# *Maximisation of customers' satisfaction within the constraints of manufacturer – A mathematical approach*

**Duraivelu K[*1], Hariharan D[2]**

[*1]*Deputy Registrar, Sri Ramachandra Institute of Higher Education & Research, Chennai, India*

[2]*R&D Head (Mechanical), Neenjas Electric Private Limited, Noida, India*

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**Abstract:**

This article presents a mathematical approach to maximise the customers' satisfaction by optimising the quality level of various quality characteristics of a product within the given constraints of the manufacturer. The mathematical model has been demonstrated with the data collected for the physical product 'bicycle'. The model presented considers not only the overall customers satisfaction, but also the manufacturer's satisfaction with the costs committed to the product. With the interactive approach, the best balance between manufacturer's satisfaction and overall customers' satisfaction can be obtained.

**Keywords:**

Product quality, quality characteristics, customer satisfaction, manufacturer constraints.

## 1. Introduction:

Organisations regularly monitor product quality and customers satisfaction in an attempt to improve customer retention. Examining the gaps between desired level of quality and that actually delivered reveals where improvements in the product quality mix are required. However, there are certain difficulties faced by the manufacturer to abridge these quality gaps [1]. Hence, at the design stage itself, the product has to be designed for optimum quality levels of the various quality characteristics of the product within the boundary of the difficulties of the manufacturer.

## 2. Measuring customer's voice:

Measuring customers' satisfaction and their requirements gives a strategic advantage in knowing where an organisation stands in the market in terms of product quality. It provides an impetus to the organisation to act and improve its position in the competitive environment. The customers' requirements are defined by a focus group in the form of quality characteristics of the product. The satisfaction of the customer can be divided into two components [2]; the cognitive component expresses the perceived quality of the product, the affective component provides an indication of customer's importance. Since all customers are not equal [3], it is important to identify those requirements, which are most important and ensure that they are delivered in the product. Quality has got eight dimensions [4], namely; performance; features; conformance; reliability; durability; serviceability; aesthetics; and reputation. For the case study carried out for the product 'bicycle', the various quality characteristics have been explored with the consideration of these quality dimensions and the four levels of customers' requirements.

## 3. Generic LPP model for maximising customer's satisfaction:

A framework called 'ProducQual' developed by Duraivelu [5,6,7] provides a mathematical model [8] to maximise the customers satisfaction, the product function of importance of the quality characteristics and their quality levels. In this study, only the two important manufacturer's difficulties have been considered as constraints, i.e., technical difficulty and economical difficulty.

Maximise $Z = \sum A_i X_i$

Subject to $X_i \leq B_i$

$\sum C_{ij} X_i \leq D$

$X_i \square E \quad \square \ i = 1, 2, 3 \ldots n$

where $A_i$ is the customers importance to $i^{th}$ quality characteristic.

$X_i$ is the $i^{th}$ quality characteristic,

$B_i$ is the minimum quality level expected by the customers for $i^{th}$ quality characteristic.

$C_{ij}$ is the proportion of difficulty to achieve maximum quality level for $i^{th}$ quality characteristic on $j^{th}$ parameter.

D is the minimum difficulty that the manufacturer has to face to achieve the optimum level of customer satisfaction.

N is the number of quality characteristics of the product.

E is the maximum point of (likert) scale of measurement.

## 4. Data collection:

Focus groups have been used to identify the various quality characteristics of the product. Among them, the ones, which have greater influence to the customers' satisfaction, are identified as key quality characteristics [9]. Key quality characteristics are the set of important, informative, achievable quality measures & indicators, which provide a summary of the overall quality of the product. It is essential to identify those quality characteristics whose improvement offers the greatest returns [10], as measured in terms of customers' satisfaction, retention rate & corporate financial performance. For the case study carried out in a leading bicyle manufacturing company, the product 'bicyle' has got the quality characteristics listed in table-1. To conduct the customer survey in order to collect the data from the customers on their importance on various quality characteristics for the product 'bicyle', and their minimum expected quality level for all the quality characteristics, a random sample of 200 of different age group; of different sex; of different work groups from different places, has been chosen. The data collected were scrutinised after subjecting them to validity and reliability tests. The data for technical and economical difficulty were generated after discussing with the design experts / product development executives and the works manager of the bicyle manufacturer. The table-1 gives the summarised data collected from customer survey and the interview conducted with the product development executives. A seven-point scale of measurement has been commonly used to measure all the qualitative parameters.

***Table. 1: Data for customers' importance / expectations & manufacturer's constraints***

| Quality characteristics of 'bicyle', $X_i$ | Customers importance, $A_i$ | Min. expected quality, $B_i$ | Technical difficulty, $C_{i1}$ | Economical difficulty, $C_{i2}$ |
|---|---|---|---|---|
| Chain non-slippage, $X_1$ | 6 | 6 | 2 | 3 |
| Effective braking, $X_2$ | 7 | 7 | 4 | 6 |
| Noiseless running, $X_3$ | 7 | 7 | 6 | 7 |
| Easy pedalling, $X_4$ | 6 | 7 | 5 | 5 |
| Free steering, $X_5$ | 6 | 7 | 5 | 5 |
| Ease of operation of stand, $X_6$ | 5 | 4 | 3 | 3 |
| Handle bar grip comfort, $X_7$ | 4 | 5 | 1 | 2 |
| Seat-Handle bar distance comfort, $X_8$ | 4 | 5 | 1 | 3 |
| Seat comfort, $X_9$ | 6 | 5 | 2 | 4 |
| Pedal comfort, $X_{10}$ | 6 | 6 | 1 | 4 |
| Carrier strength, $X_{11}$ | 3 | 6 | 2 | 7 |

| | | | | |
|---|---|---|---|---|
| Dynamo light brightness, $X_{12}$ | 4 | 7 | 3 | 6 |
| Air retention in the tube, $X_{13}$ | 7 | 7 | 5 | 3 |
| Tube durability, $X_{14}$ | 5 | 6 | 6 | 6 |
| Tyre durability, $X_{15}$ | 6 | 6 | 7 | 7 |
| Durability of Electro plating, $X_{16}$ | 7 | 6 | 7 | 7 |
| Ease of self-maintenance, $X_{17}$ | 5 | 3 | 7 | 6 |
| Paint colour, $X_{18}$ | 7 | 2 | 2 | 1 |
| Tyre size, $X_{19}$ | 5 | 2 | 1 | 5 |
| Stickers – design, $X_{20}$ | 4 | 3 | 1 | 2 |
| Electroplating appearance, $X_{21}$ | 7 | 5 | 2 | 2 |
| Mud guard appearance, $X_{22}$ | 4 | 3 | 2 | 2 |
| Lock design, $X_{23}$ | 4 | 1 | 4 | 6 |
| Body rigidity, $X_{24}$ | 7 | 7 | 7 | 6 |
| Handle bar design, $X_{25}$ | 6 | 5 | 5 | 3 |

## 5. Optimisation of quality characteristics mix:

The generic LPP model described in chapter 3 is expanded for the selected twenty-five quality characteristics of the product 'bicyle' and the technical & economical difficulties of the manufacturer, as given below:

Maximise $Z = 7(X_2 + X_3 + X_{13} + X_{16} + X_{18} + X_{21} + X_{24}) + 6(X_1 + X_4 + X_5 + X_9 + X_{10} + X_{15} + X_{25}) + 5(X_6 + X_{14} + X_{17} + X_{19}) + 4(X_7 + X_8 + X_{12} + X_{20} + X_{22} + X_{23}) + 3X_{11}$

Subject to

Minimum requirement – constraints:

$X_2, X_3, X_4, X_5, X_{12}, X_{13}, X_{24} \geq 7$

$X_1, X_{10}, X_{11}, X_{14}, X_{15}, X_{16} \geq 6$

$X_7, X_8, X_9, X_{21}, X_{25} \geq 5$

$X_6 \geq 4$

$X_{17}, X_{20}, X_{22} \geq 3$

$X_{18}, X_{19} \geq 2$

$X_{23} \geq 1$

Technical difficulty – constraint:

$0.011(X_7 + X_8 + X_{10} + X_{19} + X_{20}) + 0.022(X_1 + X_9 + X_{11} + X_{18} + X_{21} + X_{22}) + 0.033(X_6 + X_{12}) + 0.044(X_2 + X_{23}) + 0.055(X_4 + X_5 + X_{13} + X_{25}) + 0.066(X_3 + X_{14}) + 0.077(X_{15} + X_{16} + X_{17} + X_{24}) \leq D$

Economical difficulty – constraint:

$0.009\ (X_{18}) + 0.018\ (X_7 + X_{20} + X_{21} + X_{22}) + 0.027\ (X_1 + X_6 + X_8 + X_{13} + X_{25}) + 0.036\ (X_9 + X_{10}) + 0.045\ (X_4 + X_5 + X_{19}) + 0.054\ (X_2 + X_{12} + X_{14} + X_{17} + X_{23} + X_{24}) + 0.063\ (X_3 + X_{11} + X_{15} + X_{16}) \leq D$

Maximum requirement – constraint:

$X_1, X_2, X_3, X_4 \ldots X_{25} \leq 7$

## 6. Findings:

When the co-efficient of all variables are entered into the linear programming software, the optimum values for various quality characteristics for different 'D' values can be obtained. The output obtained is summarised in table-2.

***Table. 2: Optimum quality characteristics – mix for various 'D' values***

| 'D' | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $X_8$ | $X_9$ | $X_{10}$ | $X_{11}$ | $X_{12}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.0 | - | - | - | - | - | - | - | - | - | - | - | - |
| 1.1 | - | - | - | - | - | - | - | - | - | - | - | - |
| .<br>.<br>. | -<br>-<br>- | -<br>-<br>- | -<br>-<br>- | -<br>-<br>- | -<br>-<br>- | -<br>-<br>- | -<br>-<br>- | -<br>-<br>- | -<br>-<br>- | -<br>-<br>- | -<br>-<br>- | -<br>-<br>- |
| 5.6 | 6 | 7 | 7 | 7 | 7 | 4 | 5 | 5 | 5 | 7 | 6 | 7 |
| 5.7 | 6 | 7 | 7 | 7 | 7 | 4 | 7 | 5 | 5 | 7 | 6 | 7 |
| 5.8 | 6 | 7 | 7 | 7 | 7 | 4 | 7 | 6.09 | 5 | 7 | 6 | 7 |
| .<br>.<br>. | .<br>.<br>. | .<br>.<br>. | .<br>.<br>. | .<br>.<br>. | .<br>.<br>. | .<br>.<br>. | .<br>.<br>. | .<br>.<br>. | .<br>.<br>. | .<br>.<br>. | .<br>.<br>. | .<br>.<br>. |
| 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 |

| $X_{13}$ | $X_{14}$ | $X_{15}$ | $X_{16}$ | $X_{17}$ | $X_{18}$ | $X_{19}$ | $X_{20}$ | $X_{21}$ | $X_{22}$ | $X_{23}$ | $X_{24}$ | $X_{25}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| - | - | - | - | - | - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - | - | - | - | - | - |
| -<br>-<br>- | -<br>-<br>- | -<br>-<br>- | -<br>-<br>- | -<br>-<br>- | -<br>-<br>- | -<br>-<br>- | -<br>-<br>- | -<br>-<br>- | -<br>-<br>- | -<br>-<br>- | -<br>-<br>- | -<br>-<br>- |
| 7 | 6 | 6 | 6 | 3 | 2.59 | 6.91 | 3 | 5 | 3 | 1 | 7 | 5 |
| 7 | 6 | 6 | 6 | 3 | 5 | 7 | 5 | 5 | 3 | 1 | 7 | 5 |
| 7 | 6 | 6 | 6 | 3 | 7 | 7 | 7 | 6.09 | 3 | 1 | 7 | 5 |
| .<br>.<br>. | .<br>.<br>. | .<br>.<br>. | .<br>.<br>. | .<br>.<br>. | .<br>.<br>. | .<br>.<br>. | .<br>.<br>. | .<br>.<br>. | .<br>.<br>. | .<br>.<br>. | .<br>.<br>. | .<br>.<br>. |
| 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 |

For the input values for 'D' ranging from 1 to 7 i.e., for the range of same scale of measurement used for measuring the customers importance & their minimum expected value for the quality levels of various quality characteristics & used for measuring the technical / economical difficulties of manufacturer, the minimum value for 'D' is found to be at 5.6 for getting the optimum values for quality levels of various quality characteristics. For the values less than 5.6 for 'D', there is no feasible solution obtained. Hence, the manufacturer (product designer) has to go for these values of $X_i$ at this 'D' value for facing minimum technical / economical difficulty in order to achieve optimum customer satisfaction. The value for 'D' can be fixed by the manufacturers according to their ability to face the technical & economical difficulty in order to find out the required optimum values for various characteristics of the product to be manufactured.

## 7. Conclusion:

In design and quality improvement, the engineering characteristics that affect product performance are identified and improved to maximise customers' satisfaction. This is usually done empirically in conventional implementation of quality function deployment. The limited resource and increased market competition and product complexity require more accurate and optimal solutions. A new mathematical approach has been proposed in this paper to address the difficulties faced by manufacturer. The model described in this paper considers not only the overall customers satisfaction, but also the manufacturer's satisfaction with the costs committed to the product. With the interactive approach, the best balance between manufacturer's satisfaction and overall customers' satisfaction can be obtained, and the preferred solutions under different business criteria can be achieved through human-computer interaction.

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