PROCESS IMPROVEMENT BY APPLYING QUALITY FUNCTION DEPLOYMENT IN A LOCOMOTIVE MANUFACTURING

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ABSTRACT: *Quality Function Deployment (QFD) is a management tool which transforms the real customer needs into technical solutions. The main purpose of applying the quality function deployment technique is to lowering the costs, enhancing the design, improving the quality of products and services , and decreasing the production cycle time. In this research the Quality Function Deployment (QFD) tool is implemented for improving the design and manufacturing process of the locomotive bogie frame. For this purpose four phases of QFD technique is applied to provide to the Locomotive Factory an optimized and standardized Bogie frame manufacturing process with reduction in the manufacturing costs, production cycle time, and improvement in the design and quality from the company current implanted manufacturing process. By implementing the new design and process matrix' total of 400 labor hours is reduced and 26.6 % cost can be saved in a single bogie frame.*

KEYWORDS: *House of quality, Process improvement, Bogie frame, Pareto analysis, Break even analysis.*

1 INTRODUCTION

QFD used for a structured process of converting customer requirements into design and manufacturing needs. The QFD chart/matrix shows the relationship between customer needs and how these needs can be accomplished by the suggested design features.

The QFD matrix is not only lists the positive relations between the customer needs and proposed design features but also records any negative effects[1]. Quality product and services can be achieved by the help of QFD technique because it integrate customer needs in each step of product or service development, hence QFD is a strong tool for quality management and planning[2].

QFD process contains four matrices house of quality (HOQ), design matrix, operating matrix, and control matrix[3]. House of quality is the first matrix of quality function deployment technique, links the customer needs with the engineering characteristic of the product.

In quality function development "process design" is the second matrix of this technique in which the relation between component characteristics and technical requirement are shown. A relation matrix is formed between technical requirements and component characteristics. The relation can be strong, medium or weak. After scoring the critical component characteristics can be figure out. Process or operating matrix is the third matrix in quality function deployment technique. In process matrix the process involve is presenting on the horizontal axis and the component characteristics are presenting on vertical axis.

The last and fourth matrix is the control matrix, it is very important because all the processes are controlled in this matrix. A locomotive is the first part of the train; it has an engine, which makes the train move. Pakistan Locomotive Factory (PLF) is a manufacturer of locomotives (diesel-electric) for Pakistan Railways, located in Risalpur, Khyber Pakhtunkhwa, Pakistan. PLF was commissioned in 1993, with the capacity to manufacture 25 locos per annum on single shift basis[4].

1.1 Problem statement

During the manufacturing process of the locomotive bogie frame, there are issues related to process and quality which impacts the productivity and quality of the system. Quality function deployment (QFD) technique is a structure approach to design products according to customer demands. Therefore, the main objectives are

- Applying QFD approach for design and process improvement
- To identify customer requirements and to develop the house of quality
- To identify current manufacturing process and suggest improvements.

• To find the cost estimation of the existing process of the Bogie frame

2 LITERATURE REVIEW

Researcher yogi akao defined Quality function deployment as a tool for developing quality in a product or service to satisfy customers and then converting those customer needs into product design[8]. QFD technique involve all the management team to integrate the customer needs into each step of QFD analysis [9]. QFD technique required few steps to involve each and every customer wants into each matrix of QFD analysis[10]. The global competition in the middle of 20th century became one of the leading fields. The manufacturing and services industries sense the need of the improvement in their system with respect to customer satisfaction both in technical and economical perspective[11]. For the fulfilment of this gap Japan introduce the QFD technique for manufacturing process improvement and customer services as well[12][13].

In each stage of QFD voice of the customer (VOC) combined with the company polices for the product quality and service improvement [14]. QFD transfer customer needs into parameter and also convey customer wants to operation level [15]. It alter the traditional quality systems into a new system that minimize negative quality issues like poor service [16] and help the Planning and designing department in the company by providing an organized way of considering customer wishes into products and services [16]. Mitsubishi's kobe yard was the first industry implemented QFD technique [17]. Using QFD, researchers found a lot of advantages in manufacturing enhancing and service level incensement[18] and in literature these benefits reported with respect to real time practice[19]. The beauty of these techniques is that it can be implemented in each type of industry of manufacturing for system and response improvement towards the customers such as in transportation, construction, electronics, and education and service industry [19]. Toyota reduced pre-production costs by 60% from 1977 to 1984 by the implementation of QFD technique [17][20]. This approach in the organization also known as concurrent engineering where the critical step is collecting data prioritization and structuring end user desires through their voices [21][22][23]. The manufacturing and services industries sense the need of the improvement in their system with respect to customer satisfaction both in technical and economical perspective hence every manufacturing companies and services industries adopted this technique in America as well as in japan [24]. Around late 90s QFD became famous and was adopted throughout the whole world [22]. Sweden adopted this technique and was used in every manufacturing and service sectors [25][26][27]. The component characteristics in QFD shifted to process matrix and compare with each process involved [17][24].

Various steps involve constructing of process matrix which have each process involve on horizontal axis and each component characteristics on vertical axis [28]. Constructing house quality is a difficult task because it involve identification of each customer needs and each design characteristics which are the most critical parameter for conducting QFD analysis [29]. By the execution of the QFD, companies can enhance structure of organization, information flow, research and development for new products launching [17][30].

3 METHODOLOGY

The The methodology of the research work is based on the sequence shows in figure 1.

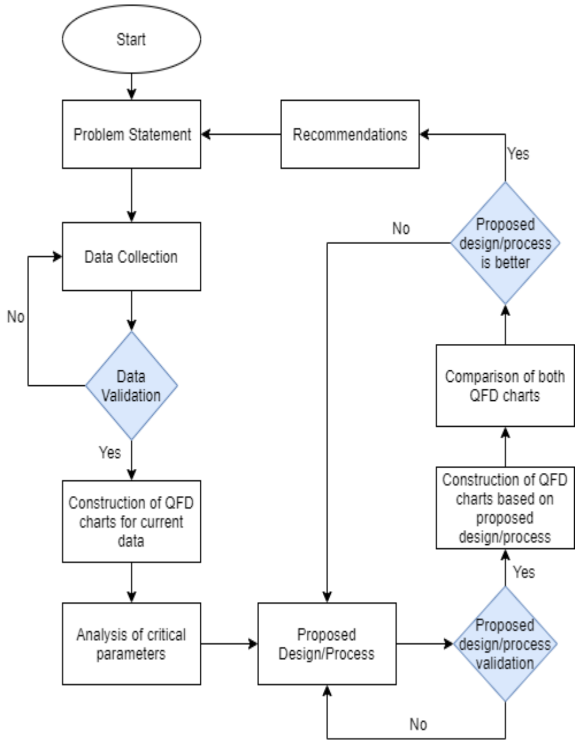

Figure 1. Flow chart of the research methodology applied in this study

Pakistan locomotive factory is selected to for the solution of problem related to the process improvement of bogie frame. By the steps of this methodology and in-lights of the literature survey the result of the project replicated in the last step of the methodology which shows improvements from the existing system of making of the parts for bogie frame in Pakistan locomotive factory.

A usual bogie frame is a steel structure manufactured from several subassemblies, two symmetrical longitudinal beams and three cross beams joining them. To these subassemblies, the brackets to mount the equipment are attached. Each longitudinal beam is usually recognized as a closed structure with cross section involving of an upper and lower plate and two webs. Plate thickness fall in the range 10mm-25mm.

4 DATA COLLECTION

In this research data was collected through filling a questionnaire from the company employees and also by observing the processes.

4.1 Customer needs of the Bogie frame

First step in the development of QFD is the identification of the customer requirements. Table 1 present the customer need.

Table1. Customer needs of the bogie frame

	Importance values					
Customer Needs of the bogie frame	FORM 1	FORM 2	FORM 3	AVG	CUM. AVG	%age
Required Size	100	100	95	98	98	97
Required weight	70	65	70	68	68	69
Reliability	75	85	75	78	79	78
Low cost	65	60	70	65	65	67
Ability to bear static and dynamic load	90	95	90	92	92	91
Stability on straight and curve track	70	80	65	72	72	70
Easy maintenance	60	55	65	60	60	62
Durability	75	80	70	75	75	73
Fatigue Strength	80	90	85	85	87	86
On time delivery	70	65	70	68	68	69
Ability to bear horizontal and vertical load	85	75	80	80	78	79
Stable with small radius curve	65	60	60	62	61	61
Other auxiliary system	25	10	20	18	16	18
Temperature resistance	40	45	40	42	42	41
Noise & vibration	35	40	45	40	42	42
Bogie space envelop	45	50	40	45	45	43
Traction system performance	40	50	45	45	47	46
Bogie envelop	45	40	35	40	38	38

4.2 Technical requirements of Bogie frame

Table 2 presents the technical requirement and its value.

Table 2. Technical requirement of the Bogie frame

	Importance value					
Technical requirements of bogie frame	FORM 1	FORM 2	FORM 3	AVG	CUM. AVG	%age
Material	100	100	100	100	100	11
Dimension	90	85	85	87	187	21
Thickness	70	80	75	75	262	29
Strength	85	90	90	88	350	39
Cost to produce	65	70	70	68	418	46
Expected life	60	65	65	63	482	53
Design of Manufacturing	55	50	55	53	535	59
Paint	50	40	40	43	578	64
Operating speed	60	65	70	65	643	71
physical concent	20	30	25	25	668	74
Track characteristic	20	20	30	23	692	77
Uniform load	80	85	80	82	773	86
Stiffness	75	80	70	75	848	94
Ability to withstand	50	60	55	55	903	100

5 DATA ANALYSIS

In this study the target product is the locomotive Bogie frame and data about the end users of Bogie frame and its technical requirements collected through the questionnaire form. The 1st phase of the QFD is consists of the developing of the House of Quality (HOQ) which relates the customer voices with the product/service technical requirements. All the end use desires weighted numerically (1-10) in the HOQ according to their importance to end users. In the HOQ matrix all the weighted values of the customer voices correlate with technical requirements according to their strength of correlation on the basis of Yogi Akao rating factor standards (1-3-9).

5.1 Existing QFD charts of the bogie frame

The HOQ is shown in figure 2.

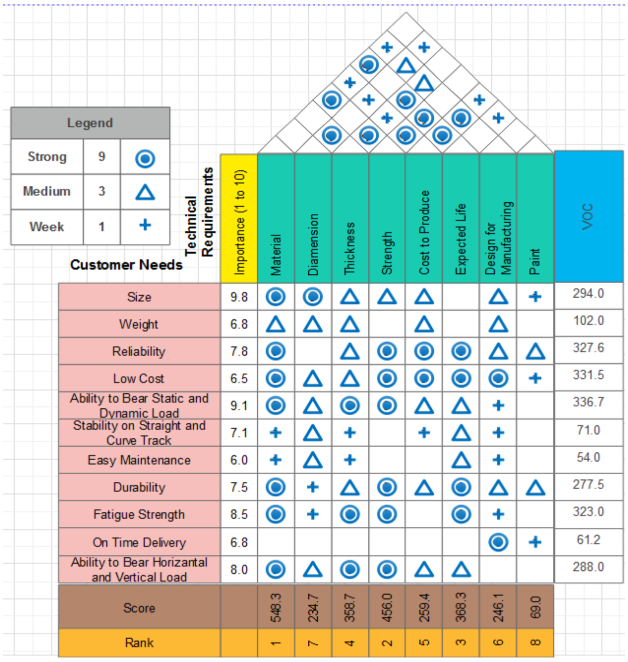

Figure 2. Existing House of Quality of the Bogie Frame

5.1.1 Mathematical formula for scoring the technical requirement

There are a number of methods for scoring attributes, but the simplest approach is to allocate a numerical value (1-3-9) according to Yogi Akao to the symbol used in the HOQ. The final scores calculated by using the following equation,

$$\mathbf{Aj} = \sum_{i=1}^{n} \mathbf{Rij\ Ci} \qquad \mathbf{(1)}$$

Where

Ai = row vector of absolute weight for the technical descriptions (i= 1... m)

Rij = weight assigned to the relationship matrix (i= 1... n, j= 1... m)

Ci = column vector of importance to customer for the customer requirements (i= 1... n)

m = number of technical descriptions

n = number of customer requirements

After ranking the most important technical requirement is shown in the figure 3,

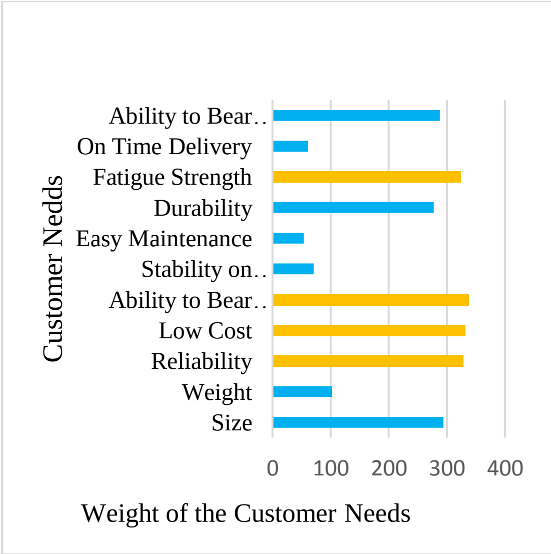

Figure 3. Customer Needs of the Bogie Frame

Figure 3, is the result for the eleven customers' needs that shown which one is the most important customer needs. In figure 3, the yellow color shown the important customer needs those are, fatigue strength, ability to bear static and dynamic load, low cost and reliability.

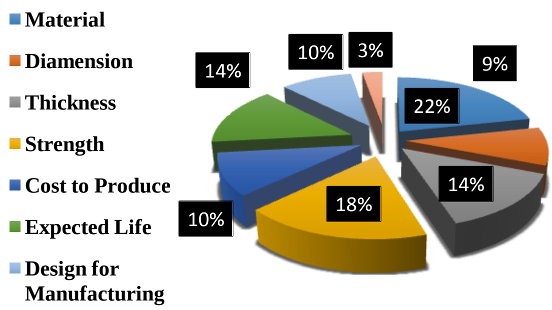

Figure 4 Respective weightages technical Requirement of the Bogie Frame

Figure 4 is the result for the eight technical requirements. From the figure 4, it's clear that material 22%, strength 18%, dimension 14% and thickness14% are the most important technical requirement.

5.2 Improved QFD charts of the bogie frame

The house of quality for both existing manufacturing processes and improved manufacturing processes of the locomotive bogie are dicussed here.

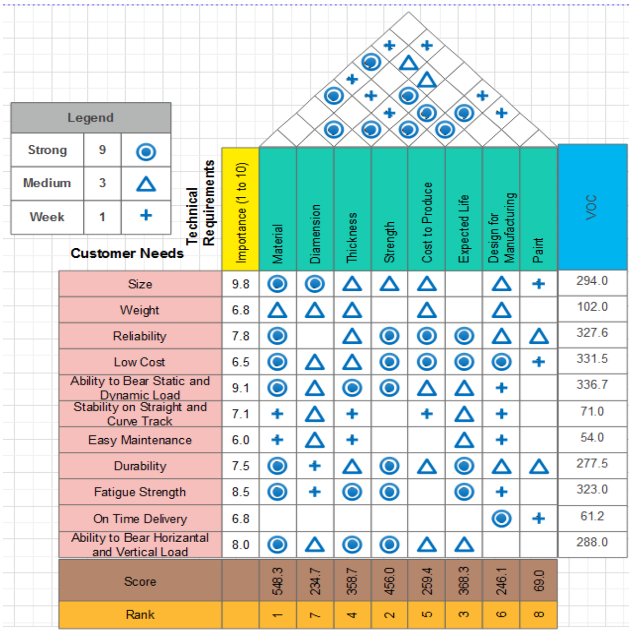

Figure 5. House of Quality of the Bogie Frame for the improved design.

The changes for the improvement in the process and design of the locomotive bogie occurred in the design matrix, process/operation matrix and control matrix of the quality function deployment. As discussed previously that the House of quality linked customer needs of the bogie frame to the technical requirements as shown in figure 5.

6 COST ANALYSIS

There are total seven processes that are used for manufacturing of the locomotive bogie frame and the total cost is calculated by multiplying the labor working hours per process with the labor cost per hour and then adding them to obtain the total cost for the bogie frame which is Rs 462000.

From available data at factory it’s clear that about 80% of the cost of bogie frame included welding without pressing, welding with pressing and gas cutting as compare to the other process such as painting, shot blasting, grit blasting, and annealing.

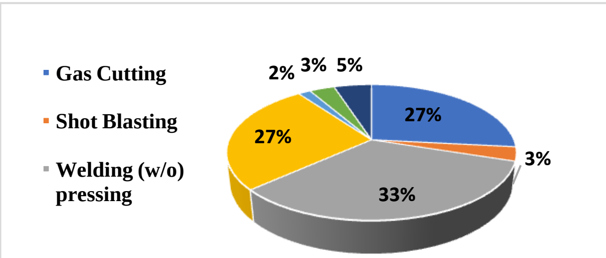

Figure 6. Percentages of cost analysis of the current manufacturing process of Bogie frame

Figure 6 shows the percentages of cost analysis of the current manufacturing processes of the bogie frame. From this chart it’s clear that welding without pressing, welding wit pressing and gas cutting are the most critical manufacturing process having a percentage of 33%, 27% and 27% respectively.

6.1 Cost analysis of the improved manufacturing process of bogie frame

In the improved manufacturing process of the locomotive bogie frame the gas cutting is replaced by plasma cutting which reduced the total labor working hours from 800 to 400 and the welding process is replace by bending the mild steel sheet in a U-shape channel using a press machine which reduce the total labor working hours from 1000 to 800 in welding without pressing and from 800 to 600 in welding with pressing as shown in Table 5. In the improved process of the bogie frame the total labor working hours reduce from 3000 to 2200 and the total cost in rupees (Rs) from 462000 to 338800.

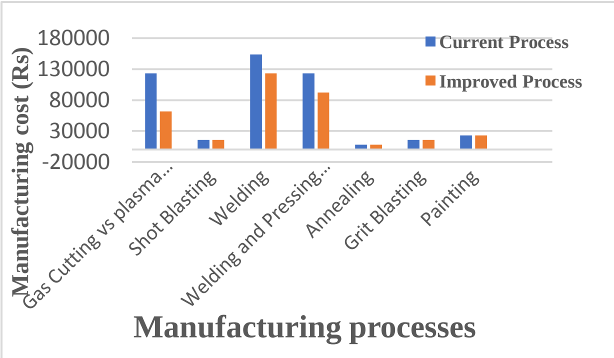

Figure 7. Comparative cost analysis of current and improved process and Design

Figure 7 shows the Comparative cost analysis of current and improved Manufacturing process and Design of the Bogie Frame. In the improve process and design of the locomotive bogie frame in which the gas cutting and welding is replaced by plasma cutting and U-shape bending it will save the cost up to 26.6% in a single bogie frame due to reducing the labor working hours in gas cutting replacing by plasma, welding without pressing, and welding with pressing by replacing it on only pressing process

6.2 Break even analysis with respect to total cost of the current and improved manufacturing process and design

Figure 8 shows the analysis of the total cost before and after installation of the plasma cutting. This graph determined the point of production at which the revenue equal to the cost. Thus after installation of the plasma cutting machine achieve the break-even point at the end of 4th month or at the start of 5th month, which mean that after 4th month the total cost line of the bogie frame after installation goes on decreasing while total cost line before installation plasma cutting machine goes on increasing.

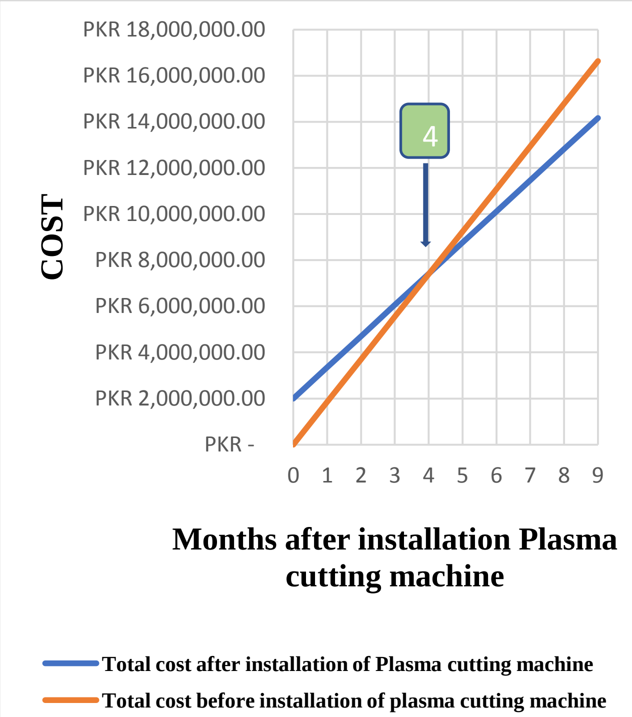

Figure 8. Break even analysis of the total cost

7 RESULT AND DISCUSSION

The main focus of this study was to investigate the current manufacturing processes of locomotive bogie frame and to identify the areas of improvement and then suggest the best possible way to improve the current manufacturing processes/design to achieve best quality product at low cost. The data was collected through questioner form production engineers at locomotive factory. Each one of them gave different importance to customer needs and technical requirements, the average results of data were considered for Pareto analysis. The applied technique significantly improved the productivity as discussed.

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