Quality Function Deployment and Sustainable Development through Circular Economy

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Abstract
Economic liberalisation and sweeping policy changes brought about by the Government of India, since 1991, have transformed the business environment. The impact of these changes is visible in de-regulation, trade liberalisation, flow of foreign direct investment, privatisation, globalisation and rapid technological advancement. The removal of trade barriers across nations is posing both new challenges and threats to the business. Total Quality Management (TQM) is no longer merely an option but an urgent need for survival and growth in the competitive environment. New techniques are being developed to bring about an improvement in quality. These include: defect prevention, zero defects, statistical quality process control, reliability engineering, quality circles, benchmarking and quality function deployment. The present paper seeks to analyse and conceptualise the concept of Quality Function Deployment (QFD). The need of the hour is to use these techniques to create more sustainable solutions to the world problems. TQM and QFD can lead to a better economic equation when zero defect can be achieved and sustainable options can be explored to reuse and recycle products leading to less exploitation of the natural resources. The present corona pandemic has made us rethink our greed of development at the cost of environmental degradation.

Keywords
Quality, customer, sustainable, TQM and QFD

I. Introduction

Quality is the buzz word these days as emphasis is on cost reduction and customer satisfaction. If product offered is of international quality and other terms and conditions are conducive, customer loyalty and equity can be created. There are many techniques found in the literature on improving quality, like, Statistical Quality Control (SQC), Six Sigma, benchmarking, Zero Defect, Total Quality Management and many more. The quality implementation has to be company-wide from top level to lower levels in order to attain effectiveness. The similar techniques are relevant for services as well but focus is on process of service delivery so that consistency of quality can be maintained.

Quality Function Deployment (QFD) is a system for designing a product or service based on customer demands that involves all members of the producer enterprise. In Japanese practice, 'deployment' refers to an extension or augmentation of activities. 'Quality Function Deployment' means the responsibilities for producing a quality item, must be assigned to all parts of a corporation. In other words, it refers to company-wide quality control and management systems. It is sometimes referred to as the most advanced form of Total Quality Control.

The system can be understood by defining each of the terms in 'Quality Function Deployment' within the context of QFD.

- Quality - Meeting Customer Requirements
- Function - What Must Be Done - Focusing the attention on key areas
- Deployment - Who will do it, when it will be done: fixing the responsibility and time schedule.

"QFD is a system of designing a product/service as a powerful tool of transforming vague requirements of customers into clear measurable technical requirements/specifications. The technique provides logical, systematic, and scientific methods for transformation of expected attributes into effective system of quality control." (Warwick Manufacturing works report). Though there are many difficulties associated with QFD, like the type of market in which it is applied, complexity, ambiguous, vigorous and confusion over requirements. Thus, lack of understanding makes it difficult for many organizations to implement the tool.

QFD is a scientific approach to defining customer needs or requirements and translating them into systematic plans to manufacture goods to meet those needs. The "voice of the customer" is the term to describe these stated and unstated customer needs. The opinion of the customer is gauged in a variety of ways: interviews, surveys, customer specifications, observation, and field reports, etc. This understanding of the customer needs is then summarized in a product planning matrix. The QFD matrices are used to transform the customer specifications into 'what' and 'how'. The customer needs are converted into product specifications based on market research and technical feasibility.

QFD includes putting together a team of persons comprised of various departments which will take up product design and development, such as, Marketing, Design Engineering, Quality Assurance, Production Engineering, Testing, Finance, Operations Management and customer/Product Support, etc. Various divisions can lead to an equilibrium between the customer needs and technical implications of the specifications and product features. It makes coordination between departments easy.

II. Advantages of Implementing QFD

The purpose of implementing the tool is to achieve efficiency in delivering value to the customer by ensuring that it meets the customer requirements. There are a number of steps in the process, such as, concept development, trade studies, process design, product design and planning. The objectives of the tool are to understand the needs of customers, improvement in concept development, design implementation on time, quality awareness throughout the enterprise, increased market share and many more. The aims are explained below:

- Better understanding of customer needs: QFD facilitates the understanding of clients in a better way as it is based on their aspirations about the company, brand and product. It employs many techniques such as primary sources viz. interview, market survey and field studies to measure customer perception and secondary sources like published reports of various research agencies. It helps in concretizing and measuring their needs.
- Improved organisation of development projects: Product

design planning requires scientific approach to project completion and scheduling. Research and innovation leads to creativity enhancing customer satisfaction as a result. The market demand is always dynamic and ever changing preferences of customers, make it a difficult process. The availability of alternate products create challenges continually. Thus, research and continuous improvement in quality is required. The technique provides basis for scientific plans for development of better processes or products.

- Improved introduction to production: When customer need analysis is done, production can be planned. The metrics approach helps in increasing the focus on key areas. The tool leads to improved production processes resulting in quality goods and systematic delivery of satisfaction to the customers. QFD creates the appropriate facilities, tools and infrastructure with focus on efficiency and upgradation with zero defects.
- Fewer design changes late in development: A systematic analysis of processes in synchronization with customer needs, lead to lesser faults in the production chain. The planning helps in creating economical and non-repetitive procedures so as to reduce wastages, leading to better utilization of scarce factors. The focus remains on the reduction of defective number of items produced in the production process. The inter-dependence of processes can be determined through scientific approach.
- Reputation for good processes/ quality: The image of the company depends upon the customer satisfaction and loyalty it is able to generate. The use of such a quality practice creates a positive impression in the minds of users, vendors and market as a whole. The good quality practices lead to a positive corporate image that indicates a high quality end product.
- • Increased business: Enhanced reputation and a positive feedback of buyers, results in more demand, repeat orders, and creation of new clients. The market share of the company increases if the word spreads in the market about quality, prompt delivery and customer care. The emphasis should be on the involvement of the entire workforce in the process of quality improvement. The six sigma technique is the end result of this QFD process. The attention is focused on key areas requiring focus to make it more economical.
- • Documented product definition based on customer requirements: QFD process is based on conversion of customer needs into targets for product attributes in product design. The success of the product/brand depends upon the understanding of the client expectations and meeting the same on time and as per the terms and conditions of the client. The end product is ensured as per the client needs.

III. Process of QFD

QFD theory started in 1972 at Mitsubishi's Kobe Shipyard when they began using a matrix that put customer demands on the vertical axis and the methods by which they would be met on the horizontal axis. In Japan, the system has been developed to include other considerations, like, better communications within design and manufacturing divisions, function of the product, potential failures, cost reduction and probable technological advances. The scope of the technique is really wide as it may be applied to services sector also. A number of service providers are using the same to improve customer satisfaction and value addition. They use matrix to match their needs such as, private banks have devised a detailed customer service delivery chart. They depict the maximum time to be taken to offer a certain service to the customer. The process flow charts are laid out in a lucid manner so that flow of work is a straight line without back n forth movements and any hurdles. **Unexplored opportunities** i.e. new methodologies or implied needs of the customer, are identified through the quality engineer, operations, or customer support representative. These can also be identified by marketing research or analysing customer behaviour and recognizing opportunities for improvement. In order to stay in business, they must sell their products/services and keep customers satisfied and happy. This can only be done with a backbone of continual satisfaction on behalf of the customer.

There is an entire customer chain which needs to be observed. It is not adequate to study our own customer but also those people who did not buy our product. An analysis of our lost customers who purchase competitive products or shift from our brand to the other is equally significant. This analysis would facilitate the process of change and improvement in product design. In the context of circular economy now, the relevance of reuse and recycle has become predominant in our design process. There is a greater need of inventing processes to reuse existing components in new products.

In the first phase, the first step is to list out identified customer requirements in clear terms. It is generally done with the help of either direct feedback or through secondary sources of information. At the second phase, the set of measurable technical specifications are derived for product design. The matrix diagrams are drawn to indicate the inter-relationships of customer needs with the technical design requirements. In the third phase, target levels for the quantified technical requirements are balanced in order to finalise the process design. It is the process of translation of design solution into realization system requirements. The fourth and last phase deals with production planning and delivery of products as conformance to desired attributes.

IV. Quality Function Deployment Flow

The basic Quality Function Deployment methodology involves four basic phases that occur during the product development process. During each phase, one or more matrices are prepared to help, plan and communicate key product and operations/process planning. At the planning stage, we try to define the customer perceptions, analyse competitive opportunities, planning a product as per customer needs, followed by establishing critical characteristic target values.

At the second stage of the QFD process, an estimate of parts, components and materials is done to place order for smooth supply. The transformation process of components replenishment into critical target values takes place. The third stage relates to process planning involving the sequence of processes, defining critical ones, determining process equipments, along with determining official processes to be implemented. The last stage relates to process/quality control comprising of identifying critical part/ process characteristics, defining methods and procedures. It also includes establishing inspection and process/product parameters of quality control/test specifications. In other words, finalising the acceptable range of defects, and fixing permissible standards of quality in final products.

V. The Holistic Requirements Model

Actually, one of the strengths of QFD is its ability to capture the vague statements, often articulated by customers. However, this can also be its downfall if the customer has provided any detailed requirements, particularly if these requirements have

a 'performance' measure and target. In such circumstances, the company has to invest more in research to meet or exceed customer expectations. The key to understanding how to apply QFD comes from a systems approach to understanding requirements. Applying systems thinking to the requirements of a customer leads to the Holistic Requirements Model. The Holistic Requirements Model provides a complete and consistent model for classifying and describing any set of requirements of a system. Furthermore, we should try to relate it to attaining a better sustainable economy through reuse and recycle techniques.

The model comprises three basic requirements types:

- Operational Requirements
- Functional Requirement
- Non-Functional Requirements

Operational requirements define the major purpose of the system, i.e. its fundamental objective, whereas, functional requirements specify what the system has to do in order to achieve operational required specifications. It provides precise direction for the development of the system so that team members can develop their own internal version.

Functional requirements specify what the system has to do in order to achieve the operational requirements. They define what exactly is to be done – not how it is to be done or how well it is done. There may be various levels of functions in a system and they need to be determined. These functions convert inputs into outputs with efficiency.

Non-functional requirements are connected to functional requirements and define how well a specific function should be performed as they are constraints regarding that function. They are divided into three parts: non-functional performance requirements, non-functional system requirements, and non-functional implementation requirements.

The holistic approach seeks to approach the problem in a scientific manner. QFD begins with product planning, product design and process design, and ends with process control, quality control, testing, maintenance, and training. As a result, this process requires multiple functional disciplines to address this range of activities. QFD is synergistic with multi-function product development teams. It can provide a structured approach for these teams to begin communicating, making decisions and planning the product design.

VI. QFD and Circular Economy

The existing business model focuses on take-make-waste but circular economy seeks to redefine growth and development in terms of society benefits. A circular economy is that type of economic system in which raw materials, natural resources and components lose little value in production through use of renewable sources of energy. The principle is based on economic activities where consumption of finite resources is to the maximum and wastages are minimized so that economic, natural and social capital can be created. The basic tenets are; reducing wastages and pollution, keeping products in use, i.e. reuse, and regenerate natural systems. It aims at refurbishing, recycling and minimizing inputs and creating a closed-loop economy through the reduced creation of wastages, pollution and carbon emissions.

The closed-loop system needs to ensure that materials which are buried into earth should not be toxic; retain the inherent energy, water and other process inputs in the product. They should focus on less consumption of natural materials, also use systems' approach to design solutions, and preserve natural resources and organisms.

In practice, it implies reducing waste to a minimum. When a product reaches the end of its life, its materials are kept within the economy wherever possible. These can be productively used again and again, thereby creating further value. This is a modification of the traditional economic model based upon take, make, use and throw pattern. This model relies on large quantities of cheap, easily accessible materials and energy. QFD can achieve these targets easily with emphasis on continuous improvement and zero defect. Moving towards a more circular economy from an old linear model, could deliver benefits, such as, reducing pressure on the environment, improving the security of the supply of raw materials, increasing competitiveness, stimulating innovation, boosting economic growth, creating jobs. The following case studies throw light on the process in a more lucid way.

A. Case Study on QFD: Amazon.com

Source: Econsultancy.com

Reasons of Amazon's mobile success:

amazon Along with eBay, Amazon was one of the first brands to see the early potential of mobile commerce and is now leading the way in terms of innovation and mobile sales. Its mobile site and apps have been a huge success and helped it to maintain its dominance of e-commerce and extend its market reach. Part of Amazon's success on mobile is due to its reputation as a trustworthy online retailer, but also its marketing strategies focussing on user experience. So let us look at few reasons that have contributed to Amazon's success in m-commerce.

1. It has a mobile site

The most basic reason for the success of amazon is that only few retailers have mobile optimised sites. It's estimated that 80% of brands do not have mobile sites, while a review of the top 20 UK retailers found that just 12 had mobile optimised sites.

2. Easy Purchase Procedure

The major reason for the success of Amazon is one click pay method which makes customers make repeat orders. It simplifies by saving the customers card details and delivery address so they only have to enter a username and password. It is more popular on mobile as consumers do not want to waste time trying to enter credit card details on a smart phone. A study has revealed that smart phones are increasing the urge to impulse buying, specifically garments with a 'no questions-return policy'. With a Covid-19 pandemic world-wide, online purchasing has seen unprecedented levels of sales.

3. Early entry

Another reason for the popularity of the site is early entry in the business by forecasting the market potential of m-commerce. Amazon established itself as a major mobile retailer before most of its competitors even started planning. Amazon has invested time and resources in developing its mobile platforms to make user experience better.

4. Consistent design across mobile site and apps

The mobile platforms of Amazon are similar to laptop version so that users find it similar. The basket and search functions are positioned in similar places and they repeatedly display recommended products on the homepage.

5. Common shopping bag across all platforms

They have designed the shopping basket in such a way the it synchronises both the platforms. When a customer adds it to bag on one platform it gets added to bag automatically on the other also. It is a great example of offering the customer a consistent experience across different channels.

6. Apps on all platforms

For many retailers, their mobile strategy does not really extend any further than iPhone, even though Android has more than 50% market share globally. Amazon has created apps for all platforms, iPhone, android and others. It gives it an edge over other competitors.

B. CASE STUDY on Recycling

SOURCE: Nick Jeffries(2017), www.http:/ circulatenews.org

- This circular design thinking has been demonstrated by **Mohawk-Niaga**, which has created a new 100% recyclable carpet material, that can be used for both the backing and surface layers. It has been estimated that carpets account for 3.5% of all material disposed of in US landfills, amounting to 2 million tonnes of lost materials each year. Mohawk-Niaga's new material could help close the loop in carpet manufacturing so that materials can be diverted from landfill and instead be continually recycled.
- In developed countries, more businesses have realized the need for recycling. There is value even in products designed in the take, make, use and throw away models. **Urban Mining**, a Texas based company, has developed a process for recycling Neodymium Iron Boron (NdFeB) magnets, a widely-used magnet with applications in products, such as, cordless drills, hard drives and electric motors. The magnets from disposed products are recycled into new components, saving resources and environment waste.
- **Case study on Taiwan's Construction Industry:** Modern construction industry is wasteful and unsustainable. It consumes a major portion of materials and resources on this planet yet little of them are reused, recycled or regenerated at the moment (Cheshire, 2016). Therefore, precious materials and resources are getting fewer yet more waste are produced every day. For Taiwan, a small island with very limited resources yet large population, this transition is even more critical. After realizing this urgent need, in recent years, many public and private sectors in the world have made circular economy (CE) a main focus for their construction industry. For example, a cross-national European research project named "Building As Material Banks (BAMB)" has been established for enabling a systemic shift in the building sector by investigating and creating circular solution. Furthermore, the establishment of financial incentive and platforms for material circularity are the key enablers in Taiwanese scenario. Concerning Building Information Modelling (BIM) uses for circular building design in Taiwan, design authoring, review, quantity take-off, phase planning, and energy analysis are recognized as strong BIM techniques.

VII. Conclusion

QFD is a tool to implement the philosophy of 'happy customers lead to success' of the enterprise. In turn, customer satisfaction can only be achieved if we can fulfill the customers' requirements. Hence, the gathering and use of customer requirements is the foundation of QFD. In the process of QFD, it is important to understand the 'customer' and design and offer products which meet their expected criteria. The paper seeks to comprise of the scope, relevance, phases and flow of QFD process. One case study on Amazon has been discussed to understand the process and flow of QFD. Other case studies emphasize upon the relevance of recycle, reuse and rebuy in order to not only preserve our environment but to achieve lower cost of production.

Thus paper emphasizes the need for maintaining quality through understanding customer needs and expectations. QFD is a technique of designing and offering a product which is suitable to create a more sustainable world economy. If the resources consumed can be minimized and outputs be maximized with almost zero defect in the transformation process, the environment can be more sustainable. The reuse and recycle approach should be considered while designing all technical processes. A number of case studies on recycle and reuse of old components and waste management have been discussed to focus on the need of sustainability in all our endeavours in order to save our environment. The systematic approach to product/process design through QFD can help reduce wastages and lead to a better environment.

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