RESEARCH ARTICLE OPEN ACCESS

An Application of Green Quality Function Deployment to Designing an Air Conditioner

Peetam Kumar Dehariya*, Dr. Devendra Singh Verma**
Department of Mechanical Engineering, IET, DAVV, Indore (M.P.), India

ABSTRACT
The paper tackles a systematic and operational approach to Green Quality Function Deployment (GQFD), a customer oriented survey based quality management system with regular improvement in product development. GQFD shows balance between product development and environmental protection. GQFD is not used to determine their attributes and their levels. GQFD captures what product developers "think" would best satisfy customer needs considering Environmental factor. This research used Air Conditioner as a case study for implementation of GQFD. In the design of a new Air Conditioner, apply GQFD to find out the most important parameter and functions from customer point of view and then find out Technical Characteristics. These important parameters are then put into house of quality and make relation matrix between voice of customer and Technical Characteristics. From the result of QFD applied to Air Conditioner are short out the parameter which are require modification according to voice of customer and the result has used for new design.

Keywords **-** Green Quality Function Deployment (GQFD), House of Quality (HOQ), Technical Characteristics (TC's), Voice of Customer (VOC).

I. INTRODUCTION

The main aim of this research was to find the feasibility of product development with Green design as the main focus. Firstly, Quality Function Deployment (QFD) introduced in Japan by Yogi Akao in 1966 and used extensively by Toyota. QFD is "an overall concept that provides a means of translating customer requirements into the appropriate technical requirements for each stage of product development and production (marketing strategies, planning, product design and engineering, prototype evaluation, production process development, production, sales)" (Sullivan, 1986)[1]. Karlsson and Luttropp [2] pointed out that the main concern for eco-design is integration of environmental consideration into product development process that would imply how to create smart products or methods, effective system solutions and attractive designs. Zhnag et al. [3] described that increasingly stringent environmental regulations, growing costs for waste disposal, and increasing threats of product liability litigation have accentuated the importance of developing environmentally friendly products. The 'voice of customer' is the term to describe these stated and unstated customer needs or requirements. The VOC is captured in a variety of ways: direct discussions or interviews, surveys, focus groups, customer specification, observations, warranty data, field report etc. This understanding of the customer needs is then summarized in a product planning matrix or "house quality". These matrices are used to translate higher level "what's" or needs into lower level "how s" - product requirements or technical characteristics to satisfy these needs [4].

Environmental issues have been introduced in new product development especially from the 90's and QFD transformed into GQFD considering environmental factor. GQFD is a powerful tool for developing environmentally friendly products. In GQFD, put environmental requirements into product design and process development. In this research GQFD, first used to establish a relationship between the developer, customer and eco-product itself. GQFD was used to analyse products based on criteria that the customer value the most along with green design guidelines in product development [5]. Wong and Juniper (2002) [6] developed the Green Quality Function Deployment (GQFD). It relates environmental requirements and demanded quality to product specifications. Kato and Kimura (2003) [7] developed the environmental QFD to systematize environmental and technological issues. Quality demanded is divided into 3 types of requirements: user, social and companies. The last one is related to environmental requirements.

There are six basic elements of GQFD, which are:

1. Determining the Environmental Voice of Customer (WHAT's).
2. Meeting how the requirements can be achieved, Technical Characteristics (Hows).

3. Relationship between the WHAT's and HOW's they are to be met.
4. Target values for the requirements.
5. Relationships between how the requirements are to be met.
6. A quantification of the importance of the requirements.

II. METHODOLOGY

The basic Quality Function Deployment methodology involves four basic phases that occur over the course of the product development process. These four phases are Product Planning, Assembly/Part Deployment, Process Planning and last Process/Quality Control. During each phase one or more matrices are prepared to help plan and communicate critical product and process planning and design information. This QFD methodology flow is represented in the figure 1.
Once Environmental Voice of Customers are identified, preparation of the "House of Quality (HOQ)" begins. The sequence of preparing the HOQ is as follows:

1. The first step on the GQFD method is how to identify environmental voice of customer that would be called What's on the HOQ [8]. Customer requirements are stated on the left side of the matrix as shown below. Insure the customer needs or requirements reflect the desired market segment (s).

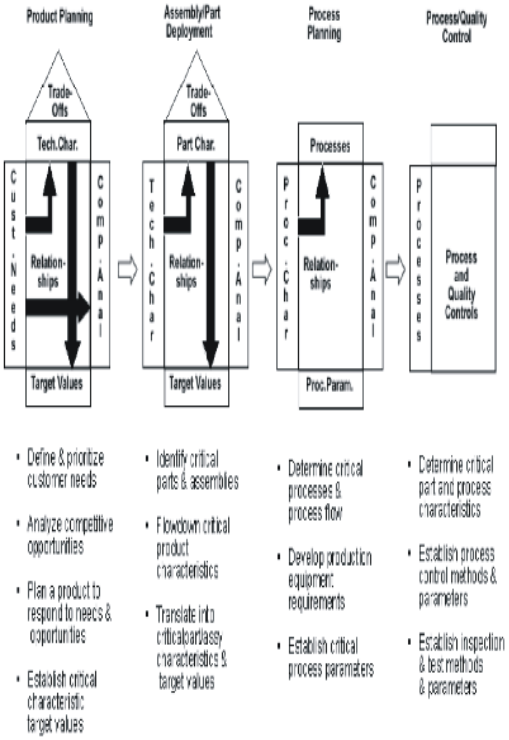

Fig 1: Four Phase QFD Methodology Flow Diagram
(Reference: https://encryptedtbn2.gstatic.com/images?q=tbn:ANd9GcSO0NO61Vp7e_C2qwhqJwhC-MfFb8f3NCck8iT2StKSVLhKc-oh)

If the number of needs or requirements exceeds twenty to thirty items, decompose the matrix into smaller modules or subsystems to reduce the number of requirements in a matrix. Draw a matrix form of interrelate between HOQ & considering different Environmental weight age factor such as less consumption energy, less emission, lighter weight, longer life span, recyclability, easy disassembly, better energy efficiency etc. with the planning matrix using experts, deep discussion, brain storming etc[9].

2. Technical responses identify the Technical Characteristics (TC). Going from user requirements to technical specifications involves translating from qualitative requirements to quantitative measurable characteristics [10]. Evaluate prior generation products against competitive products. Use surveys, focus groups/clinic or customer meetings to obtain feedback. Include competitor's customers to get a balanced perspective identify price points and market segments for products strategy.

3. Establish product requirements or TC to respond to VOC and organize into related categories. Characteristics should be stated in a way to avoid

implying a particular technical solution so as not to constrain designers.

4. Develop relationships between customer requirements and product requirements or technical characteristics.

5. Develop a technical evaluation of prior generation products and competitive products. Get access to competitive products to perform product or technical benchmarking. Perform this evaluation based on the defined product requirements or technical characteristics. Obtain other relevant data such as warranty or service repair occurrences and costs and consider this data in the technical evaluation.

6. Development preliminary target values for product requirements or technical characteristics.

7. Calculate importance ratings. Give a weighting factor to relationship symbols (9-3-1, 4-2-1, or 5-3-1). Multiply the customer importance rating by the weighting factor in each of box of the matrix and add the resulting products in each column.

8. The matrix and finalize the product development strategy and product plans. Determines required actions and areas of focus. Finalize relative weight. Are relative weights are properly set to reflect appropriate tradeoffs? Do target values need to be adjusted considering the difficulty rating? Are they reasonable with respect to importance ratings?

III. STRATEGY FOR GQFD OF AIR CONDITIONER

For design of Air Conditioner using GQFD, following steps are involved:

1. Survey planning and the implementation

The First step of this work is to get customer requirements from open market. There is no predetermination of what will be important to a customer. All narratives written by customer are analyzed and prevailing themes are identified. Based upon the frequency of the themes a formal attitude survey is design to collect the voice of customer data. Since there are so many feature of Air Conditioner to explore, the most frequently mentioned themes are good bases for forming the attitude questionnaire. The method of collecting information about the VOC and the VOE are through the questionnaire from the open market survey. The users are selected from open market. The questionnaire containing **23** questions in the form of VOC data collection and the **15** points has been selected. Sample size was taken **100**.

After the critical QFD method and machine quality improvement, feedback is used to modify the survey. Resurveying provides more information about dissatisfaction and other service problems as they emerge.

Three normally used medium capacity Air Conditioner for household purpose, with same Capacity are selected from following three manufacturing organization:

I. Samsung
II. LG
III. Hitachi

These three Air Conditioners are similar characteristics, target the similar focus group of customer and are well recognized in market.

2. Types of data

There are two types of data used to find the customer requirements and methods used to obtain it are as follows:

Primary data

Primary data collected from Email-based survey. Also some information came from listening to comments of customer at retail stores. When designing an Air Conditioner important thing are considered such as Price, Brand, Innovation, Quality, Value. From survey report top two most important things in designing an Air Conditioner, they are Price and Quality.

Secondary data

The secondary data used in analysis came from specialized magazines and research

journals.

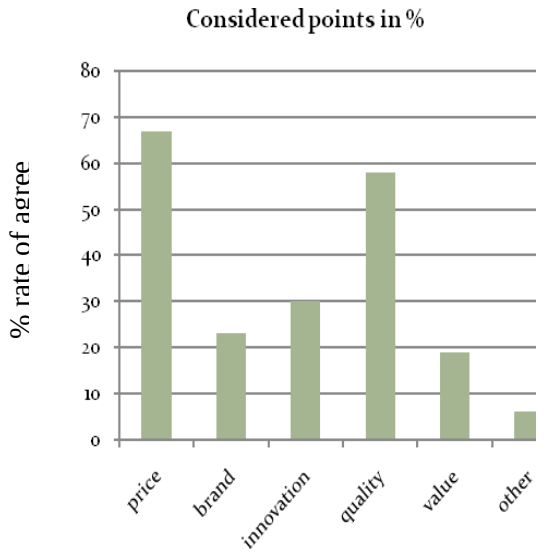

Figure 2: Considered points from survey report

IV. HOUSE OF QUALITY

After collecting and analyzing information, it was decided to take only analysis of final user because there was not enough information about the other customers.

The HOQ would be more useful if it could be based on real strategic marketing information. There is a series of priorities for the customer requirements that are based on their importance to be development team's requirements are ordered by priorities, seeing the focuses into nine priorities. These customer requirements in the form of WHAT's and HOW's are shown in the matrix of QFD house.

These priorities are as:

1. Less energy consumption
2. High durability
3. High performance
4. Cools quickly
5. Quiet
6. Operates safely
7. Operates easily
8. Easy to repair
9. Harmless to living environment

In this case the targets are easy to find because most of the superior levels of customer satisfaction can be achieved with no dramatic change in the product moreover, in the most of the cases only the change is possible in one specific way and not in other.

Masui et al. [11] proposed what kind of requirements and attributes should be considered from the environmental point of view through a whole product life cycle, and then integrated those environmental items into a set of feasible green VOC and TC, and their correlation factors. The environmental VOC and TC items are as follow:

Environmental VOC's (Adopted from Masui et al.)

- Less material usage
- Easy to transport and retain
- Easy to process and assemble
- Less energy consumption
- High durability
- Easy to reuse
- Easy to dissemble
- Easy to clean
- Easy to smash
- Easy to sort
- Safe to incinerate
- Safe to landfill
- Harmless to living environment
- Safe emission
- Possible to disposed at ease

Environmental TC's(Adopted from Masui et al.)

- The weight of product
- The volume of product
- Number of parts
- Number of types of materials
- Likelihood to get dirt
- Hardness
- Physical lifetime
- Amount of energy consumption
- Rate of recycled materials
- Mass of air pollutant
- Mass of water pollutant
- Mass of soil pollutant
- Biodegradability
- Toxicity

V. IMPORTANT GQFD PHASE

Table 1 shows the deployment of Environmental VOC to Technical Characteristics (TC's) (Phase I). VOC items in the table include the environmental VOC items such as "less material usage" as well as requirements items from customers such as "cools quickly" and "quiet." Usually VOC items are based on market survey to show the "Customer Weights." "9" shows that it is very important, "3" shows it is important, and "1" shows it is relatively important. The degree of importance of environmental VOC is dependent on the concept of developed product or the context of product life cycle. Further, they might be decided based on the result of LCA, which is the quantitative evaluation method,

Table 1 GQFD Phase 1 of an Air Conditioner

		Technical Characteristics																	
Green Quality Function Deployment Phase I Voice of Customer	customer weights	air circulation	air temerature	moisture removal	balance(torque)	weight	volume	numbers of parts	numbers of types of materials	likelihood to get dirt	hardness	physical lifetime	amount of energy consumption	rate of recycled materials	noise,vibration	mass of air pollutant	mass of water pollutant	mass of soil pollutant	toxicity of materials
cools quickly	9	9	9	9									9		9				
quiet	9	9		1									9		9				
operates safely	3	1	3	1	3					1	3	9			9				
operates easily	9				3										1				
reliable	3	1	1					3	3		9	9	1		1				
less material usage	1					9	9	1	3					9					
easy to transport & retain	1					9	9						3						
easy to process & assemble	3							9					9						
less energy consumption	9	9	9	9						3			9						
high durability	9				9					1	9	9							
high performance	9	9	9	9	9			1		1			9		3				
easy to maintain	3							1		3									
easy to repair	9							3											
easy to reuse	3									9		9		3					
easy to disassemble	3					1	1	9	9				3						
easy to clean	3						1	1		9			3						
easy to sort	1							9	9				3						
harmless to living environment	9	9	9						3		3				9	3	3		9
safe emissions	3					3	9									9	9	9	9
possible to dispose at ease	3					1	1		1					3		3	1	1	9
	raw score	411	336	255	198	31	54	115	78	111	144	162	378	27	309	63	57	30	135
	relative weight	0.14	0.12	0.09	0.07	0.01	0.02	0.04	0.03	0.04	0.05	0.06	0.13	0.01	0.11	0.02	0.02	0.01	0.05

applied to a similar product. On the other hand, TC's items include new items such as "amount of energy consumption" as well as traditional items such as "air circulation." At crossing points between VOC items and TC items are shown numbers indicating magnitude of both factors called "Relational Strength" determined by "Relative Weight" for each item is obtained by the Raw Score / Sum of the Raw Score. From table 1 shows that "air circulation", "air temperature" , "amount of energy consumption" and "noise & vibration" are relatively important as TC items to satisfy customer requirements such as "less energy consumption," "high durability," "high performance" and "harmless to living environment" as well as traditionally required quality items such as "cools quickly," "easy to repair" and "operates easily."

VI. CONCLUSION

In this paper apply GQFD to develop a design and development procedure for a product like an Air Conditioner. To determine the importance of various Air Conditioner parameter to users and then subsequently design both a lower cost alternative as well as a high performance model with GQFD technique. Customer requirements are recorded in the rows of HOQ matrix and the design characteristics are placed in the columns of matrix. Empty row in the relation matrix identify the unmet

customer expectation and empty columns identify the mechanisms that meet no customer need. From Phase I four most important parameters are consider to modification for improvement in design, these parameters are Air Circulation, air temperature, amount of energy consumption & noise and vibrations.

ACKNOWLEDGEMENT

This work was supported in part by the Institute of Engineering & Technology (IET), Devi Ahilya Vishwavidyalaya (DAVV), Indore, Madhya Pradesh, India.

REFERENCES

[1] Sullivan, L.P., "Quality Function Deployment, Quality Progress," 19 (6) 39-50.
[2] R. Karlsson and C. Luttropp, "EcoDesign: What's happening? An overview of the subject area of EcoDesign and of the papers in this special issue," *Journal of Cleaner Production*, vol. 14, no. 15-16, pp. 1291-1298, 2006.
[3] C Dong, C Zhang, B Wang, "integration of green quality function deployment and fuzzy multi-attribute utility theory-based Cost estimation for environmentally conscious product development," International Journal of Environmentally Conscious Design & Manufacturing, Vol. 11, No.1, 2003.
[4] A. S. Khangura and S. K. Gandhi, "Design and Development of the Refrigerator with Quality Function Deployment Concept," International Journal on Emerging Technologies 3(1) : 173-177, 2012.
[5] C. S. Wang, P. Y. Lin, T. R. Chang, "Green Quality Function Deployment and Modular Design Structure Matrix in Product Development," Proceedings of the 14th International Conference on Cooperative Work in Design, 2010.
[6] Wong K. ; Juniper J. "Quality Function Deployment (QFD) and the Environment," International Interdisciplinary Conference on the Environment,8 , 2002.
[7] Kato S.; Kimura F., "Systematization of Product Life Cycle Technology Utilizing the QFD method," International Symposium on Environmentally Conscious Design and Inverse Manufacturing, 3.,2003.
[8] P. Pusporini, Kazem Abhary, L. Luong, "Integrating Environmental Requirements into Quality Function Deployment for Designing Eco-Friendly Product ," International Journal of Materials, Mechanics and Manufacturing, Vol. 1, No. 1, February 2013.
[9] T. Sakao, "A QFD Centred Design Methodology for Environmentally Conscious Product Design," International Journal of Production Research, vol 45, No. 18-19, pp. 4143-4162, 2007
[10] A. Halog, F. Schultman, O. Rentz, "Using Quality Function Deployment for Technique Selection for Optimum Environmental Performance Improvement, " Journal of Cleaner Production 9 (2001) 387-394
[11] K. Masui et al., "Applying Quality Function Deployment to Environmentally Conscious Design," International Journal of Quality and Reliability Management, vol. 20, no.1, pp. 90-106, 2003.