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# IMPROVEMENT OF QFD EFFECTIVENESS WITH BLEND OF VOICE OF CUSTOMER AND RED GREEN CHART ON COMPLEX MECHATRONICS PRODUCTS

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## ABSTRACT

Quality Function Deployment (QFD) is widely used in total quality control in an organization by giving more importance to the customer voice. The QFD is also an industrial engineering tool which is widely used to improve the product design and development in an organization. In practical, it is identified that the implementation of all Voices of customer in complex design products are impractical but it is possible for certain extend. So, this paper aims in blending the Voice of customer with a novel concept of Red Green Chart (RGC) concept to build the House of Quality to improve the effectiveness of the selection of the components in the area of fundamental design changes. Overall, Quality Function Deployment (QFD) concept is applied to predict the appropriate technical requirements in each stage of product development and production. A case study is taken to carry out the proposed technique and comparison analysis is also done with traditional QFD method.

**KEYWORDS:** QFD, RGC, Voice of Customer, Affinity Diagram, House of Quality.

## 1.0 INTRODUCTION

Yoji Akao (1966), the founder of Quality Function Deployment (QFD) stated that "QFD is a method for developing a design quality aimed at satisfying the consumer and then translating the consumer's demand into design targets and major quality assurance points to be used

throughout the production phase". QFD is used for predicting and ensuring the customer requirements and translate it for the improvement of product quality. Nowadays, manufacturing and service industries are subjected to focus more on increased competitive pressures and rising customer expectations. So, it is important to incorporate the customer expectations in products and also processes to improve quality at all levels. Strictly speaking, it is not possible to implement all kind of customer expectations in the products and processes due to different constraints, limitations, rules etc which is followed by the particular industry which is practicing QFD concept (ReVelle et al.,1995). So, Building House of quality from voice of customer without feasibility study in product and processes is not fully valid in the implementation of traditional QFD. It is important to find the feasibility study and also the validation of the customer expectation in the design modification of the complex products which poses more expenses in the fundamental design changes. So, the aim of this paper is to find a new concept for the implementation of the voice of customer in the design changes of the complex product with the help of Red Green Chart.

## 2.0 LITERATURE REVIEW

Kaulio (1998) defined as "QFD is a method for bringing Voice of customer into the development process and is being described as technique to generate that customer needs drive the product design and manufacturing process". According to Kaulio (1998) statement, the product design is based on only voice of customer without considering the feasibility in manufacturing process. This paper published more than a decade ago which considered only the traditional concept of QFD and have not implemented any modern concept or interdisciplinary concept of quality management.

In achieving maximum overall customer satisfaction, Fung et al., (2003) proposed a mathematical model for operational QFD planning, considering the technical and resource constraints. The impact of the correlation among Technical attributes was considered and solved by a heuristics-combined Simplex Method.

Bove et al. (2005) represented the importance on reviewing and trusting the voice of the customer in the improvement of product design. He has found that the fake information from the customer may lead to wrong concept or technology which may spoil the company's reputation. So, he has insisted the importance of service manager role in the collection of voice of customer in his paper. But, this paper says clearly that the voice of customer should not be taken without validation of their opinion.

With the growing demands from the customer, the manufacturing companies are posed with increased pressures to satisfy them. Luo et al., (2008) proposed an optimization method for components selection, based on QFD to minimize the difference between the customer's expectation and the selected product. The mapping relations among the customer requirements, technical attributes, and component attributes are developed by matrices of house of quality (HoQ), and showed that the optimal solution corresponds reasonably with the customer requirements. This paper deviates from traditional concept of QFD and insist that the technical attributes and component attributes are also playing a vital role in the product development.

Manikandan et al.,(2009) applied the quality Matrix for an economic sampling plan design in which customer requirements are identified based on economic perspective. This paper implicitly indicates the evidence to consider the economic factors according to the company's capital budget allocation.

According to Sharma and Rawani (2009), QFD is playing a vibrant role in product development which has to be fast in order to incorporate the latest trends in the product using consumer demands. They added that QFD allows a virtual design before building the product. So, it is needed to concentrate feasibility of the product design modification in research. It is believed that the proposed tool Red Green Chart could be the right choice to find the possible design modification according to the customer's need.

Rahanjo et al., (2010) extended the QFD technique into DQFD (Dynamic Quality Function Deployment) in which they dealt the customer needs dynamic, in terms of their relative weights, in the QFD. The dynamic QFD takes into account the change over time with the traditional QFD. This paper clearly indicates that there is a need of change in the traditional QFD, based on time variable.

Based on vast literature review, it is found that the VOC is an important tool in the quality improvement, but there should be a validation tool before it is going to implement in real time environment. So, the proposed concept of VOC blend with of Red Green Chart (RGC) will improve the implementation of VOC in an effective way in the consideration of fundamental design changes of the products particularly complex in nature.

## 3.0 PROBLEM BACKGROUND

For the wellbeing, day by day the customer demands keep increasing with the technology. This poses a challenge to the companies to satisfy the need within a short span of time to compete in the market. So it necessitates identifying the demands of the customer and use of various modern techniques for solution in appropriate design of product to satisfy the customer. There are lots of restrictions posed from the manufacturing companies to meet all the demands of customer. So manufacturing companies mainly takes the most prioritized demands from the customer and produce components. Even though the customer voice gives positive results, sometimes, in the prioritization of customer demand may lead to wrong concept or technology or more investment or design fault which may spoil the company's reputation (Sharma and Rawani,2007). So, a right methodology or tool is required to solve the negative problem in the implementation of Total Quality Management.

## 4.0 PROPOSED METHODOLOGY

Quality function deployment is playing a vital role in Total Quality Management (TQM) for an industrial product. In QFD, there are many steps. Initially, the voice of customer will be collected about the product. After collection of voice of customer, affinity diagram will be used to arrange and organize a lot of language data. After arranging the factors, the House of Quality will be build based on importance of the attributes. The HoQ will give the ranking among the attributes in which the designer/manufacturer has to consider the required changes to improve the quality of the product based on higher ranking (Delgado and Aspinwall,2003)

Red Green Chart (RGC) is the new concept which will be collected from the emplotyees who have connected to the attributes which is given by the customer. There will be a chance of difficulty in implementing the attributes which is given by the customer. So, the opinion from the employees who is responsible for implementing the customer needs is collected prior to the building of House of Quality. To collect the opinion from employees , a new concept is proposed here is Red Green Chart. The RGC contains Reg, Green and Not applicable column for each attibutes. The various department in the industry is responsible to collect the opinion from its employees and required to include red/green signal to implement the attributes. It is required to give the explanation for red light.The proposed methodology is shown in the Figure 1. In the proposed concept, the traditional QFD methodology deviates after implementation of affinity diagram. The attributes are categorized based on VOC in the affinity diagram as in traditional QFD. The major design attributes are given to various

departments in order to find the feasibility of the design changes. In this view, the Red Green chart is required to collect from each and every department to find the feasibility of the product design change and also to find the practicability of the implementation of the changes.

The possible design attributes based on the outcome of the RGC is fed to build the house of quality to find the ranking of the overall design attributes which will be given to the top management for approval process.

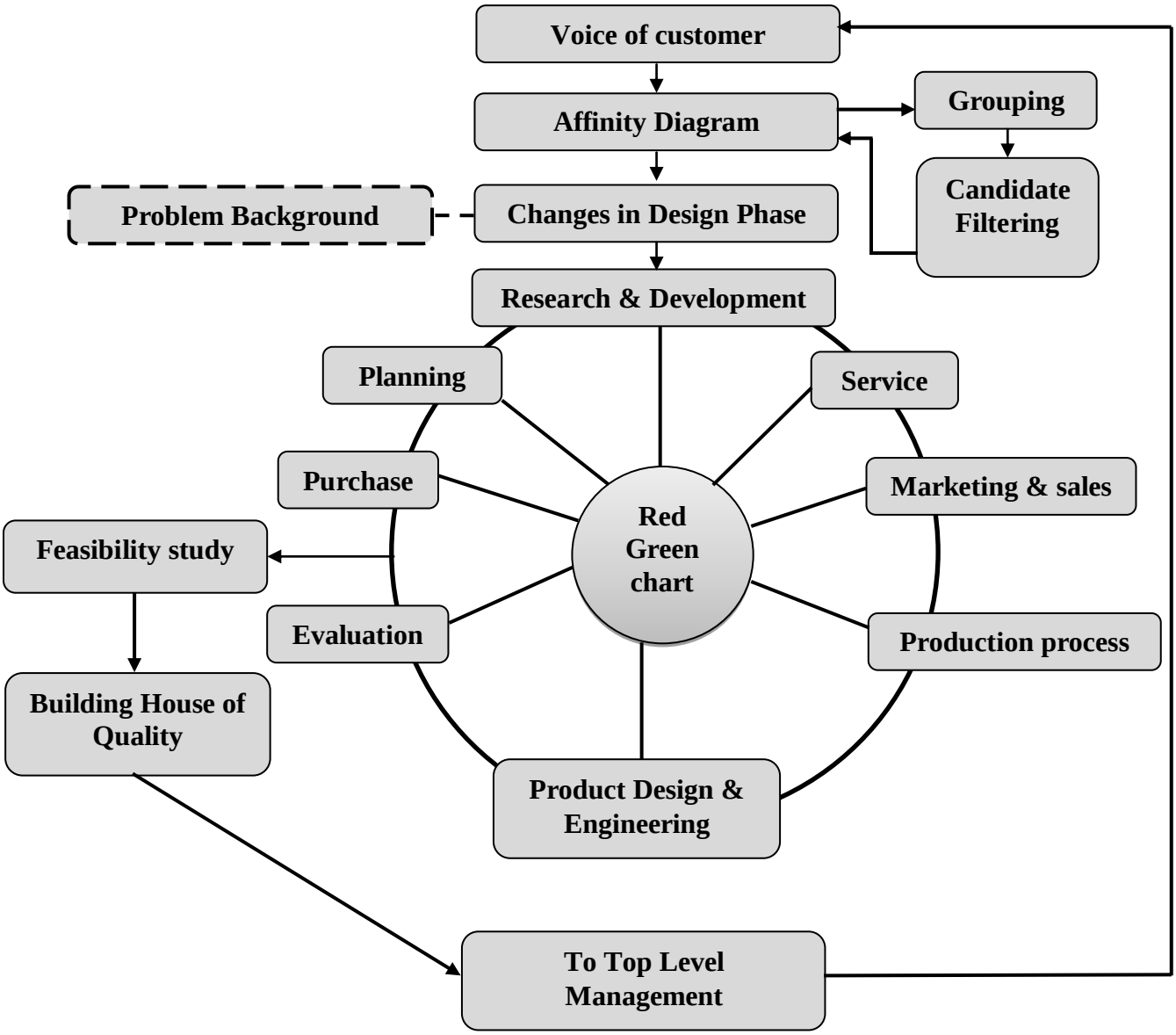


**Figure 1: The blend of QFD and Red Green concept.**

## 5.0 Application of Proposed methodology in Mechatronics Products

In modern digital factories, software based Mechatronics systems are widely used to automate various processes. The advances in microchip and computer technology are playing vital role in manufacturing products and processes. Cyber technology in automation systems is changing the existing manufacturing systems. However, the implementation of the mechatronics technique in a system or product is more complex, time consuming and also it involves more cost. So, a detail research work is required before it can be fully explored as how to take advantage of the new technology and transform it to the products or processes. A modern electro mechanical system consists of sophisticated software and hardware components to achieve the quality products and processes. This type of systems is called as software based Mechatronics systems. Bolton described the term mechatronics in his book in this way.

Mechatronics involves the bringing of a number of technologies: mechanical engineering, electronic engineering, electrical engineering, computer technology, and control engineering. This can be considered as the application of computer based digital control techniques, through electronic and electrical interfaces, to mechanical engineering problems." (Bolton, 2007).

Implementing QFD techniques in to the complex mechatronics systems are not easy because of its complex design. The proposed technique of blending QFD and Red Green Chart is one of the right ways to implement in a complex mechatronics system for continuous improvement of the product. To study the proposed technique, software based Electro pneumatic system used for low cost automation in four different industries are considered. The selection of circuit is based on the following conditions.

1. The electro pneumatic circuit is controlled by microcontrollers.
2. The electro pneumatic circuit uses minimum three cylinders in its operation.
3. The specified system controlled by the line pressure of 8 bar and 24 Volts for its solenoid.
4. The system is procured from the same supplier and being used.

### 5.1 Voice of Customer

"Voice of Customer" is a process of receiving the verbal and non-verbal need, features and expectations from the customer in the form of feedback in order to provide the best quality in product and service. This can be identified using surveys, interviews, discussions and questionnaires. This may be collected with the help of marketing executives, sales executive, service engineer, special groups etc. The customer provided data is used to identify the

quality attributes needed for a supplied component or material to be incorporated in the product or process for continuous improvement. The initial step is to identify the right customer involved in the application of the product or process. Then, it is needed to record the customer's own word to create the list of customer requirement.

To categorize Affinity diagramming is a useful tool to assist this effort.

**Table 1: Voice of customer for an Electro pneumatic system with Microcontroller.**

| | |
|---|---|
| 1 | No flexibility of changing the program in microcontroller (d) |
| 2 | The cycle time is fixed and could not be altered (o) |
| 3 | Positioning accuracy and repeatability (o) |
| 4 | Noise during operation of the system(m) |
| 5 | Implications of interfacing between microcontroller and solenoid(d) |
| 6 | Life of the system components (d) |
| 7 | Malfunction during pressure fluctuation (f) |
| 8 | Fault in operation during voltage fluctuation(f) |
| 9 | Reliability issues (m) |
| 10 | Leakage through connectors (d) |
| 11 | Cost involvement during the installation / operation (o) |
| 12 | Delay in procuring the spares (m) |
| 13 | Need for technical knowledge to operate/maintain the system (o) |
| 14 | Implementation of sensor to control strokes |
| 15 | Fail safe/stand-by mechanism (d) |

### 5.2 Affinity Diagram

Affinity diagram is a tool used in QFD technique to arrange and organize all verbal and nonverbal data received from the customer. The arrangement will be made under logical categories based on user perceived relationships and conceptual frame working to organize and present large amounts of data (ideas, issues, solutions, problems). So, the important and valid points in customer requirement record is refined, sorted and constructed as affinity diagram. The affinity diagram for the specified case study of software based electro pneumatic system is shown in the Figure:

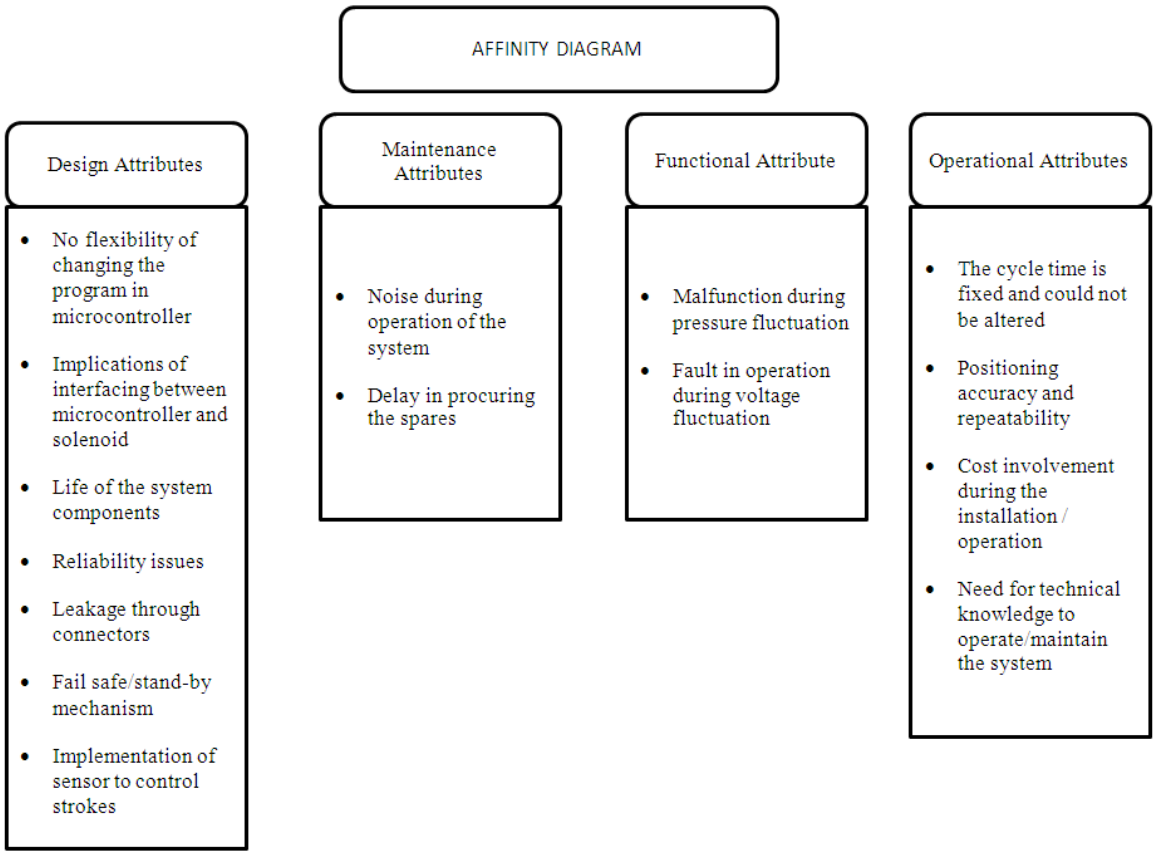


**Figure 2: Affinity Diagram for an Electro pneumatic system with Microcontroller.**

### 5.3 Red Green chart

This is the concept which devistes from traditional approach of QFD. After completion of affinity diagramnormally, we used to progress with kano model and then House of Qulaity. In this stage, there is no confirmation or opinion received from the people who are responsible to do the changes in product based on VoC. So, the Red Green Chart is used to collect the employees opinion who are directly connected with the product development. Aginst the indetified attributes from VOC, different department will give Red/ Green signal for the possibility of implementation in their department. If the particular attribute is not related to the department , they will give yello signals which means “Not Applicable” (NA). To facilitate this, there are column under each department/section (Red, Green & NA).

Against the collection of Red or Green signal, total number of acceptance is quantified based on Green signal from each department. Attributes which have got more than 60% acceptance will be eligible for further process. The red green chart for the electro pneumatic system with microcontroller obtained from five different departments and the attributes which are accepted for the further process of QFD is shown in Figure 3.

| S. No. | Attributes | R& D Department | | | Manufacturing Department | | | Quality Assurance Department | | | Marketing department | | | Sales and Service Department | | | Total No. of acceptance signal | The possible attributed for further process of QFD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Green | Red | NA | Green | Red | NA | Green | Red | NA | Green | Red | NA | Green | Red | NA | | |
| **1** | No flexibility of changing the program in microcontroller (d) | ● | | | | | ● | ● | | | ● | | | ● | | | 4 | YES |
| **2** | Implications of interfacing between microcontroller and solenoid | ● | | | ● | | | | ● | | ● | | | | ● | | 3 | YES |
| **3** | Life of the system components (d) | | ● | | | ● | | | | | | | ● | | | ● | Nil | NO |
| **4** | Reliability issues (m) | | ● | | | ● | | ● | | | ● | | | | ● | | 2 | NO |
| **5** | hrough connectors (d) | ● | | | ● | | | ● | | | ● | | | ● | | | 5 | YES |
| **6** | Fail safe/stand-by mechanism (d) | ● | | | | ● | | | | ● | | ● | | | ● | | 1 | NO |
| **7** | Implementation of sensor to control strokes | | ● | | ● | | | | ● | | | | ● | ● | | | 2 | NO |
| **8** | Noise during operation of the system(m) | | ● | | ● | | | | ● | | | | ● | ● | | | 2 | NO |
| **9** | Delay in procuring the spares (m) | | | ● | ● | | | ● | | | ● | | | ● | | | 4 | YES |
| **10** | Malfunction during pressure fluctuation (f) | | ● | | | ● | | | ● | | | | ● | | ● | | Nil | NO |
| **11** | Fault in operation during voltage fluctuation(f) | ● | | | ● | | | ● | | | ● | | | ● | | | 5 | YES |
| **12** | The cycle time is fixed and could not be altered (o) | ● | | | | ● | | ● | | | ● | | | | ● | | 3 | YES |
| **13** | Positioning accuracy and repeatability (o) | ● | | | | ● | | ● | | | ● | | | | ● | | 3 | YES |
| **14** | Cost involvement during the installation / operation (o) | | ● | | | ● | | | ● | | | ● | | | ● | | Nil | NO |
| **15** | Need for technical knowledge to operate/maintain the system (o) | ● | | | ● | | | ● | | | ● | | | ● | | | 5 | YES |

**Figure 3: Red Green chart for an Electro pneumatic system with Microcontroller.**

The attributes from VOC is filtered and organized according to the red green chart given in the table. The currently rejected attributes are provided to the management attention for further research and future development. The accepted attributes are based on the current resources available in the company. So, the following attributes are going to be considered for further process of QFD.

**Table 2: Filtered Voice of customer using RGC Concept.**

| S. No. | Attributes |
|---|---|
| **1** | No flexibility of changing the program in microcontroller (d) |
| **2** | Implications of interfacing between microcontroller and solenoid |
| **3** | Leakage through connectors (d) |
| **4** | Delay in procuring the spares (m) |
| **5** | Fault in operation during voltage fluctuation(f) |
| **6** | The cycle time is fixed and could not be altered (o) |
| **7** | Positioning accuracy and repeatability (o) |
| **8** | Need for technical knowledge to operate/maintain the system (o) |

The eight attributes which are given in table 8 are the possible attributes to consider for the modification of product/ process. This is not based on the facilities which will be adoted by the company in future. It is based on the company's present facilities. The rejected attributes are having possibility to consider in future if management is ready to invest or when it is improving company's infrastructure.

### 5.4 House of Quality

The House of Quality Matrix is the most recognized and widely used form of this QFD method. It translates customer requirements, based on marketing research and benchmarking data, into an appropriate number of engineering targets to be met by a new product design (Govers,1996). The House of Quality is the first matrix in a four-phase QFD process. Four phases are: product planning, parts deployment, process planning and production planning. It's called the House of Quality because of the correlation matrix that is roof shaped and sits on top of the main body of the matrix. The correlation matrix evaluates how the defined product specifications optimize or sub-optimize each other. The attribute quantification is done by building the House of Quality. The quantification is done according to the relationship between the requirements and also the correlation between the requirements. The quantification is done using the 10 point scale in this process.

In building house of quality, the relationship between the quality attributes and components are classified into three categories. They are i) strong (H) ii) medium(M) iii) weak (L) and the

score value allotted based on the strength of H,M,L is 9, 3, 1 respectively. Then, the target direction is taken according to the components information requirements with regards to ERP software. This is classified in this research as more is better, less is better and specific amount. Then the correlation between the components (interaction of the software components) are considered in terms of strong +ve , +ve , -ve and strong - ve. The most demanded quality attributes are considered and allotted the weight value according to the customer opinion. Here, functionality, reliability, usability, maintenance and portability factors are considered and the weight value of 5,5,3,3,3 have been allotted respectively.

According to this information about software based electro mechanical system components, everything are analyzed and then, it is build the house of quality to identify the most important component and quality attributes and to find the importance in building the software. The house of quality result for system is shown in Figure 6.

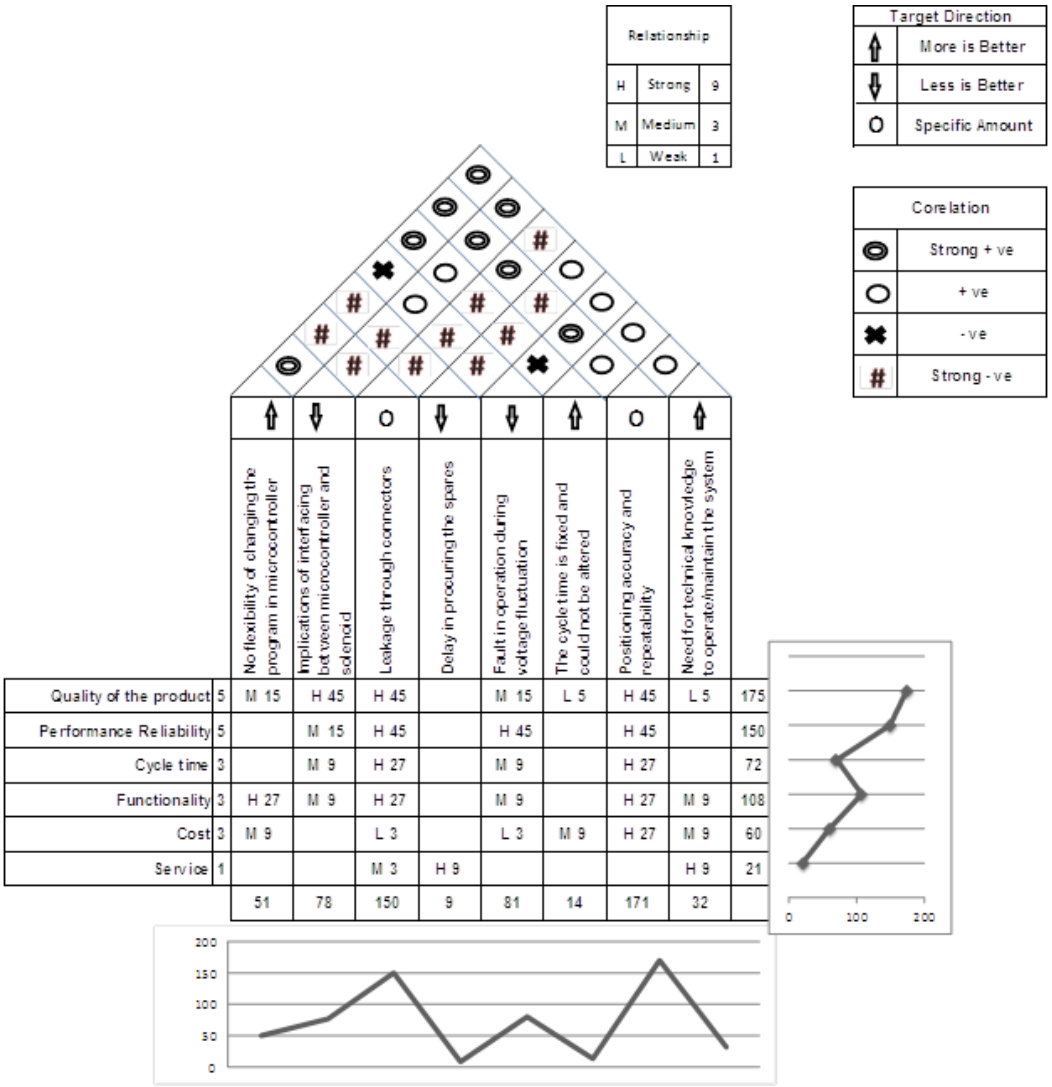


**Figure 4: House of Quality.**

**6.0 Comparison of the proposed Algorithm with Traditional QFD**

The RGC gives deviation from the traditional QFD. The implementation of the concept of RGC will give more advantages than traditional QFD technique. Some of the important advantages are as follows:

1. As it is reducing the number of attributed based on the RGC, the complexity involved in building HoQ is largely reduced.
2. During RGC process, Acceptance from the concern departments are collected. So, there is no possibility of further rejection in improvement of product.
3. Each attributes are deeply analysed in the respective department. So, the elimination of unwanted demands from the customer is done at the earlier stage itself.
4. The implementation of new Concept will reduce the workload or time spent by the quality department experts.
5. Total time required to build HoQ will be drastically reduced.
6. Without affecting the improvement of the product (or) eliminating the importance of Voice of Customer.
7. The RGC will provide path to every department in the company to understand the current facilities , optimal usage of resources and possible improvement in the existing product.
8. This will provide to bring enhanced product within short period of time.

According to traditional theory the total number of attributes is fifteen as per the voice of customer in the given case study. As per the new approach it is reduced to eight attributes. So the analysis of the target direction is also reduced from fifteen to eight, which shows clearly that the complexity of having more number of attributes is reduced. According to the traditional QFD, the number of correlation analysis will be calculate using the formula:

$$\frac{n*(n+1)}{2} \quad where\ n\ is\ the\ number\ of\ attributes - 1$$

$$14 + 13 + 12 + 11 + 10 + \cdots + 1 = \frac{n*(n+1)}{2} = \frac{14*(14+1)}{2} = 105$$

So the number of correlation analysis is 105.

Based on proposed theory, the number of correlation analysis will be calculated as follows.

$$7 + 6 + 5 + 4 + 3 + 2 + 1 = \frac{n*(n+1)}{2} = \frac{7*(7+1)}{2} = 28$$

This shows that the time required to analyze the relationship between the attributes are remarkably reduced because of the required quantity of finding correlation between the factors are 28.

The relationship analysis between the product requirement and the attributes are also reduced as per the new approach.

## 7.0 CONCLUSION

The proposed approach is a new method in which there will scope to reduce the complexity of QFD without affecting the objective of the problem. It is believed that Red/Green chart will play a vital role in building HoQ before going to propose the design of concept modification in a product. The present approach is applied in micro controller based electro-pneumatic system and found that the complexity and time to implement QFD is reduced positively compared to the traditional approach. Particularly the new approach is very useful in finding the relationship between the various factors. The Red/Green Chart is collected from the concern departments who are responsible for the design / concept modification. This will avoid future ambiguity or rejection of proposed modification with the available facility inside the factory. This approach can be used for any industrial application where ever traditional QFD is possible to implement to enhance the quality of the product.

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## BIOGRAPHY

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