey questions, revealed that the factors influencing customer purchase of the product is the brand reputation, as shown in figure 6. Other results like the mean and standard deviation on the factors influencing customer purchase of the products are presented as follows:

i. Mean = 3
ii. Standard deviation = 1.10



Figure 6: Showing results for factors influencing customer purchase decision

The results for the standard deviation indicate that the respondents have varied opinions or preferences when it comes to factors influencing their purchase decision for the product. This is because as previously identified; a higher standard deviation suggests that there is greater variability or diversity in the responses.

3.6.Results for Level of Customer Satisfaction

The results obtained from the participant responses to the survey questions, also revealed that the customers are very satisfied with the product, as shown in figure 7. Other results like the mean and standard deviation on the factors influencing customer purchase of the products are presented as follows:

i. Mean =2.6
ii. Standard deviation =1.02



Figure 7: Showing results for level of customer satisfaction

The results for the standard deviation indicate a higher level of agreement or consistency in the level of satisfaction among the respondents. This is because, a lower standard deviation value, indicates more consistent levels of satisfaction with the product.

3.7.Results for The Significance Between the Level of Satisfaction and Factors Influencing Customer Purchase

The results obtained from the study participants, also revealed that there is a significance between the level of customer satisfaction, and the factors influencing customer purchase. This is because from the results (shown in figure 8), it was discovered that participants who mentioned factors like "Price" tend to report higher levels of satisfaction with the product, while those who mentioned "Brand Reputation" reported varying levels of satisfaction. This could imply that if Emos Best Industry Limited consistently maintains its current price, it will consequently improve its customer services, thereby leading to increased customer satisfaction.

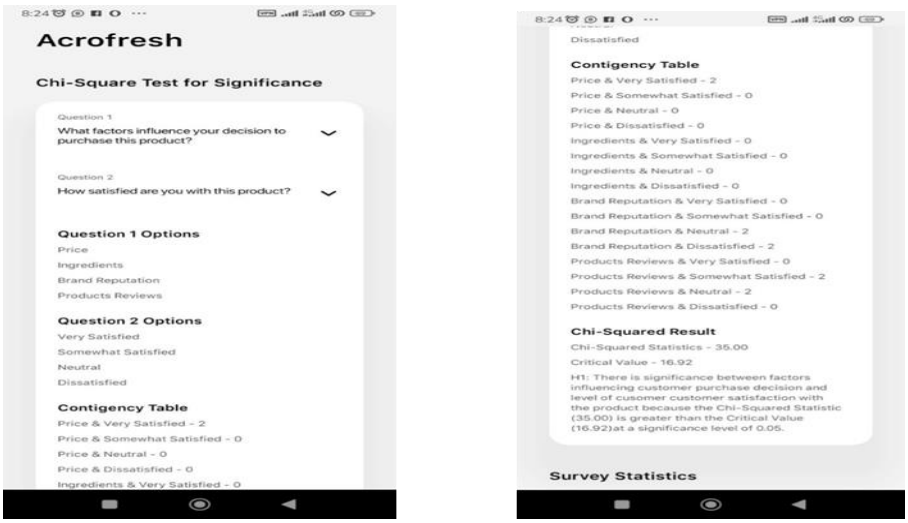


Figure 8: Results from the significance test

Table 2: Contingency table for the significance test

	Level of customer satisfaction				
	FACTORS	Very satisfied	Somewhat satisfied	Neutral	Dissatisfied
Factors Influencing Customer Purchase	Price	2	0	0	0
	Ingredients	0	0	0	0
	Brand Reputation	0	0	2	2
	Product Reviews	0	2	2	0

This consequently leads to a rejection of the null hypothesis which states that, "there is no significance between the factors influencing customer purchase and the level of satisfaction of the customer"; and an acceptance of the alternate hypothesis, which is in contrast to the null hypothesis, and states that "there is significance between the factors influencing customer purchase and the level of satisfaction of the customer", as seen in table 2.

The results obtained from the various analyses executed by the software are clear indications that the QFD approach can be used to identify various factors that can be used to improve customer services, as obtained from the Voice of Customers (VOC).

The results of responses to other survey questions can also be analyzed and displayed using the developed Cosmeticsqfd software, to reveal other technical aspects that can be used to improve customer service.

3.8.Results for Data Validation and Consistency

The results for the spearman's correlation test as calculated by the SPSS software are presented in table 3.

Table 3: Showing results of the calculated Spearman's coefficient

Correlations				
			Factors_influencing_customer_purchase_decision	Product_satisfaction
Spearman's rho	Factors_influencing_customer_purchase_decision	Correlation Coefficient	1.000	.631
		Sig. (2-tailed)	.	.050
		N	10	10
	Product_satisfaction	Correlation Coefficient	.631	1.000
		Sig. (2-tailed)	.050	.
		N	10	10

A positive value (0.631) means that as one variable increases, the other variable also tends to increase. This suggests that higher ratings on the factors influencing the purchase decision are associated with higher levels of customer satisfaction with the product. This also implies that there is a meaningful relationship between the factors influencing customer purchase decisions (e.g., price, ingredients, brand reputation, product reviews) and their level of satisfaction with the product. This means that as the factors that influence purchase decisions are rated more favorably, customer satisfaction tends to be higher.

3.9.Implication of Results for Ebi Limited

The case of EBI Cosmetics Manufacturing Company demonstrates the significant benefits of QFD in the manufacturing industry. By systematically addressing customer needs, the company improved product quality, increased customer satisfaction, and reduced development time. However, it is noted that the successful implementation of QFD approach requires careful planning, adequate training, and ongoing commitment from all stakeholders, as it was noted to ensure seamless integration into standard operating procedures.

4. Conclusion

Quality Function Deployment is a valuable methodology for manufacturing firms aiming to enhance product quality and customer satisfaction. While the process can be complex, the benefits far outweigh the challenges. Future research should focus on developing simplified QFD tools and techniques to facilitate broader adoption in the industry

After completing the development of the Cosmeticsqfd software using the QFD approach, as well as the HOQ matrix, and using it to determine the significance between the results obtained from the survey responses (VOC), it can be concluded that the study's aim and objectives have been satisfied. This is because, based on the significance analysis of responses, the software was able to identify two factors: brand reputation and customer reviews which are responsible for increased customer satisfaction.

5. Recommendations

The developed Cosmeticsqfdsoftware is highly recommended for companies who want to improve on their customer service using the QFD approach. This is because the software can be used to identify various factors affecting the quality of business performance in real time.

Nonetheless, it is the recommendation of the researcher that carrying out analysis on the voice of customers(VOC) on a regular basis and for a considerable amount of time, will enable sufficient time to collect the necessary customer input for producing more specific findings. It is also recommended that periodic and regular training sessions should be carried out, before implementing QFD approach into existing workflows. This is so as to ensure seamless adoption of the results obtained into existing company standard operating procedures, for improved quality assurance.

6. Contributions to Knowledge

This study contributes significantly to existing knowledge on the subject of quality function deployment. The development and test results of the Cosmeticsqfd software tool, is a testament to the potential benefits companies particularly in the manufacturing industry, stand to gain by deploying the software for improved quality assurance.

7. Declaration of Competing Interest

The author declares that there are no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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