

‘ProducQual’- A Framework for Bridging Quality Gaps across Product Life Cycle

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ABSTRACT

A conceptual model ‘ProducQual’ is presented to explore the potential quality gaps for any physical product across its product life cycle. The six different quality gaps across different stages of the product life cycle are explored, with the probable reasons for the various quality gaps. A framework consisting of various quality tools and techniques to bridge the various quality gaps also is presented. With the various interactive approaches discussed in this article, the best balance between the manufacturer's constraints and overall customers satisfaction can be attained.

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1. INTRODUCTION

Examining the quality gaps between the desired level of product quality and that actually delivered reveals where the improvement in the product quality mix is required. When the quality is to be made measurable, it is split into parts, which can be measured. These parts cannot

contain all the aspects of quality. So, the quality aspects are also simplified. This simplification is called the quality model [1] which helps to decide what kind of quality level is required for different parts of the product. In general, a quality gap can be defined as the disparity between perceived quality and expected quality of a customer. Perceived quality [2] is defined as an evaluative

verdict of an attitudinal nature, formulated by the customer.

The service quality model 'ServQual' [3] explores quality gaps during delivery of service to the consumers by the service provider. The model ServQual is pioneer in explaining the service quality gaps. However, this model is pertaining to only service quality. As there are many differences between product quality and service quality, a distinct model for exploring the quality gaps for any physical product is required to be developed.

A manufactured product's quality is determined in terms of performance, features, conformity, durability, serviceability, aesthetics and perceived quality while the service quality is determined in different terms. As the production of service and its delivery differ from that of manufacturing a product and its delivery in a number of ways, the service quality also differs from the product quality. Quality is a multi-dimensional phenomenon. For example, in product quality, it could be reliability of performance, conformance to standards, features and serviceability, whereas in service quality [4], it could be functionality, reliability, responsiveness, assurance, empathy and tangibles. Duraivelu et al [5] developed a generic conceptual model, ProducQual to explore the potential quality gaps of a product across the product life cycle (PLC). Also, this model prescribes a framework with appropriate quality tools that can be used to bridge the quality gaps explored by it.

The following are the objectives of the research carried out:

- To develop a generic conceptual model in order to explore the potential product quality gaps across PLC.
- To enumerate the credible reasons for the different quality gaps in order to frame out a strategy to close the quality gaps.
- To develop a generic framework consisting of quality tools and techniques in order to enhance or maintain the quality of a product across PLC.
- To increase the value of the product with reduced cost by optimising the product quality level using the resources effectively.
- To measure the customers' satisfaction and quality gaps in order to give a strategic advantage to the organisation in knowing where the organisation positions in the market in terms of product quality.
- To facilitate the manufacturer to know the customer perception of their products and the customer's actual requirements in an effort to improve customer retention rate.
- To increase the manufacturer satisfaction along with the customers overall satisfaction by finding out the best balance between them with various interactive strategies.

2. CONCEPTUAL MODEL FOR QUALITY GAP ANALYSIS

The potential quality gaps at different stages of the product, from the idea of creating a product to its disposal stage, are explored in this research and are shown in Fig.1. Two different types of lines are used in Fig. 1 to indicate clearly the influence of one quality gap over other quality gaps and one stage over the other stages of the product across PLC.

Fig. 2 explores the various quality gaps in terms of the differences between the quality levels at different stages of PLC.

The prospective quality gaps as visualized by ProducQual are described below:

- Quality gap 1 is considered as the difference between the manufacturer's intended level and customer's expected level of quality characteristics of the product.
- Quality gap 2 is the difference between the quality levels at the manufacturer's intended stage and at the design stage.
- Quality gap 3 is the difference between the quality levels at the design stage and production stage.
- Quality gap 4 is the difference between the product quality after production and the product quality perceived by the customers.
- Quality gap 5 is the difference between the expected and perceived levels of the customers
- Quality gap 6 is the difference between the quality level perceived by the customer and the quality noticed at the disposal stage of the product.

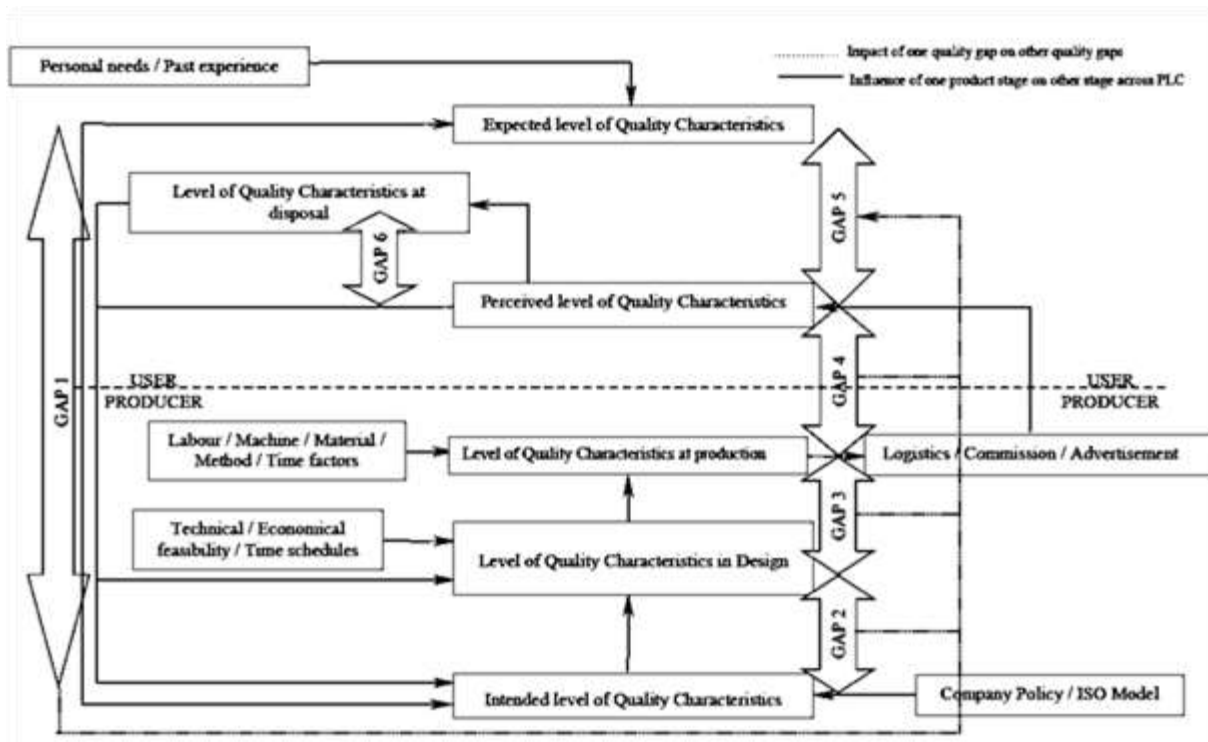


Fig. 1. ProducQual – A model for product quality gap analysis.

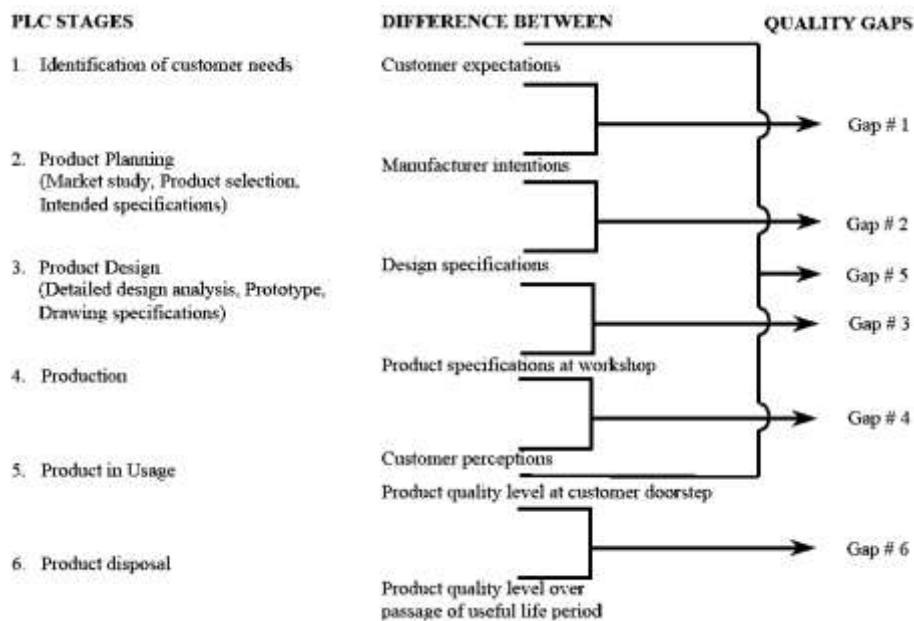


Fig. 2. Different product quality gaps.

The following are the possible reasons for the various quality gaps:

- For quality gap 1: Due to poor marketing and inadequate communication, the customer’s exact expectations may not be identified properly. The existing company policy, competitive environment and financial constraints may influence the manufacturer’s intended level of various quality characteristics of the product to be manufactured.
- For quality gap 2: Time restrictions, financial constraints and technical difficulty may influence the quality level at the design stage.
- For quality gap 3: Ineffective manufacturing techniques and machines, lack of technology, incompetent workforce, and poor understanding of the quality importance may

affect the quality level at the manufacturing stage.

- For quality gap 4: Poor product delivery and installation methods, improper packaging, destitute logistics, and deprived demonstration on usage of the product will influence this gap.
- For quality gap 5: Customer over expectations and the combined effect of the first four quality gaps will influence this gap.
- For quality gap 6: Poor maintenance practices, improper method of usage, and shortened durability of the product will expand this gap slowly from the usage stage to the disposal stage.

3. RESEARCH METHODOLOGY

The research problem has been identified as described in the conceptual model for quality gap analysis. The outline procedure to carry out the research in the area of product quality gap analysis is given below:

- Step 1: A literature survey is conducted in the area of Quality Engineering, and Quality Gap Analysis before formulation of the research problem. A Conceptual model for the research problem is designed after a careful study of the research problem.
- Step 2: A framework is developed considering the appropriate quality tools and techniques for bridging the various quality gaps explored by the conceptual model. A literature survey is then conducted on the quality tools specified in the framework before carrying out the analysis.
- Step 3: To test the validity of the conceptual model, a physical product is chosen for the analysis. The key quality characteristics, and quality dimensions [6] of the product are selected using a Focus group. Consequently, the significant customer requirements in terms of product quality characteristics are listed to include them in the questionnaire.
- Step 4: A Questionnaire along with a measurement scale is prepared to collect the data from customers of the product and the leading manufacturer of the product. A pilot survey is conducted with a few persons to test the purpose of the Questionnaire for which it is prepared. A slight modification if any is done in the questionnaire after the

pilot survey is conducted to check the validity and reliability of the questionnaire.

- Step 5: Suitable sample size is statistically calculated. Quota and random sampling techniques are generally adopted to collect the data on customer weightage, minimum expected quality level, and perceived quality level on various quality characteristics of the product.
- Step 6: Surveyed data is consolidated and subjected to statistical tests using SPSS for finding out fundamental statistics like data distribution, mean, standard deviation, correlation, etc. Using Factor Analysis, the 'n' number of variables is reduced to an optimum number of independent variables, before subjecting the data for further quality gap analysis.
- Step 7: A personal interview is conducted with design and development executives of the product to gather the data on manufacturer's financial and technical constraints to achieve the various levels of quality characteristics and also the production cost of the critical components involved in the analysis.
- Step 8: Various quality gaps explored by the conceptual model are analyzed using the framework consisting of the quality tools like House of Quality, Linear Programming, Design for Manufacturability, Multi-Criteria Decision Making, Maintainability models, Fault Tree Diagram, Total Quality Management principles in production and logistics, etc to bridge the quality gaps of the product chosen for testing the conceptual model.

4. A FRAMEWORK FOR QUALITY GAP ANALYSIS

Fig. 3 shows the block diagram giving the details of various quality tools proposed to bridge the six different quality gaps explored by ProducQual. Also, it gives the idea of connectivity between various quality tools and techniques used for quality gap analysis.

Analysis of Quality Gap 1:

This gap may be measured by conducting survey with customers and manufacturer. Using 'House of quality' of Quality Function Deployment, the important quality characteristics [7] and their

quality levels that will provide more overall satisfaction to the customers can be identified [8-10].

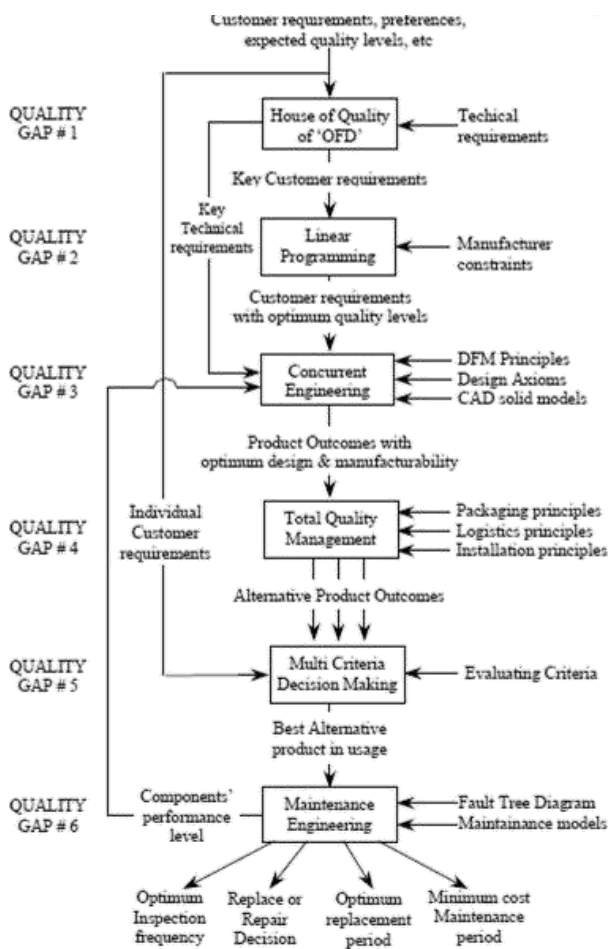


Fig. 3. Framework for product quality gap analysis.

Analysis of Quality Gap 2:

Comparing the actual product design specifications with that of the company policy can quantify this quality gap. In this research, a Linear Programming (LP) model [11] is developed to find out the optimal level for each quality characteristic of the product within the manufacturer's financial constraints. The generic LP model for maximising customers satisfaction is given as:

$$\begin{aligned} \text{Maximise} \quad & Z = \sum A_i X_i \\ \text{Subject to} \quad & \sum C_i X_i \leq D \\ & X_i \geq B_i \\ & X_i \leq E \quad \forall i = 1, 2, 3 \dots n \end{aligned}$$

where

Z is the overall customers' satisfaction, A_i is the customers' preference for i -th quality characteristic of the product, X_i is the decision variable i.e. i -th quality characteristic for the

optimum value is to be computed, B_i is the minimum quality level expected by customers for i -th quality characteristic of the product, $C_i X_i$ is the production cost function for i -th quality characteristic of the product for various quality levels, D is the maximum manufacturing cost that the manufacturer can afford to manufacture the product with all ' n ' quality characteristics, n is the number of quality characteristics of the product for which the optimum quality levels have to be determined, E is the maximum point of the Likert scale of measurement.

Using any Operations Research software, the LP model with the given ' n ' number of product quality characteristics can be solved to find out the optimum level of the product quality characteristics within the manufacturer's financial constraints [12].

Analysis of Quality Gap 3:

The difference in the level specified in the production drawing in terms of tolerances and in the product just after manufacturing will measure this quality gap. Making the shop floor managers involved in the design, i.e., by implementing Concurrent Engineering principles, this quality gap can be reduced. Design for Manufacturability principles are employed to reduce this quality gap.

Analysis of Quality Gap 4:

The difference between the quality level just after manufacturing and the quality level when it reaches the customer can quantify this gap. Proper training on quality awareness to sales persons; and high-quality logistics can make the customers avail the quality found at the manufacturing stage. In this research, various TQM principles are discussed during the production of the product, product packaging and logistics to sustain the quality level of the product between the production stage and the delivery of the product to the customers.

Analysis of Quality Gap 5:

Using a customer satisfaction survey, the difference between the customer expectations and perceptions can be quantified. By facilitating the customers to choose the best product among

the alternatives available in the market, the disparity between the customer expectations and perception can be reduced. Multi-Criteria Decision Making models [13] will serve the purpose of selecting the best brand of products to fulfill most of the customer requirements to the maximum level of satisfaction. In this study, the Analytic Hierarchy Process is applied to select a best model for the product.

Analysis of Quality Gap 6:

The change in the quality level from the time when the customer starts using the product to the time when it is disposed of, measures this gap. To uphold the quality level for a longer period, the maintainability concepts have to be implemented effectively. However, there is also a downtime for each maintenance and considerable maintenance cost is involved. So, it is also desirable not to carryout maintenance activity frequently. Therefore, the problem arises of finding out the optimal number of inspections, in order to minimise the downtimes of the inspections and the expected downtime due to failure. The models developed by Charles E Ebeling [14] are applied to the critical components of the product as identified from the Fault Tree Diagram.

5. CONCEPTUAL MODEL VALIDATION

To validate the various qualitative analyses described in the previous chapters, it is required to collect real-life data for any physical product. As such, the product 'bicycle' is selected for the case study. The required manufacturer's data like quality characteristics of the bicycle, technical requirements to achieve the quality characteristics, manufacturer financial difficulty, etc are obtained from a leading bicycle manufacturer. Similarly, customer data like customer expectations, customer perceptions, and customer importance to various quality characteristics of bicycle are obtained from customers located around a major city. Prior to the collection of data, a suitable measuring instrument is developed. In this study, a Likert scale is used to measure all the qualitative data. Various quality dimensions and characteristics of bicycles are explored. After collecting the data, they are subjected to statistical tests to validate the data. Then the framework discussed in the previous chapter is applied to bridge the quality

gaps identified by ProducQual for the selected product 'bicycle'.

A summary of the steps followed to collect the required data from customers and manufacturer of the product is given below:

- Stage 1: All the product quality characteristics that may influence customer perception of quality are documented for the product 'bicycle' selected for the study.
- Stage 2: The product-related 'n' quality characteristics are grouped using the product quality dimensions.
- Stage 3: Using the Delphi technique, a group of a few experts are asked to express their degree of agreement on the inclusion of items to make up the scale. Then a pilot sample of a few questionnaires is tested out. The trial will result in a reduction of the scale to a few product quality characteristics. The quality characteristics, which are too ambiguous for their evaluation, are eliminated.
- Stage 4: After finding out the suitable sample size statistically, the collection of data is achieved through a survey and is consolidated and tabulated for further analysis.
- Stage 5: The data obtained are subjected to Factor Analysis for data reduction, and Correlation Analysis for checking interdependency between the variables, required mean, standard deviation, distribution of data, etc. before they are used for further analysis.
- Stage 6: The manufacturer's technical and financial constraints are obtained through the personal interview with product design and development executives of the leading manufacturer.

The 'House of Quality' is discussed with the product 'bicycle'. The findings from the 'House of Quality' are carried over to the next stage of optimisation of quality levels. A linear-programming model for bicycle customer satisfaction is developed here for the top-ranked quality characteristics identified by 'House of quality'. Using operations research software, the optimised quality levels for the various quality characteristics within the manufacturer's financial constraint are obtained. Next, the various generic DFM guidelines and design axioms are discussed about the product 'bicycle'. CAD solid models for a few DFM prototypes of

spoke-less wheel rim and bicycle pedal bar are developed. Cost-benefit analysis is carried out for the results obtained from optimisation technique and for the DFM designs before suggesting them for implementation. In this chapter, the Analytic Hierarchy process is discussed to choose the best model of 'the bicycle. Eventually, the various maintainability models to maintain the quality level of the critical components of a bicycle identified from the Fault Tree Diagram are discussed with real-life data.

6. CONCLUSION

A conceptual model *ProducQual*, a first of its kind explores the various quality gaps across its product life cycle. A unified framework consisting of the quality tools House of quality; Linear Programming; Design for Manufacturability; TQM principles in logistics; Multi Criteria Decision Making Process and Maintainability models has been developed. The framework has been tested with the product bicycle for many of the quality issues.

Some of the limitations presented below, if rectified for future researchers, will further provide guidelines for the effective implementation of *ProducQual* for all types of products under any circumstances. Some of the limitations associated with the research are:

- The conceptual model *ProducQual* explores only six major potential quality gaps across six major stages of the life cycle of a generic product. However, the exploration of quality gaps can be extended into the minor level for effective abridgment of quality gaps and thus improvement of customers satisfaction.
- *ProducQual* considers the quality gaps between manufacturer and end users only, not the other stakeholders like material suppliers, wholesalers, retailers, transport agencies, marketing agencies, etc.
- Only Likert scale is used for the measurement of customer satisfaction based on the assumption that customer satisfaction increases linearly with the product quality level and that the manufacturer constraint of increasing the product quality level is linear proportional to the product cost. This assumption may not be good for all kinds of products.

ProducQual is not a solution for evading quality gaps, but for bridging the quality gaps. It is expected that the attempt initiated in this research will motivate more researchers along the lines of the judicious implementation of quality tools in improving product quality and thus improving customer satisfaction.

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