

## ***Deployment of Quality Function for Improving the Process of Product Design Conceptualisation – A Case Study***

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### ***Abstract***

*Minimizing product development time, increasing product quality, lowering costs, and meeting customer criteria have all become critical in today's business rivalry. The product design concept's attitude has shifted from a passive response to a more active approach to design process control. Designers may plan ahead of time and avoid complications throughout the development stages. There are several design control solutions available to examine all potential concerns and avoid the time and money loss caused by poor design. QFD is a technique for transforming user needs into design quality, deploying functions forming quality, and deploying ways for attaining design quality into subsystems and component components, and eventually to particular aspects of the manufacturing process. The goal of this case study is to improve design methodology by integrating proactive approaches with basic design process features. This research paper will present a broad overview of the QFD methodology and approach to the product development process, analyse the fundamental causes, do a Pareto analysis to prioritise the reasons, and examine literature to establish essential parts of the design process and proactive techniques. To complete the suggested methodology, the proposed analysis is the integration of Quality Function Deployment, which is the fundamental result of the study that fills the research gap, and its methodical approach is produced. So this study demonstrates how to enhance design technique by using QFD, and it will also be useful in understanding how to prevent subsequent design modifications and boost product success,*

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*particularly in terms of quality and dependability.*

**Keywords:** - *Quality function deployment, Design, Product Development, Quality.*

## INTRODUCTION

New product creation, in conjunction with the adoption of the innovation paradigm, is becoming a winning weapon and a long-term strategy for the many economic sectors, regardless of the level at which they are presented. NPD is not considered distinct from innovation because it is the process of getting a product (goods and services) to market. While developing products, the design stage is critical in defining the physical shape and function of the product in order to fulfil customers' demands. Engineering design, such as mechanical, electrical, and software design, as well as industrial design, such as aesthetics, ergonomics, and user interfaces, are all part of the design functions.

The concept design has a significant influence on the entire success of product development. Nowadays, design methodology is done by employing many design methodology enhancement technologies. For example, Quality Function Deployment (QFD) is used to transform customer needs into engineering

characteristics, allowing for a technically possible design idea to be realized through a customer-driven solution. The success of a product is mostly determined by how customer wants are considered (quality); what activities must be performed to meet needs; and how precisely a failure analysis is performed (reliability) (cost and time). Quality, time, and cost are all factors that influence a product's worth. Thus, improving the college's design methodology and managing these competing issues is required to develop a scientific method for concept generation and evaluation; to assist designers in designing products easily, efficiently, and correctly; to consider product reliability and quality characteristics early in the product development process, and to reduce later design changes, customer loss, and resource waste. The design process is defined in this study as the mapping of requirements, functions, and components. This research also attempts to incorporate and understand QFD in the design process in a systematic manner.

## **SUMMARY OF LITERATURE REVIEW**

The literature study discusses concept design, conceptual design phases, common concept development, and assessment methodologies. Various proactive product design strategies were thoroughly investigated in the literature review. This literature demonstrates how the strategies are effective instruments for enhancing the quality and dependability of a product. Methods play an important part in the early stages of product design. The QFD proactive technique was utilised in Toyota Company, TV remote control, and safety shoe to transfer client requirements into design requirements. Furthermore, the QFD processes were thoroughly shown. As a result, QFD are strong methodologies that every business should use in order to help industries improve their designs. According to the literature, the fundamental aspects of a conceptual design are necessity, function, and component. Finally, the methods for identifying customer requirements are engineer insights, competitive benchmarking, and market survey; the methods for deploying functions are questioned asking technique; and the methods for defining components are brainstorming, Delphi method, analogy, and natural system analysis. Furthermore,

the stage-gate product development process was examined to ensure that the end product meets specific criteria for a successful product. There is no literature on incorporating QFD design principles. As a result, the focus of this study is on the incorporation of the QFD proactive technique into the conceptual design process.

### **Quality Function Deployment Method**

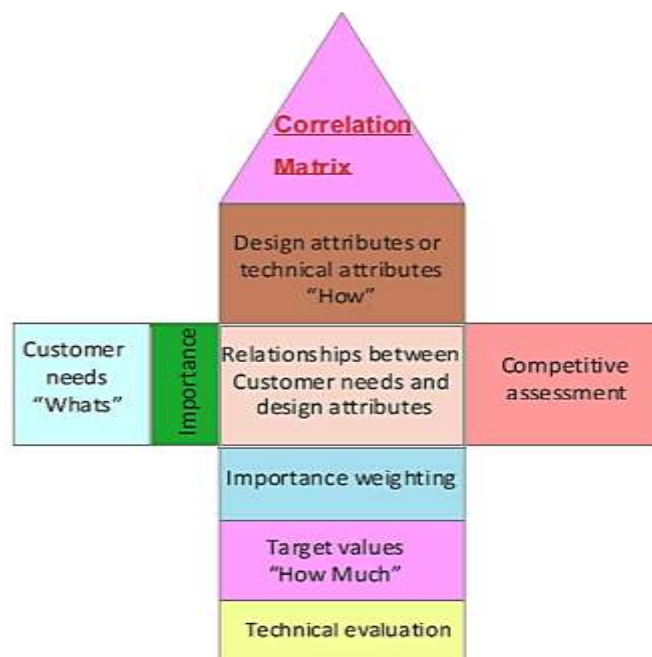
QFD has been utilized in Japan since the early 1970s to improve the efficiency of the product development process. QFD is described as a methodical approach to correctly converting client needs into applicable technical descriptors at each step of product development and manufacturing. As a result, meeting or surpassing consumer expectations entails more than simply maintaining or enhancing product performance. It entails creating and manufacturing items that satisfy clients (Lai-Kow and Ming-lu, 2002). Nadia (2011) described Quality Function Deployment (QFD) as a systematic design technique for translating customer needs into engineering characteristics, allowing for the creation of a technically feasible design idea via a customer-driven product. In the QFD analysis, a matrix known as 'the house of quality' is employed, and the analysis is

carried out in a series of phases. According to John and Herman (2008), there are nine processes in QFD analysis, starting with understanding what consumers require and ending with competitive evaluation. Figure 1 depicts the QFD analysis procedure. Finally, a comparative evaluation of the company's and rivals' products in light of consumer requirements must be conducted through customer surveys. In general, the QFD phases are iterative until the designer is satisfied that the design fits the customer's needs.

**Problem Statement**

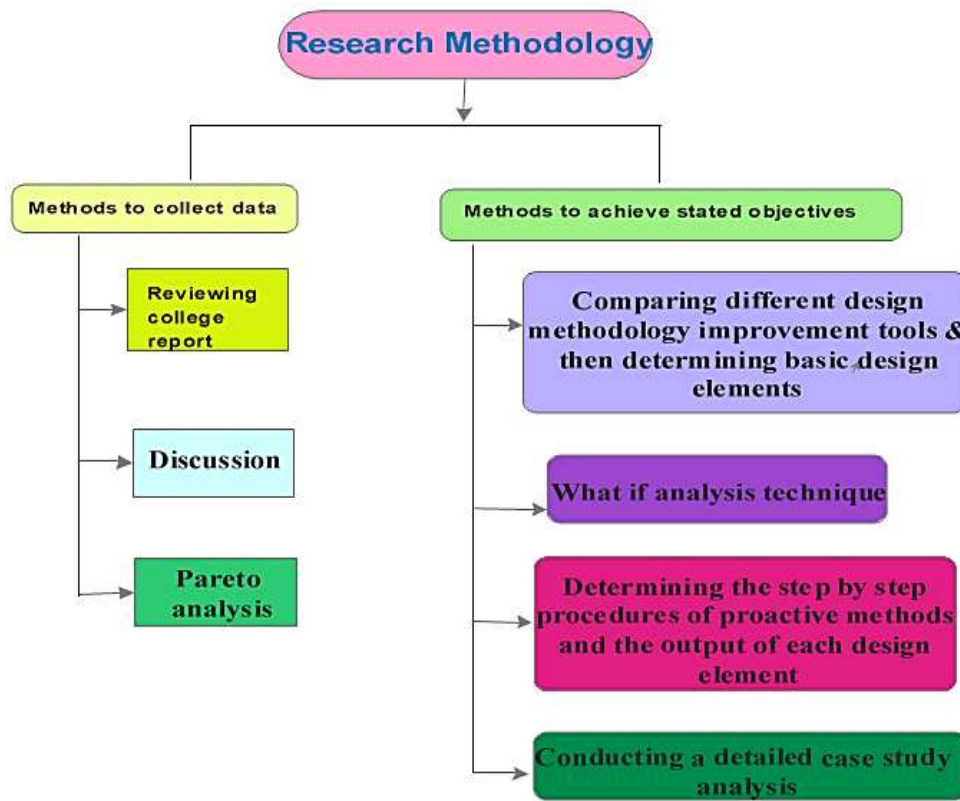
This case study was carried out at Bahir Dar Polytechnic College in Bahir Dar,

Ethiopia. Bahir Dar Polytechnic College disseminates innovative technology to manufacturing firms or directly to customers. 70% of the new items that were developed and expected to be transferred to clients were unable to pass product tests, resulting in a financial loss. According to early study utilizing the Pareto analysis tool, the design problem contributed 58.8%. The design problem is mostly the outcome of a bad engineering product design process in which the designer's technique is a 'run to build approach,' which does not allow the designers to do requirement, function, and failure analysis throughout the conceptual design phase.



*Figure 1: QFD analysis method*

**RESEARCH METHODOLOGY**



*Figure 2: Research Methodology*

Figure 2 depicts the approach used by the research to reach the goal, which is separated into a chronological series of six phases. The first step is to review the existing literature. A literature review was conducted to obtain the necessary information about the generic product development process, conceptual design, and elements of the engineering product design process, well-known proactive method QFD and their practical applications that can be integrated in the design process, and to identify research gaps relevant to this study.

The second stage is to get data from Case College. The following data gathering procedures were used to get the relevant data: Personal observation: successful and failed items were closely examined, and design issues with failing goods were found.

**Secondary data collection:** relevant data was reviewed and relevant information such as the percentages of successful and unsuccessful new goods (from a population size of 24) was gathered. The functioning

concept of the case product and the likelihood of occurrence for failure modes of components were discussed with people with agricultural expertise. Following a Pareto analysis, a design flaw is identified as the primary reason of product failure, and the researchers choose an oxen-pulled plough from among the unsuccessful items to validate the design technique. An integration model and associated methodical approach are created to reflect the suggested design methodology. The third phase was to compare the basic aspects of the design process and proactive techniques; a QFD model was chosen to develop the integration framework that was used to understand how the foundational and representative design elements connect with proactive methods.

The fourth phase was to design a recommended methodical approach for the selected model by first establishing the QFD procedures that are applicable to this investigation. Once the model and its methodical approach, which is the suggested design methodology, have been established and merged, it must be determined whether the methodology is appropriate for conducting a product design. The fifth stage is to undertake a comprehensive examination of the oxen-pulled plough that was used as a sample in

the QFD analysis. This step's primary goal is to illustrate and validate the design technique. The sixth stage is to validate the suggested approach by comparing it to other research.

Furthermore, this study's research methodology includes a discussion, conclusion, and suggestion.

### **Reasons for New Product Failure and Pareto Analysis**

Bahir Dar Polytechnic College not only teaches those who wish to study scientific or technical courses in preparation for a certain employment, but it also distributes new technologies to clients through micro, small, and medium-sized firms. Product development is the most important aspect of their job when it comes to conveying new technology. However, thus far, the technological transfer has not proven effective. The causes for the failure of technology transfer are connected to design, production, supply, and other factors (such as management and teamwork).

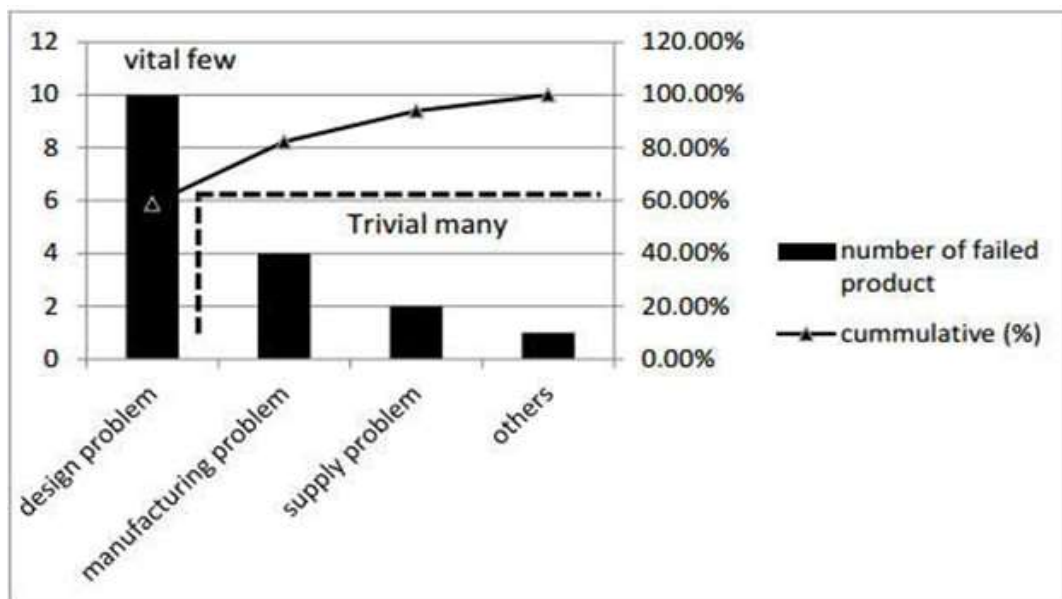
Poor engineering product design process, inability to employ newest design methodologies such as finite element method, lack of training for product designers, and poor cooperation are all

design-related issues. Poor engineering process design, inability to employ newest design approaches such as process failure mode and effect analysis (PFMEA), design of experiment (DOE), lack of training for process designers, and poor cooperation are examples of manufacturing-related issues. The college's product designers do not adhere to any formal engineering

product design procedures or scientific methodology. As a result, product failure is common. Table 1 shows the reasons for and the quantity of unsuccessful goods gathered from the college. Appendices I and II indicate the total number of new goods introduced by Bahir Dar Polytechnic College, together with their names and status.

**Table 1: Reasons and number of failed products**

S.N	Reasons	Number of failed products	Relative(%)	umulative(%)
1	Designproblem	10	58.8	58.8
2	Manufacturing problem	4	23.5	82.3
3	Supplyproblem	2	11.7	94
4	others	1	6	100
	Total	17		



**Figure 3. Pareto analysis of new product failure during product test**

Pareto Analysis is a statistical decision-making approach that is used to pick a small number of activities that have a substantial overall influence. It employs the Pareto Principle (also known as the 80/20 rule), which states that the vast majority of issues (80%) are caused by a few important factors (20%). This is often referred to as the crucial few or the trivial many. Although the core Pareto principle is 80-20, there are other 70-30 and 60-40 concepts in use today.

According to the Pareto analysis, approximately 60% of new product failure is caused by less than 40% of the reason. In other words, one of the four factors (25%), design flaw, is responsible for 58.8% of new product failure. In other words, bad engineering product design process, which is the foundation for the rest of the product development processes, contributes significantly to product failure. This is because any faulty practise during the initial stages of product development had a disastrous consequence. The Pareto analysis in Figure 3 reveals that the college's inadequate design technique leads to increased product failure.

### **Proposed Design Methodology**

To create the integration framework, first define the key parts of the design process

and proactive approaches that will serve as the framework's pillars. The integration model is created in order to integrate QFD into the design process. To establish a methodical technique for the framework, a methodical strategy for applying QFD alongside the design process is provided. Finally, by merging the chosen integration model and its methodical technique, the recommended design methodology is created. Table 2 shows how this study identifies and summarizes the building blocks, in this instance critical parts of the design process, and proactive techniques for the integration purpose before the model is produced. QFD integration with Design Process approach This technique employs QFD as a strategy to enhance the requirement portion of the design process, as illustrated in figure 4 and in table 3's comparison of the present design with QFD. The case study begins by establishing five frequent client needs for the oxen-pulled plough, which is a popular instrument used by farmers. Table 4 shows the result of the needs domain after QFD analysis and reasoning: relationship values, correlation values, and a list of prioritized technical features.

The procedures below will help you identify the prerequisites.

- Step 1: Identify customer requirements

- Step 2: Rate the importance of each requirement to customer based on some scale
- Step 3: Determine technical characteristics those can meet customer requirements
- Step 4: Decide the relationships between customer requirements and technical characteristics
- Step 5: Decide correlations among technical characteristics
- Step 6: Determine the absolute and relative importance of each technical characteristic
- Step 7: Put the target values for technical characteristics.

**Table 2: Basic elements of design process and proactive method**

Basic Elements	
Design Process	Proactive Method
	QFD
Requirement	Technical characteristics
Function	Relationship between customer requirements (Whats) and Technical characteristics (Hows),
Component	Correlation among Hows
	Importance of each technical characteristics



**Figure 4: Integration of QFD with design process approach.**

**Table 3: Comparison of existing design process and QFD**

Basic questions	Existing design process approach	QFD
Can the requirement be improved?	No	Yes
Can the function and component Be improved simultaneously?	No	Yes
Can the component be improved?	No	Yes

**Table 4: The absolute, Relative weighting value and Rank of technical characteristics**

S.N	Technical Characteristics	Absolute weightage	Relative Weightage (%)	Rank
TC <sub>1</sub>	Weight	39	9.2	3
TC <sub>2</sub>	Rake Angle	36	8.4	4
TC <sub>3</sub>	Ploughing Depth	36	8.4	4
TC <sub>4</sub>	Cutting edge thickness	36	8.4	4
TC <sub>5</sub>	Cutting edge Sharpness	36	8.4	4
TC <sub>6</sub>	Pulling Force Requirement	81	19.0	1
TC <sub>7</sub>	Ploughing Width	45	10.6	2
TC <sub>8</sub>	Speed	18	4.3	6
TC <sub>9</sub>	Soil Strength	36	8.4	4
TC <sub>10</sub>	Frictional Force	18	4.3	6
TC <sub>n</sub>	Ergonomy	18	4.3	6
TC <sub>12</sub>	Material	27	6.3	5
	Total	426	100	



**Figure 5: QFD Analyses of Oxen Pulled Plough**

## RESULT AND DISCUSSION

The research methodology with a chronological sequence of six steps is illustrated as the output of the first step indicated, the researchers and practitioners concluded that QFD are powerful methods that every industry should use to improve product design, primarily in terms of quality and reliability of a product, and play a significant role if the methods are applied at an early stage of product design. Integrating QFD design components, on the other hand, improves the design process.

After the second step, collecting secondary data from technology transfer office reports was used to obtain relevant information such as the percentages of successful and failed products; discussing the College's Product Development Process with designers; discussing reasons for product failures with designers, manufacturers, technology transfer manager, and those who were present while products were being tested in the field. Finally, a conversation was held with persons with agricultural knowledge concerning the functioning principle of the case product and the likelihood of occurrence for failure modes of components.

Following that, a Pareto analysis was performed to establish the contributions of causes for product failure, and it was discovered that design problems, manufacturing problems, supply problems, and others contribute 58.8%, 23.5%, 11.7%, and 6%, respectively. A sample BPTC product and its design issues are examined. There is a significant gap between the study of the sample product, the comparison of the college's product development process with the generic product development process, and the use and applications of QFD. As a result, it is possible to conclude that the college's design process is inadequate. Framework integration model scenarios were proposed following the third stage integration. The importance of twelve technical factors is selected after evaluating QFD for oxen drawn plough, determining connection and correlation value. Among the twelve technical factors, pulling force needed (19%), ploughing width (10.6%), and weight (9.2%) were ranked first, second, and third, in that order. The outcome of QFD analysis includes relationship values, correlation values, and prioritised technical features, as shown in schematic figure 5 of the methodical technique of QFD. The QFD study of an oxen-pulled plough confirms this. In other words, the model determines the connection, correlation

values, and prioritized technical qualities. As a result, in order to enhance farm production and fulfill the most essential client needs, we must carefully analyse the output of the requirement domain. To summarize, the most essential customer need is "I need to plough more with fewer trips," while the top two technical features are pulling force required and ploughing breadth. This means that engineers can expand the ploughing breadth while requiring less pulling power by improving other factors. This demonstrates the significance of QFD analysis.

## CONCLUSION

This study aims to enhance design methodology since the research gap in design methodology discovered in Bahir Dar Polytechnic College's design methodology, which is the major cause of product failure, is incorrect. The suggested design methodology includes the integration of QFD in their essential aspects of the design process with its methodical technique. After applying QFD to validate the case study of an oxen-pulled plough, the pulling power need (19%), ploughing breadth (10.6%), and weight (9.2%) were improved. So, for the first time, this study illustrates how to enhance design technique by systematically combining well-known methods, and this

study will be crucial in helping us understand how to prevent subsequent design modifications and boost product success, particularly in terms of quality and dependability. In the future, after evaluating the proposed methodology under real-world conditions to improve validation and merging proactive approaches with other methods such as heuristic methods to improve design methodology reliability. Future recommendations include creating manufacturing methodologies that incorporate Process Failure Mode and Effect Analysis (PFMEA) and Taguchi Design of Experiment (TDE) (TDOE).

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