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A Case Study on Improvement of Conceptual Product Design Process by Using Quality Function Deployment

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ABSTRACT

To minimize the products development time, increase the quality of products, reduce cost and meet the requirements of customers have become crucial in nowadays enterprise competition. The attitude of product design concept has been changed from passive response to be more aggressive in design process control. Designers can discuss in advanced and avoid problems during the later develop stages. There are many design control strategies to evaluate all possible issues and avoid the time and cost waste from improper design. Quality function deployment (QFD) is a method to transform user demands into design quality, to deploy the functions forming quality, and to deploy methods for achieving the design quality into subsystems and component parts, and ultimately to specific elements of the manufacturing process. The aim of this case study is to improve the design methodology through the integration of proactive methods with basic elements of the design process. This research paper will provide a general overview of the QFD methodology and approach to product development process, assess the root causes, Pareto analysis has been made to prioritize the causes, and literature is reviewed to determine key elements of the design process and proactive methods. The proposed analysis is the integration of Quality Function Deployment, which is the core finding of the study that fills the research gap, is selected and its methodical procedure is developed to complete the proposed methodology. So this study shows, that how to improve the design methodology by integrating the QFD and also this study will be important to help us understand how can prevent later design changes and increase products success especially in terms of quality and reliability.

Key Words: *Quality function deployment, Design, Product Development, Quality.*

1. INTRODUCTION

New product development along with the incorporation of innovation paradigm is becoming a winning weapon and a sustaining strategy for the various economic sectors whatever the level they are presented. New Product development (NPD) is not seen separately with innovation as it is a process of bringing a product (goods and services) to the market. The design stage plays a significant role in defining the physical form and the function of the product to satisfy customers' needs while developing products. The design function includes engineering design such as mechanical, electrical, software, and industrial design such as aesthetics, ergonomics, and user interfaces. The concept design has a great impact on the overall product development success. Now a day the design methodology is practiced by using different design methodology improvement tools. For instance, Quality Function Deployment (QFD) is used to translate the customer requirements into engineering characteristics, thus it enables to have a technically feasible design concept via customer driven product.The success of a product is mainly depend on how customer needs are considered (quality); what functions must be done to satisfy needs and how accurately a failure analysis is made (reliability); how later design change is prevented (cost and time). Quality, time, and cost, which determine the value of a product, conflict each other. So, improving the college's design methodology and managing these conflicting issues is necessary to develop a scientific method for concept generation and evaluation; to help designers to design products easily, efficiently, and in the right way; to consider product reliability and quality characteristics early in the product development process, and to reduce later design changes, loss of customers and waste of resources. In this study considers the design process as the mapping of requirements, functions, and components. This study also tries to integrate and interpret QFD, in the design process systematically.

2. SUMMARY OF LITERATURE REVIEW

The literature review that covers about concept design, steps in conceptual design, the common concept generation and evaluation methods. In the literature survey, different proactive product design methods were studied in detail. From this literature, it can be understood that how the methods are powerful tools in improving the quality and reliability of a product. The methods have a great role at an early stage of a product design. The QFD proactive method is used to translate customer requirements into design requirements and it was applied in Toyota Company, TV remote control, and safety shoe. In addition, the procedures of QFD were explicitly shown. Therefore, QFD, are powerful methods that every industry is better to utilize so that the methods help industries in improving product designs.The other understanding from the literature is that the key elements of a conceptual design are requirement, function, and component. Finally, the methods to identify the customer requirements are insights from engineer, competitive benchmarking and market survey; the methods to deploy functions are questioned asking technique and the methods to define components are brainstorming, Delphi method, analogy, analyzing the natural system. Furthermore, the stage-gate product development process was reviewed to make sure the final product is produced based on some criteria of a successful product. Integrating QFD, design elements has not been found in the literature. So, the research area of this study is focused on the integration of the QFD proactive method in the conceptual design process.

3. QUALITY FUNCTION DEPLOYMENT METHOD

QFD has been used since the early 1970s in Japan with the purpose of making the product development process more efficient. QFD is defined as a systematic means of accurately translating customer requirements into relevant technical descriptors for each stage of product development and production. Therefore, meeting or exceeding customer demands means more than just maintaining or improving product performance. It means designing and manufacturing products that delight customers (Lai-Kow and Ming-lu, 2002). Nadia (2011) also defined Quality Function Deployment (QFD) as a systematic design tool to translate the customer requirements into engineering characteristics, thus it enables to have a technically feasible design concept via the customer driven product. In the QFD analysis, a matrix is used which is called 'the house of quality', where the analysis is carried out through a number of steps. According to john and Herman(2008), there are nine subsequent steps of QFD analysis, ranging from understanding what customers need up to competitive evaluation. Figure 1 show QFD analysis method. Finally, competitive evaluation through customer surveys on company and competitors product in the view of customer requirements need to be made. Generally, the QFD steps are iterative till the designer feels the design meets the customer requirements.

4. PROBLEM STATEMENT

This case study was conducted in Bahir Dar Polytechnic College which is located in Bahir Dar, Ethiopia. Bahir Dar Polytechnic College transfers new technologies through manufacturing enterprises or directly to customers. The70% new products that have been produced and planned to be transferred to the customers out of them were unable to pass the product tests which resulted in a loss of cost . From this, as preliminary analysis using Pareto analysis tool revealed, design problem contributed 58.8 %. The design problem is mainly resulted from poor engineering product design process in which the designer's methodology is 'a run to build approach' that does not enable the designers to make requirement, function, and failure analysis during conceptual design process.

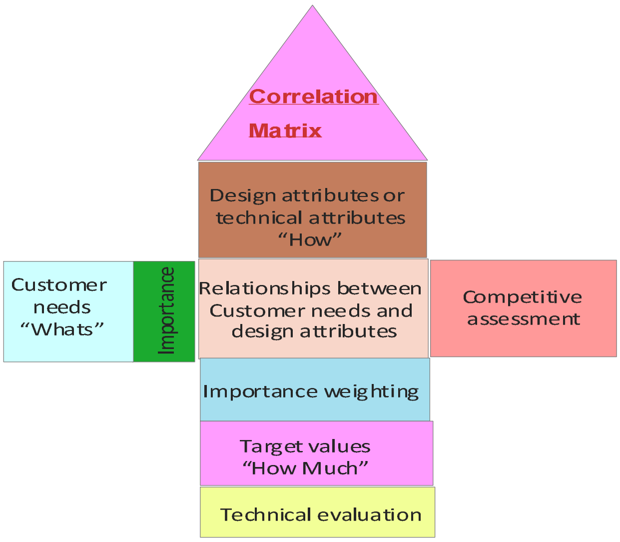

Figure 1 QFD analysis method

5. RESEARCH METHODOLOGY

The methodology that the research employed to achieve the objective is divided into a chronological sequence of six steps as shown in figure 2. **The first step** is a study of available literature. Literature review was employed in order to get the required information about generic product development process, conceptual design, and elements of the engineering product design process, well known proactive method QFD and their practical applications those can be integrated in design process and to identify research gaps related to this study.

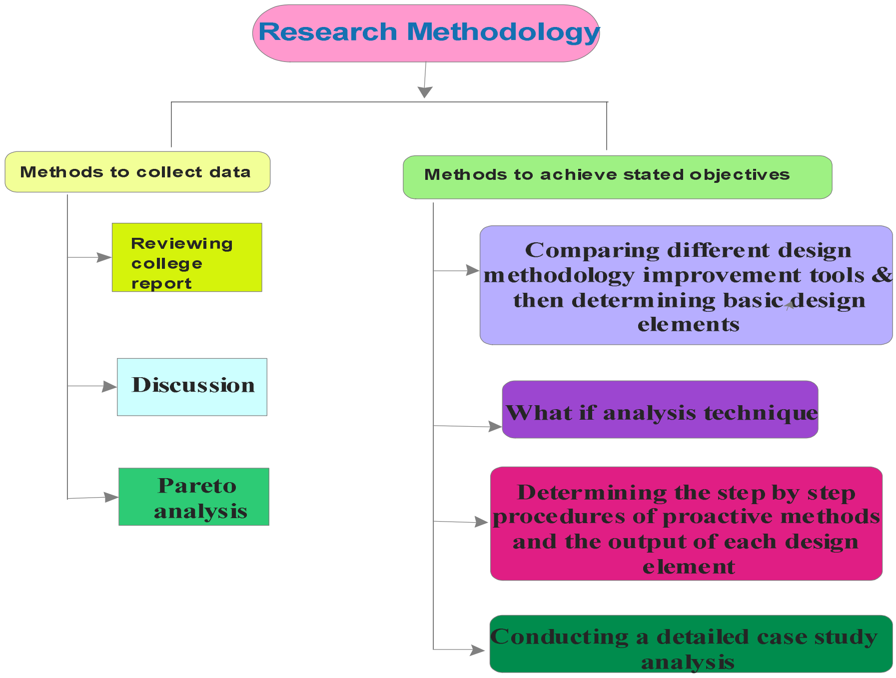

Figure 2. Research Methodology

The second step is a data collection from case college. The data collection methods that were employed in order to get required data were: Personal observation: successful and failed products were critically observed and then the design related problems for failed products were identified. Collecting secondary data: relevant data was assessed and relevant information such as the percentages of successful and failed new products (from 24 population size)were obtained. Discussion was made with those who have experience in farming about working principle of the case product and the probability of occurrence for failure modes of components. After Pareto Analysis is made, a design problem is found as a main cause for product failure and from failed products the researchers select oxen pulled plough to verify the design methodology. To represent the proposed design methodology, an integration model and its methodical procedure is developed. **The third step,** the basic elements of design process, proactive methods were determined through comparison; A QFD model was selected to build the integration framework that used to understand how the foundational and representative design elements integrate with proactive methods **The fourth step**, a proposed methodical procedure for the selected model was developed by first determining the procedure of QFD, that are relevant to this study. Once the model and its methodical procedure were developed and combined, which is the proposed design methodology, it needs to be checked whether the methodology is right to conduct a product design. **The fifth step** is a conducting of detailed analysis of oxen pulled plough, which was taken as a sample, in QFD, analysis. The main purpose of this step is to demonstrate and verify the design methodology. **The sixth step** is the validation of the proposed methodology through comparison of related studies. In addition, discussion, conclusion, and recommendation are part of the research methodology of this study.

6. REASONS FOR NEW PRODUCT FAILURE AND PARETO ANALYSIS

Bahir Dar Polytechnic College not only trains people who want to study scientific or technical subjects especially for a particular job but also it transfers new technologies through micro, small, and enterprises or directly to customers. While transferring new technologies product development is the main part of their task. However, the technology transfer has not been successful so far. The reasons for the technology transfer failure are related to design, manufacturing, supply and others (such as management and teamwork). Design related problems include poor engineering product design process, unable to use latest design methods such as finite element method, lack of training for product designers and poor teamwork. Manufacturing related problems include poor engineering process design unable to use latest design methods such as process failure mode and effect analysis (PFMEA), the design of experiment (DOE), lack of training for process designers and poor teamwork. The product designers in the college do not follow any of the formal engineering product design processes and scientific methods. As a result, the product failure is high. Reasons and number of failed products collected from the college are shown in Table 1. The total number of Bahir Dar Polytechnic College's new products with their name and status is shown in appendix I and II.

Table 1. Reasons and number of failed products

S.N	Reasons	Number of failed products	Relative (%)	Cumulative (%)
I	Design problem	10	58.8	58.8
2	Manufacturing problem	4	23.5	82.3
3	Supply problem	2	11.7	94
4	others	I	6	100
	Total	17		

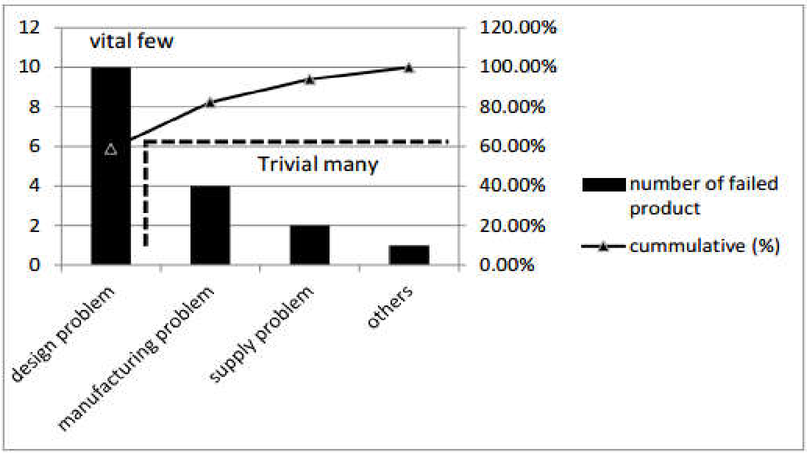

Figure 3. Pareto analysis of new product failure during product test

Pareto Analysis is a statistical technique in decision-making, which is used for the selection of a limited number of tasks that produce a significant overall effect. It uses the Pareto Principle (also known as the 80/20 rule), the idea in terms of quality improvement is a large majority of problems (80%) are produced by a few key causes (20%). This is also known as the vital few and the trivial many. Even though 80-20 is the basic Pareto principle, nowadays there are also 70-30 and 60-40 principles. From the Pareto analysis, it can be seen that about 60% of new product failure is caused by less than 40% of the cause. In other words, design problem which is one of the four causes (25%), is a cause for 58.8% new product failure. In other words, among these problems poor engineering product design process, which is a base for the rest product development processes, contributes a lot for product failure. This is due to the fact that any poor practice in earlier product development stage resulted in a catastrophic effect. Figure 3 shows the Pareto analysis ensures that the college's poor design methodology causes for higher product failure.

7. PROPOSED DESIGN METHODOLOGY

To develop the integration framework', first the basic elements of the design process and proactive methods which are the cornerstones of the framework were determined. The integration model is developed so that QFD the design process can be integrated. To develop a methodical procedure for the framework' a methodical procedure is proposed to apply QFD, along with the design process. Finally, the proposed design methodology is developed by combining the selected integration model and its methodical procedure. This study identifies and summarizes the building blocks in this case key elements of the design process and proactive methods for the integration purpose before the model is developed and it is shown in Table 2. Integration of QFD with Design Process approach. This approach uses QFD as a method to improve the requirement element of the design process as shown in figure 4 and comparison shown in table 3 between the existing design and QFD. In the case study, it was started by listing five common customer requirements for the oxen pulled plough which is popular tool that has been being used by the farmers. After QFD analyses and reasoning the output of requirements domain: relationship values, correlation values and a list of prioritized technical characteristics are shown in table 4 . The following steps given below to identify the requirements.

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

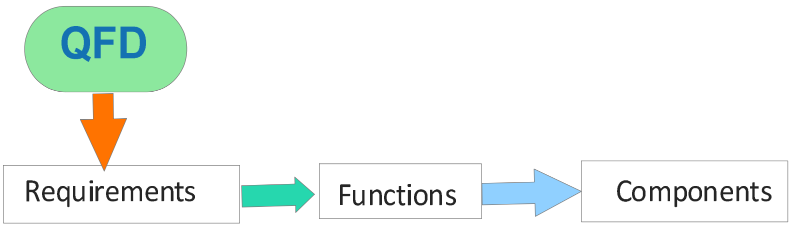

Figure 4 Integration of QFD with design process approach

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
TCi	Weight	39	9.2	3
TC_2	Rake Angle	36	8.4	4
TC_3	Ploughing Depth	36	8.4	4
TC_4	Cutting edge thickness	36	8.4	4
TC_5	Cutting edge Sharpness	36	8.4	4
TC_6	Pulling Force Requirement	81	19.0	1
TC_7	Ploughing Width	45	10.6	2
TC_8	Speed	18	4.3	6
TC_9	Soil Strength	36	8.4	4
TCio	Frictional Force	18	4.3	6
TCn	Ergonomy	18	4.3	6
TC12	Material	27	6.3	5
	Total	426	100	

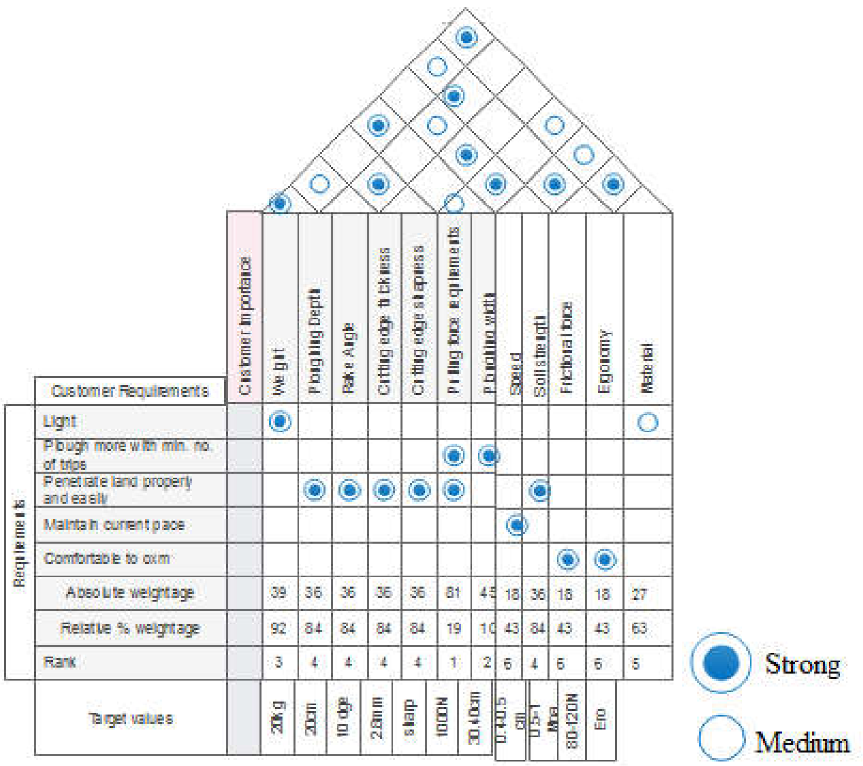

Figure 5 QFD analysis of oxen pulled plough

8. RESULT AND DISCUSSION

The research methodology with 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 is better to utilize so that method help industries in improving product design mainly in terms of quality and reliability of a product and play a great role if the methods are applied at early stage of a product design. However, integrating QFD design elements that improve the design process. Following the second step, Collecting secondary data from reports of technology transfer office was used to obtain relevant information such as the percentages of successful and failed products; the discussion was made on College's Product Development Process with designers; reasons for product failures with designers, manufacturers, technology transfer manager and those who were during products are being tested in the field. Finally, the discussion was made with those who have experience in farming about working principle of the case product and the probability of occurrence for failure modes of components. After that Pareto analysis to determine the contributions of causes for product failure was made and Design problem, Manufacturing problem, Supply problem and others contribute 58.8%, 23.5%, 11.7% and 6% respectively. Sample BPTC product and its design problems are analyzed. From the analysis of sample product, comparison of college's product development process with Generic product development process and from use and applications of QFD there is a huge gap. Therefore, it can be concluded that the college's design process is poor. Following the third step integration, framework integration model scenarios were proposed. After analyzing QFD for oxen pulled plough, determination of relationship and correlation value, the priority of twelve technical parameters are identified. Among twelve technical parameters pulling force requirement (19%), ploughing width (10.6%) and weight (9.2%) have got the first, second and third priority respectively. From the schematic figure 5 of the methodical procedure of QFD, the output of QFD analysis are relationship values, correlation values and prioritized technical characteristics. Here, the QFD analysis of oxen pulled plough verifies it. In other words, based on the model, the relationship, correlation values and the prioritized technical characteristics are determined. Therefore, in order to improve farm productivity and to meet the most important customer requirements, we need to consider carefully the output of requirement domain. To sum up, the most important customer need "I need plough more with minimum number of trips" and the top two technical characteristics are pulling force requirement and ploughing width. This implies the engineers can increase the ploghing width with minimum pulling force requirement by optimizing other parameters. This reflects the important of QFD analysis.

9. CONCLUSION

This study attempts to improve the design methodology since the research gap in design methodology is found in Bahir Dar Polytechnic College's design methodology, which is the main reason for product failure, is not right. The integration of QFD, in their basic elements of the design process with its methodical procedure, which is the proposed design methodology, is developed. After verifying the case study of oxen pulled plough using QFD, pulling force requirement (19%), ploughing width (10.6%) and weight (9.2%) were improved using QFD. So this study shows, for the first time, that how to improve the design methodology by integrating the well known method systematically and this study will be important to help us understand how to prevent later design changes and increase products success especially in terms of quality and reliability. In future, after testing the proposed methodology under the real condition to make the validation more acceptable and integrating the proactive methods with other methods such as heuristic methods to make the design methodology more reliable. The recommendation for the future is developing manufacturing methodology by integrating Process Failure Mode and Effect Analysis (PFMEA) and Taguchi Design of Experiment (TDOE).

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