

## APPLICATION OF QUALITY FUNCTION DEPLOYMENT FOR RECYCLING OF SLI BATTERIES IN REVERSE SUPPLY CHAIN

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**Abstract** Now a days remanufacturing / recycling has become renowned as a popular option in many reverse logistics settings. In remanufacturing / recycling, firms take back products at the end of their use, disassemble them to obtain components and reassemble these components into a “good as new” remanufactured product. Though the technical solutions for the recovery of products from waste materials become more and more available, it is often imperative to adopt the view point of an individual firm and ask whether it would be wise to engage in product recovery activities or not. In the context of rapidly changing perspectives in the field of reverse logistics, the solution of a great variety of engineering problems calls for innovative application of knowledge and requires logical thinking, analytical capability, reasoning and judgment. In this paper the environmental impact of recycled SLI (Starting, Lighting and Ignition) batteries are considered and used for the disposition of used SLI batteries with the help of reverse logistics. Based on an extensive literature review, it is proposed to use a methodology for applying Quality Function Deployment (QFD) for the development of a new reverse logistics network with the environmental analysis of used SLI batteries. This methodology will incorporate environmental aspects into QFD to handle the environmental and traditional product quality requirements simultaneously.

**Key words:** SLI batteries, Remanufacturing / Recycling, Reverse Logistics and QFD.

### 1. INTRODUCTION

Quality is simply another way of describing what the customer wants. If your product or service satisfies those wants better than the competitor's does, then you have achieved superior quality (Hochman and O'Connell, 2003). Quality is a relative term. The definition differs from consumer to another. Liberalization of economy, opening up the trade barriers, the gradual integration of local market into a global environment, the internationalization of engineering activities and global access to knowledge and information have all contributed to a growing appreciation of quality requirements and assurance in all industrial activities. To survive and remain competitive in global market, goods/services offered should not only be of high quality, but also be reliable, safe, energy-efficient, environment friendly and cost effective (Vinay, 2005). One Japanese design and development methodology that aids in this effort is quality function deployment (QFD). The QFD methodology provides a structured framework for concurrent engineering that ensures that the “voice of the customer” is incorporated into all phases of product development [Grovers, 1996]. A customer may not explicitly demand improvement in the environmental dimensions of the product, but may be concerned about the environmental impacts associated with the product and process outputs (Hochman and O'Connell, 2003).

Reverse logistics is the new frontier of management and includes the handling and disposition of returned products and information (Meyar, 1999). Reverse logistics is the process of moving goods from their typical final destination for the purpose of capturing

value or proper disposal (Rogers and Tibben-Lembke, 1999). Reverse logistics system incorporates a supply chain that has been redesigned to manage the flow of products (or) parts destined for remanufacturing, recycling (or) disposal and to effectively use resources (Dowlatshahi, 2000). This paper attempts to apply the methodology of QFD in developing a new reverse logistics network taking into account the environmental aspects in SLI batteries.

The paper is organized in the following manner. The literature survey is summarized in section 2. In section 3, a brief description about the problem is given along with the methodology adopted and the case illustration. Section 4 is results are analyzed and discussed.

### 2. LITERATURE SURVEY

Quality function deployment (QFD) is a customer-oriented approach to product innovation. It guides product managers and design teams through the conceptualization, creation and realization process of new products (Grovers, 1996). Approaches to quality based on the concept of Total Quality Control (TQC) as introduced by Feigenbaum (1961) are fundamentally different from the Japanese TQC concept. In this vision TQC is "Company Wide Quality Control". It is more comprehensive and characterized by deploying customer desires horizontally and vertically throughout the organization.

Companies attempting to implement QFD have reported a variety of the benefits and also the problems with the method. Kwong and Bai (2002) proposed a fuzzy analytic hierarchy process (FAHP) approach to

determine the importance weights for the customer's requirements. Erol and Ferrell (2003) presented a methodology in which the fuzzy QFD is used for converting qualitative information into quantitative parameters and then combine these data with the other quantitative data to parameterize a multi-objective mathematical programming model. Chen et al. (2004) formulated a new fuzzy regression based mathematical programming approach for the QFD product planning. Bu'yu'ko'zkan et al. (2004) used an analytic network process, the general form of analytic hierarchy process (AHP), with the fuzzy triangular number to prioritize design requirements (DRs) by taking the degree of the interdependence between the customer needs (CNs) and DRs, and their inner dependences into account. Kannan et al., (2007) has proposed fuzzy average method to improve the quality characteristics in an automobile company.

### 3. PROBLEM DESCRIPTION

The development of a new reverse logistics network with environmental analysis of used SLI batteries is the problem undertaken in this work. The methodology adopted must incorporate environmental aspects to handle the environmental and traditional product quality requirements simultaneously. A manufacturer needs develop a reverse logistics network taking into account the environmental issues related to the used SLI batteries, when the used batteries is transported back to the point of origin from the consumption end. The reverse supply chain for used SLI battery is shown in figure 1. The main objective of the work is to develop a reverse logistics network measuring the environmental impact of the process. A methodology is needed to compare the needs of a customer with the technical requirements and develop a model which can maximize the objective.

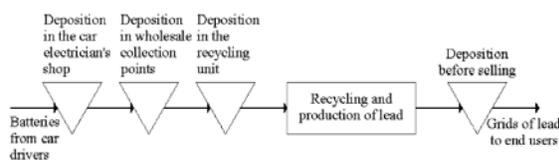


Figure 1 SLI batteries reverse supply chain. (Source: Tsoufias et al., 2002)

#### 3.1. Methodology adopted

QFD based tool can be used to identify the performance measures that closely reflect the concerns of the customer and to ensure that these performance measures are used (and measured) in the re-engineered business process (Jagdev et al., 1997). QFD enables an organization to build a quality into the product and to control the development process from concept to the commencement of manufacturing operations (Govers, 2001). The basic foundation of QFD is to systematically take the customers' desires down to the level of detailed operations. The two QFD processes, the American

Supplier Institute's (ASI) Four-Phase approach and the GOAL/QPC Matrix of Matrices approach, are widely accepted as effective processes to implement it (Revelle et al., 1998). The ASI's Four-Phase approach translates the customers' needs into technical requirements, and subsequently component characteristics, process steps and operational steps (Fig. 1).

Each of the translations uses a matrix, called a House of Quality shown in fig. 2 in which the customer requirements (WHAT) are translated into design characteristics (HOW) on the basis of market research and past experiences (the WHY scores).

HOQ (Cohen, 1995) is a very complex matrix that provides means for inter functional planning and communications. The House of Quality as it was named by Hauser and Clausing (1988). The QFD is not only a technical tool, but also a managerial philosophy that can enhance the organizational and managing effects. Technically, QFD can reduce the product the product development time, while simultaneously improving product quality and delivering the product at a lower cost, and consequently can increase the market share. QFD can also facilitate continuous product improvement with emphasis on the impact of organization learning on innovation (Kannan et al., 2007)

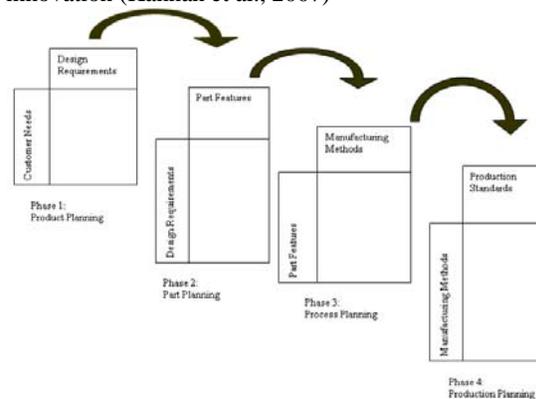


Fig. 2: Four Phases of QFD (Source: Kannan et al., 2007)

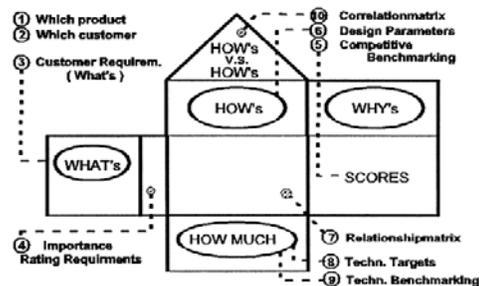


Fig 3. House of Quality (HOQ) showing the rooms of the various steps in the product planning phase of the QFD process (Source: Grovers, 1996)

#### 3.2. Case illustration

Rapid changes are taking place in the field of reverse logistics. In this work the environmental impact of recycled SLI (Starting, Lighting and Ignition) batteries are considered, as this study is more crucial for the safer

disposition of used SLI batteries without having an impact on environmental aspects. The manufacturer is responsible to collect the used batteries and recycled without affecting the ecological balance. The company chosen is manufacturing SLI batteries in the southern part of India. With the help of literature review, it is proposed to use a methodology of Quality Function Deployment (QFD) for developing a new reverse logistics network for the battery manufacturer incorporating the environmental aspects of used SLI batteries.

In this case study, the new brand was evaluated by considering 7 customer needs shown in table 1. A questionnaire survey was conducted with the help of 300 customers randomly taken from public, sales, and service and company recycle shops and the customer requirements are tabulated.

Then the customers were asked to rate the importance of the reverse logistics in the recycling of

Table 1. Customer needs

Customer needs	Rating
Quality of recycled battery	9
Easy to return used battery	7
Easy to disassemble	5
Energy consumption	9
Weight of battery	3
Environmental aspect	8
Safe transportation	8

#### 4. RESULTS AND DISCUSSION

The overall weight is calculated by multiplying the customer weighting and numerical weighting of the

Table 3. Individual rating Calculation

	Customer rating	Technical requirements								
		Technology of recycling	Location of collection centre	Technique for battery breaking	Resource consumption	Less material/ parts	Volume	Safer incineration	Better sorting	Safe packing for transportation
Quality of recycled battery	9	9	1	3	9	1	1	1	3	1
Easy to return used battery	7	1	9	1	9	1	3	1	1	1
Easy to disassemble	5	1	1	9	3	3	3	3	9	1
Energy consumption	9	9	9	1	1	1	1	3	1	1
Weight of battery	3	1	1	3	3	9	9	1	3	3
Environmental aspect	8	3	1	3	1	1	1	9	9	9
safe transportation	8	1	9	1	1	3	3	1	1	9
Overall weight		209	241	129	193	99	113	141	177	183
Normalized individual rating		0.867	1	0.535	0.801	0.411	0.469	0.585	0.734	0.759

SLI used batteries, their requirements and compared with the existing system. The rating of the customer demands was done on a scale of 1 to 10. On this scale, 10 denote most important and 1 denotes relatively low importance. Preference is given only to the customers to assign the ratings. The corresponding technical requirements are tabulated with the help of an expert team comprising technical experts from industry and academicians. The technical requirements are given in table 2. The relationship between the technical requirements and the customer needs are rated on a 1-3-9 scale. 1 denotes a weak relation, 3 denote a moderate relation and 9 denote a strong relation.

relationship and summing these together of each product characteristic is given as overall weight. The purpose of calculating the overall weight is to identify the characteristics that are influencing the customer satisfaction to the greatest extent. A high overall weight may preferably be gained if there is a strong relationship between the product characteristic and customer needs with a high customer rank.

The Normalized Individual Rating (NIR) for each characteristic is also determined so that it will be easy for a comparison with another methodology. The normalized individual rating is calculated as

$NIR = \text{Individual Rating} / \text{Max. Individual rating}$

The overall weight calculated for the case study is tabulated in table 3. It is understood that location of collection centre is more significant as its overall weight (=241) is the maximum. Technology of recycling is the second significant technical requirement with a weight of 209. Less material or parts is least with 99 as weight.

#### 4.1 Individual Rating

Individual Rating for Technology for recycling = 209, Individual Rating for location of collection centre = 241, Individual Rating for technique for battery breaking = 129, Individual Rating for resource consumption = 193, Individual Rating for less material = 99, Individual Rating for volume = 113, Individual Rating for safer incineration = 141, Individual Rating for better sorting = 177, Individual Rating for safe packing for transportation = 183. The maximum weight of columns is for location of collection centre (i.e. 241). To compare the values obtained by other methodology, the normalized individual ratings are determined.

#### 4.2 Normalized Individual Ratings:

Normalized Individual Rating for Technology for recycling =  $209/241 = 0.867$ , Normalized Individual Rating for location of collection centre =  $241/241 = 1.00$ , Normalized Individual Rating for technique for battery breaking =  $129/241 = 0.535$ , Normalized Individual Rating for resource consumption =  $193/241 = 0.801$ , Normalized Individual Rating for less material =  $99/241 = 0.411$ , Normalized Individual Rating for volume =  $113/241 = 0.469$ , Normalized Individual Rating for safer incineration =  $141/241 = 0.585$ , Normalized Individual Rating for better sorting =  $177/241 = 0.734$ , Normalized Individual Rating for safe packing for transportation =  $183/241 = 0.759$ .

### 5. CONCLUSIONS

The analysis of the result obtained states that the location of collection centre is more significant as its overall weight is the maximum and technology of recycling used is the second significant technical requirement. The least significant technical requirement is the need for less material or parts with less overall weight.

As a scope for future, the traditional QFD can be compared by using fuzzy QFD. With the help of the normalized individual rating, the crisp weights obtained from the traditional QFD can be compared with fuzzy weights obtained from the fuzzy QFD.

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