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Application of Quality Function Deployment in Developing an Air-Conditioning Unit

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Abstract:- In today's competitive market, companies continually need to keep themselves updated with the changing demand of the customer. The customer now has a wide variety of products at competitive prices to choose from. In order to survive in this stringent competition, it is very important to monitor the requirements of the consumer. This is where Quality Function Deployment plays an earnest and unfathomable role. Quality Function Deployment (QFD) is a veracious process, which helps to determine product development characteristics, which includes technical requirements based on customer preferences. With the use of integrated matrix called House of Quality, the process considers the various influences acting during the design to promote concurrent engineering, leading to aggrandize product acceptance. It is a planning tool used to fulfill customer expectations including important quality assurance points, which would be used until the production stage. This paper gives a systematic method to generate House of Quality with an example of an air conditioner.

Application of this tool not only saves time and efforts to manufacture a new air conditioner, but also reduces risks related to the launch of a new product in the market because of increasing competitiveness with other existing brands.

Keywords:- *House of Quality, Voice of Customer, Weighted Approach, Technical Characteristics, Correlation Matrix, Importance Ratings.*

I. INTRODUCTION

A customer's alacrity is for a reliable, capable and appeasing product, which performs without any difficulties. The Product Development and design transforms the customer expectations into particular engineering and quality characteristics. These characteristics can be efficiently fulfilled by the Total Quality Management (TQM) tools namely Quality Function Deployment, Concurrent Engineering, etc.

Quality Function Deployment also known as Matrix Product Planning, Decision Matrices and Customer Driver Engineering, is a focused tool for carefully understanding the voice of customers and then effectively condone the changes required according to the needs. Every organization has customers (internal/ external/ many times both). When working on either satisfying the needs and/or just delighting the customers, Quality Function Deployment is an eminent tool. It was first developed in Japan in the late 1960s as a kind of Cause-and-effect analysis, and then it was brought to the United States of America in the early 1980s. It obtained its immense popularity as a result of numerous successes in automotive field. The flow-down process of quality function deployment requires building of House of Quality. Quality Function Deployment is composed of four steps:

- Completing the House of Quality.
- Product design (understanding the tolerance of each sub-part of a product in order to satisfy the customer needs)
- Process design (understanding the required production process)
- Process control (determination of quality standards)

Many companies consider that Quality Function Deployment is focused only on the first stage. However, all stages are equally important for beneficial product development. Quality Function Deployment is most essential when used in product development activities such as Planning, Evaluation and Deployment.

Planning: The basic requirement of product planning is to have a precise definition of the customer domain. The main objective is not only to create performance parameters, but to enable the building of stratagem for approaching and understanding customer needs. The critical parameters thus considered, then form the content for measurements of design.

Evaluation: For the provided product solution to get accepted, it must be carried through basic functionality such as industry touchstones. The evaluation process includes a detail of the expected technical needs for the upcoming product.

Organizations are required to carefully consider the effect of this process, as if long duration is required for collecting and implementing Voice of Customer then it might happen that these needs had already altered.

Deployment: During this process, the company must determine which components are included in delivering various targets and up to what percent they are involved in required targets.

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II. IMPORTANCE OF HOUSE OF QUALITY

The House of Quality is the initial matrix in the four phase Quality Function Deployment process. It's named as the House of Quality because of the correlation matrix being roof-shaped is placed on the head of the main body of the matrix structure. The correlation matrix is used to understand in what ways the defined product parameters optimize or sub-optimize each other. House of Quality is the most prospective and simple tool used to transform customer needs into technical attributes. House of quality is also known as Quality Matrix. It renders us with details like customer requirements, technical points, relationship between the descriptors and target values for each of those. The skeleton of House of quality is as follows.

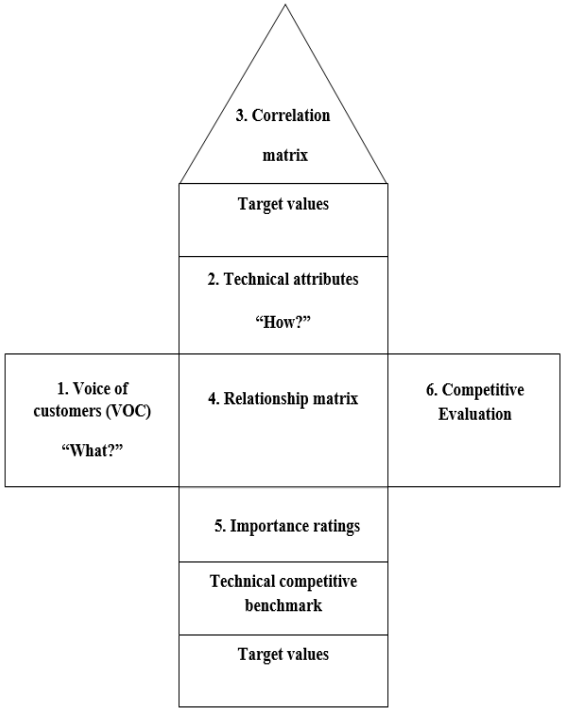

Fig 1:- Skeleton of House of Quality

The ceiling of the house provides various technical attributes. They are provided with various engineering constraints in design, necessities and various parameters. The roof of the house shows the inter-relationship between various technical parameters. On the left side, the list of customer needs is provided and on right side, prioritized customer requirements are mentioned showing the importance of needs. The interior of the house shows the inter-relation between the voice of customers and technical parameters. The cornerstone of the house reflects the prioritized technical views.

The focus in House of Quality is the correlation listed customer needs, called the 'Whats', and the engineering parameters, called the 'Hows'. It is kind of map which provides required for communication and planning. All departments need to work all together to prepare House of Quality. So, the Quality Function Deployment team involves the marketing, design and manufacturing departments all working as one whole team.

Advantages of House of Quality:

- Decreases the amount of time required for the planning stage.
- Values all kind of customer needs.
- Decreases the changes in design.
- Improves the product quality.
- Reduces costs relating to manufacturing and design.
- Prioritizes customer satisfaction.

III. STEPS INVOLVED IN BUILDING OF HOUSE OF QUALITY

For the design of Split Air Conditioner with 1 TR Capacity, following steps needs to be considered.

A. Capturing customer wants/needs (what are consumer desires?)

The first step in the process for building a House of Quality is to obtain the customer requirements from market. Based on the narratives of the customers, a survey (questionnaire) was prepared with the gathered information. The questionnaire required the target audience to rate the parameter on a scale of 1 to 5 (very unlikely to very likely). An example is shown below in Figure 2. The priorities (responses) in terms of weights were obtained from 1 to 5 (where, 1 states customer's without any need and 5 states customer with high needs) from the aforementioned survey using weighted approach. The target audience was selected randomly and involved 27 responses. Additional needs were also recorded via feedback and Voice of Customers not included in initial survey were added with a weight of 3. This turns out to be the left side wall or the Y – axis of the House of Quality structure.

For example, for after sales service, the scales tipped on the upper side depicting that a large portion of the target audience were very likely to consider after sales service as an important factor when purchasing a new air conditioner. 22 samples out of 27 (Figure 3) gave after sales service a rating of 5. This data was then put in the formula for weighted approach shown below to obtain the respective weight of the Voice of Customer. All the weights were calculated in a similar manner and they are listed below in Table 1

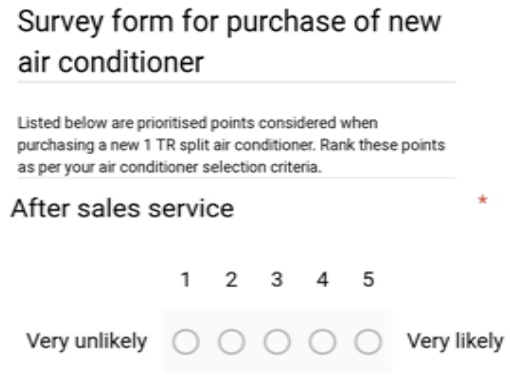

Fig 2:- Survey Sample Questionnaire for After Sales Service

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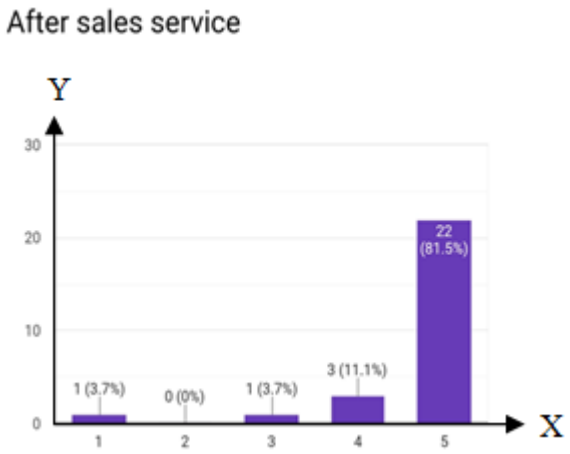

Fig 3:- Recorded Customer Responses

Where, X- axis = Importance rating,
Y-axis = Number of customers surveyed.

Weighted approach = (A + B + C + D + E)/No of Responses
= (1(1) + 2(0) + 3(1) + 4(3) + 5(22))/27
= 4.66 = 5

Where,
A=Number of customers who gave after sales service a rating of 1,
B =Number of customers who gave after sales service a rating of 2,
C = Number of customers who gave after sales service a rating of 3,
D = Number of customers who gave after sales service a rating of 4,
E = Number of customers who gave after sales service a rating of 5.

Sr No	"What" customer needs? / Voice of customers (VOC)	Weight
1	Cooling time	4
2	Warranty/ reliability	5
3	Star rating	4
4	After sales service	5
5	Aesthetics	3
6	Brand	4
7	Price range/cost (25000 to 40000rs)	4
8	Noiseless operation	3
9	Durability	5
10	Leakage tendency and condensate dripping	3

Table 1:- Recording Voice of Customers

To build a House of Quality, ruminating into these main features is essential,

- Cooling time implies how soon the air conditioner can achieve the set temperature.
- Warranty is usually a manifestation of the satisfaction and it gives the customer a sense of assurance.
- Star rating is a depiction of how efficiently an appliance can function. A 5-star rating in the scale implies lower energy consumption. It is calculated on the basis of Energy Efficiency Ratio (EER) which is simply the ratio of cooling effect produced (in watts) to the electrical energy.
- After Sales Service is not a factor considered in the design phase. It is a gesture to ensure customer satisfaction.
- Aesthetics includes the looks, shape, size, weight and color options available for the air conditioner.
- Brand value is a long-term process, which is a by-product of prolonged consumer satisfaction in the market. It is an indirect return for maintaining desired quality levels over a period. Brand value signifies the trust-worthiness of a Brand in the market.
- Price range implies the budget of the target consumer.
- The major contributor for development of noise is the compressor. Noiseless operation may play an important role in commercial surrounding.
- Durability implies that the components perform their intended function without failure, damage over a period of time.
- Leakage/ dripping includes refrigerant leakage from the refrigerant lines as well as condensate dripping.

B. Developing Technical Portion of the Matrix

After creating the Voice of Customer's section of the matrix, the next section is evaluated by asking "How will the product respond to Consumer wants/needs?" This includes set of parameters which when optimized, will lead to complete customer satisfaction. These parameters are to be decided by the surveyors and planning team with the

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help of the technical team. The techniques used here may include quality circle, brainstorming etc. The selected technical characteristics are depicted in Table 2. As shown in the Table 1, the Voice of Customers (VOC) are denoted using numbers.

The Voice of Customers are given their respective numberings from table 1. i.e. cooling time is numbered one, warranty/ reliability is numbered two and so on. The Table 2 depicts the relationship between the technical parameters and the Voice of Customers. For example, Air circulation is a technical attribute which has a strong correlation with Voice of Customers like cooling time (1) and noiseless operation(8). All such relationships are listed in Table 2. On the other hand, Autonomous Operation doesn't manifest a strong correlation but is an important attribute nevertheless (refer Table 3).

Technical Characteristics	Voice of Customer (Customer Wants)
Air Circulation	1,8
Air Temperature	1
Moisture control	1,10
Compressor type	1,2,9
Type of refrigerant	1,8
Noise and vibration	1,8
Amount of energy consumption	1,3
Extra features	7
Autonomous operation	-

Table 2:- Voice of Customers Transformed into Technical Attributes

C. Identifying Inter-relationship between the Technical Attributes

The next step in building a House of Quality is to identify the inter-relationship between the technical attributes. This step forms the triangular roof of the House and is also called as Correlation Matrix. When designing a new split air conditioner, an increase in Technical Characteristic A may bring about a change in Technical Characteristic B. The goal of this step is to identify such correlations and meter them accurately. For simplicity, we incorporate the following symbols in our house of quality,

- "+" = Positive (Strong) Correlation
- " " = No Correlation
- "–" = Negative Correlation

For example, the melting and boiling point of a refrigerant limit the temperature of air achievable inside the room and thus refrigerant type is directly related with air temperature. All such positive relationships are identified with the symbol "+". Similarly, an increase in air circulation results in reduction in air temperature due to increased convection. All such negative relationships are identified with the symbol "–". Technical Characteristics with no relationship (mutually exclusive) between them are left blank in the roof of House of Quality. This is shown in Figure 4.

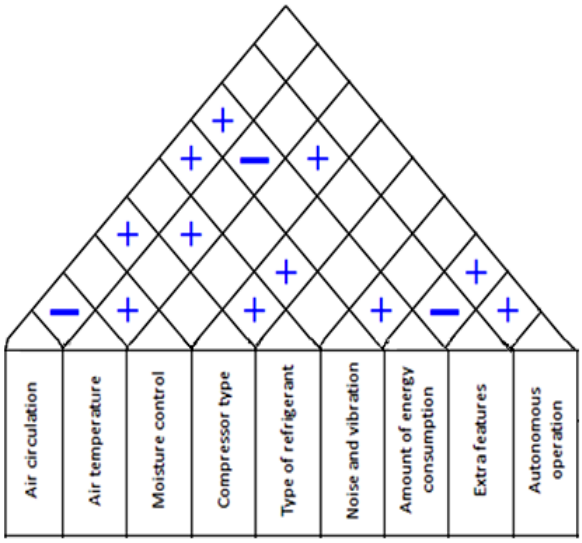

Fig 4:- Correlation Matrix

D. Developing Relationship Matrix

In this particular step, the relationship between the Voice of Customers and technical attributes is identified. Each Voice of Customer is referenced with every technical characteristic to discover how the specific technical characteristic is identified with the particular Voice of Customer. A Worth of nine is allocated for very solid connection between Voice of Customer and technical characteristic and worth of three and one is allotted for solid and weak relationship respectively. For instance, the Voice of Customer, "Cooling time" has "Exceptionally Solid" association with technical characteristics like "Air circulation", "Air temperature" and so forth. So in relationship grid, the estimation of "9' is appointed. For technical characteristic "compressor type" and Voice of Customer "star rating" an estimation of "3" is allocated, which depicts "Strong Relationship". For technical characteristic, "extra features" and Voice of Customer "warranty/reliability" estimation of "1" is allocated, which is for "Weak Relationship". Similarly, for each technical characteristic, relationship is found with each Voice of Customer and their respective grading is depicted in table 3 shown below.

0 implies No relationship
1 implies Weak relationship
3 implies Moderate relationship
9 implies Strong relationship

Sr No	"What" customer needs? / Voice of customers (VOC)	Weight	Air circulation	Air temperature	Moisture control	Compressor type	Type of refrigerant	Noise and vibration	Amount of energy consumption	Extra features	Autonomous operation
	"How" to satisfy customer? / Technical attributes →										
1	Cooling time	4	9	9	9	9	9	9	9	0	1
2	Warranty/ reliability	5	1	1	0	9	0	1	0	1	1
3	Star rating	4	3	3	0	3	0	1	9	3	3
4	After sales service	5	0	0	1	0	0	1	3	0	0
5	Aesthetics	3	9	9	0	0	0	0	0	0	0
6	Brand	4	0	0	0	0	0	0	0	3	1
7	Price range/cost	4	0	0	0	1	1	0	0	9	3
8	Noiseless operation	3	9	9	1	0	0	9	3	3	3
9	Durability	5	0	0	0	9	0	0	0	0	0
10	Leakage tendency and condensate dripping	3	3	3	9	1	3	1	0	0	0

Table 3:- Relationship Matrix

E. Developing Importance Ratings/ Raw Score

To ascertain the importance rating, importance rating, Weights for different Voice of Customers are multiplied by the respective grading with the technical characteristic created in step 4. Then the summation of these calculated values is done for the whole segment to acquire the raw score for that column.

For example, the customer desires aesthetics which has an importance rating of 3 out of 5. Aesthetics has a strong relationship with air circulation with 9 points. So, for its importance rating we simply multiply 3 by 9. Similarly values of every column of technical characteristics is multiplied with weights of Voice of Customers and summation of the scores for each column is noted in the form of raw score/importance rating [i.e. for air circulation (9*4 + 5*1 + 4*3 + 3*9 + 3*9 + 3*3 = 116)].

Sr No	"What" customer needs? / Voice of customers (VOC)	Weight	Air circulation	Air temperature	Moisture control	Compressor type	Type of refrigerant	Noise and vibration	Amount of energy consumption	Extra features	Autonomous operation
	"How" to satisfy customer? / Technical attributes →										
1	Cooling time	4	9	9	9	9	9	9	9	0	1
2	Warranty/ reliability	5	1	1	0	9	0	1	0	1	1
3	Star rating	4	3	3	0	3	0	1	9	3	3
4	After sales service	5	0	0	1	0	0	1	3	0	0
5	Aesthetics	3	9	9	0	0	0	0	0	0	0
6	Brand	4	0	0	0	0	0	0	0	3	1
7	Price range/cost	4	0	0	0	1	1	0	0	9	3
8	Noiseless operation	3	9	9	1	0	0	9	3	3	3
9	Durability	5	0	0	0	9	0	0	0	0	0
10	Leakage tendency and condensate dripping	3	3	3	9	1	3	1	0	0	0
Raw score			116	53	71	154	49	80	96	74	46
Percentage importance			15.7	7.2	9.6	20.8	6.6	10.8	13	10	6.3

Table 4:- Developing Importance Ratings

F. Evaluate Competing Products and Determine Technical Attributes

Similar surveys can be circulated wherein customer grades competing brands for similar Voice of Customers as Good (G), Fair (F) or Poor (P) instead of Importance Ratings.

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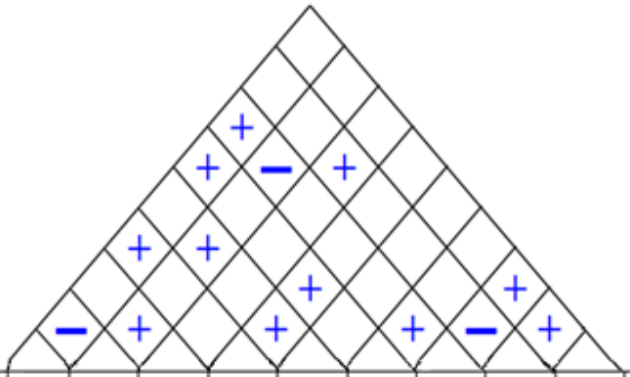
Now Voice of Customers with maximum weights can be targeted and specifications for the new product can be determined. For e.g. Warranty has a weight of 5. Both competing brands are graded as good in warranty. Thus, the new product also has to maintain similar or better levels of reliability



Sr No	"What" customer needs? / Voice of customers (VOC)	Weight	Air circulation	Air temperature	Moisture control	Compressor type	Type of refrigerant	Noise and vibration	Amount of energy consumption	Extra features	Autonomous operation	Competitive evaluation		
	"How" to satisfy customer? / Technical attributes →											Company A	Company B	Our product
1	Cooling time	4	9	9	9	9	9	9	9	0	1	G	G	
2	Warranty/ reliability	5	1	1	0	9	0	1	0	1	1	G	F	G
3	Star rating	4	3	3	0	3	0	1	9	3	3	G	G	
4	After sales service	5	0	0	1	0	0	1	3	0	0	F	F	F or G
5	Aesthetics	3	9	9	0	0	0	0	0	0	0	F	G	
6	Brand	4	0	0	0	0	0	0	0	3	1	G	F	
7	Price range/cost	4	0	0	0	1	1	0	0	9	3	P	G	
8	Noiseless operation	3	9	9	1	0	0	9	3	3	3	F	P	
9	Durability	5	0	0	0	9	0	0	0	0	0	F	F	F or G
10	Leakage tendency and condensate dripping	3	3	3	9	1	3	1	0	0	0	G	G	
Raw score			116	53	71	154	49	80	96	74	46			
Percentage importance			15.7	7.2	9.6	20.8	6.6	10.8	13	10	6.3			

Table 5:- Finalized House of Quality

IV. BENEFITS OF QUALITY FUNCTION DEPLOYMENT

➢ ***Customer Driven***
Focus on Customer Requirements
Prioritizes Resources
Identifies Items that can be acted on

➢ ***Reduces Implementation Time***
Decreases midstream design change
Limits post introduction problems
Identifies future application opportunities

➢ ***Promotes Teamwork***
Open communication
Identifies action on interfaces

➢ ***Provides Documentation***
Easy to understand
Provides framework for sensitive analysis.

V. CONCLUSION

Customer's requirements and their correlations with the design parameters are the tedious tasks of Quality Function Deployment (QFD) methodology. However, this tool gives manufacturers an option to effectively comprehend, what the expectations of the potential customers are, so that they can consolidate them in the planning and design phase. Products manufactured with this technique will be esteemed by the clients. It enables the companies to build quality into the required product and also to control the development process. Quality Function Deployment has been successful in manufacturing and developing new products and a large number of companies in many industries are using Quality Function Deployment.
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