Methods and Techniques to help Quality Function Deployment (QFD)

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Abstract

Quality function deployment (QFD) is a management tool that provides a visual connective process to help teams focus on the needs of the customers throughout the total development cycle of a product or process. It provides the means for translating customer needs into appropriate technical requirements for each stage of a product/process-development life-cycle. It helps to develop more customer-oriented, higher-quality products. While the structure provided by QFD can be significantly beneficial, it is not a simple tool to use. This article outlines how techniques such as fuzzy logic, artificial neural networks, and the Taguchi method can be combined with QFD to resolve some of its drawbacks, and proposes a synergy between QFD and the three methods and techniques reviewed.

Key Words: Fuzzy logic, House of quality, neural networks, Quality function deployment, Taguchi methods.

INTRODUCTION

If a product is to be designed well then design team needs to know what they are designing and what the end users will expect from it. Quality Function Deployment (QFD) is a systematic approach to design which is based on a close awareness of customer requirements along with the integration of corporate functional groups. It consists in changing customer desires into design characteristics for each stage of the product development (Rosenthal, 1992).

The goal of QFD is to transform often subjective quality criteria into objective ones that can be quantified and measured and then this can be used to design and manufacture the product. It is complementary method of determining how and where priorities are to be assigned in the product development. This aim is to utilize objective procedures in increasing detail throughout the development of the product. (Reilly, 1999) QFD was developed by Yoji Akao in Japan in 1966. In the year of 1972, QFD was well demonstrated at Mitsubishi Heavy Industries Kobe Shipyard. (Sullivan, 1986) In 1976, the first book on this subject was published in Japanese then later it was transferred into English in 1994. (Mizuno and Akao, 1994).

According to Akao, QFD is a method for developing a design quality which is 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. it is a way to assure the design quality while the product is in the design stage. He had pointed out very important side benefits are that QFD has demonstrated the reduction of development

Figure 1: Techniques used

time by one-half to one-third. (Akao, 1990)

Figure 2: Different phases of product development

The three main goals in implementing QFD are:

1. Priority of spoken and unspoken customer wants and needs.
2. Translate these needs to technical characteristics and specifications.
3. Build and deliver a quality product or service by focussing everyone towards customer satisfaction.

After its introduction, QFD has helped to transform companies in many ways:

1. Plan new products
2. Design product requirements
3. Determine process characteristics
4. Controlling manufacturing process
5. Document already existing product specification

RESEARCH METHOD

The research design is descriptive in nature. The method of data collection is mainly based on secondary data. So various literatures are used for data collection. However, an effort is made to collect primary data by taking information from competent persons off and on.

DIFFERENT PHASES OF MATRIX

QFD uses some principles from concurrent Engineering in that cross functional teams are involved in all phases of the product development. Each of the phases in a QFD process uses a matrix to translate customer requirements from initial planning

stages through production control. (Becker Associates Inc, 2000) Each phase or the matrix represents a more specific aspect of the product's requirements. Relationships between elements are assessed for each phase. The important aspects from each phase are deployed into the next matrix.

1. Phase 1, Product Planning: This is led by the marketing department and is also called as The House of Quality. Many organizations only get through this phase of a QFD process. Phase 1 requires customer requirements, warranty data, competitive opportunities, product measurements, competing product measures, and the technical ability of the organization to meet the customer requirement. Getting the good data from the customer in phase 1 is important for the success of the entire QFD process.

2. Phase 2, Product Design: This phase 2 is led by the engineering department. This requires creativity and innovation team ideas. Product concepts are created during this phase and some of the specifications are documented. Parts that are determined to be most important to meet the customer needs are deployed into process planning, or phase 3.

3. Phase 3, Process Planning: This process is led by manufacturing engineering. In this phase manufacturing processes are flowcharted and process parameters or target values are documented.

4. Phase 4, Process Control: In production planning, performance indicators are created to monitor the production process, maintenance schedules, and skill training for operators. In this phase decisions are made as to which process poses the most risk and controls are put in place to prevent failures. The quality assurance department in concert with manufacturing leads to Phase 4.

THE HOUSE OF QUALITY

The first phase in the implementation of the QFD process involves putting together a "House of Quality" (Hauser and Clausing, 1998) which is shown below and it is for the development of a climbing harness (Lowe and Ridgway, 2001)

Figure 3: House of quality

Figure 6: Customer Rating of the Competition

descriptors may exist that one's organization is already using to determine product specification. Although new measurements can be created to

ensure that your product is meeting customer needs.

Figure 7: Technical Descriptors

6. **Step 6, Direction of Improvement:**
When the team defines the technical descriptors, a determination must be made as to the direction of movement for each descriptor.

7. **Step 7, Relationship Matrix:**
In relationship matrix the team determines the relationship between customer needs and the company ability to meet those needs. The team asks the question like, "What is the strength of the

Figure 8: Direction of Improvement

DIRECTION OF IMPROVEMENT				↓		↑		↑		↑					
		Performance measures		Size of range		Technical details		CUSTOMER RATING							
HOW'S 															

Figure 9: Relationship Matrix

DIRECTION OF IMPROVEMENT					↓	↑	↑	↑	↑							
HOW'S			CUSTOMER IMPORTANCE		Performance measures		Size of range		Technical details		CUSTOMER RATING					
					Meet European Standards	Harness weight	Webbing strength	No. of coils	No. Sizes	Padding thickness	No. of buckles	No. of gear loops				
WHAT'S																
						</										

● Strong - 9
○ Medium - 4
△ Weak - 1

relationship between the technical descriptors and the customer needs?" Relationships can be either weak, moderate, or strong and carry a numeric value of 1,3 or 9.

8. Step 8, Organizational Difficulty:

Now rate the design attributes in terms of organizational difficulty. It is very possible that some attributes are in direct conflict. Increasing the number of sizes may be in conflict with the company's stock holding policies.

9. Step 9, Technical analysis of competitor products:

To understand the competition in a better way, engineering then conducts a comparison of competitor technical descriptors. This process involves reverse engineering competitor products to determine specific values for competitor technical descriptors.

10. Step 10, Target values for technical descriptors:

In this stage the QFD team begins to establish target values for each technical descriptor. The

Figure 10: Organizational Difficulty

DIRECTION OF IMPROVEMENT				↓	↑	↑	↑	↑									
HOWS WHATS			CUSTOMER IMPORTANCE	Performance measures			Size of range		Technical details		CUSTOMER RATING						
				Meet European Standards	Harness weight	Webbing strength	No. of colours	No. Sizes	Padding thickness	No. of buckles	No. of gear loops	<div>□ Our company</div> <div>△ Company A</div> <div>○ Company B</div>					
				1	2	3	4	5									
Facilitates enjoyment of climbing	Usability	Easy to put on	2					○		●			□		△	○	
		Comfortable when hanging	5					○	●	○				△		□	
		Fits over different clothes	1					○	○	●				○	△		□
		Accessible gear loops	3								●	○			□		
	Performance	Does not restrict movement	5		○			○	●	○				□	○	△	
		Light weight	3		●	○			○	△	△			□	△	○	
		Safe	5	●	○	●									□		
		Attractive	2		△		●		△	△				□	○	△	
ORGANISATIONAL DIFFICULTY (5=difficult, 1=easy)				2	4	3	3	5	2	3	1						
HOW MUCHES																	

● Strong - 9

○ Medium - 4

△ Weak - 1

● Strong - 9
 ○ Medium - 4
 △ Weak - 1

Figure 11: Technical analysis of competitor products

target value represents 'how much' for the technical descriptors, and can then act as a baseline to compare against.

11. Step 11, Correlation Matrix:

This is the room in the matrix where the term House of Quality comes because it makes the matrix look like a house with a roof. The correlation matrix is the least used room in the

house of quality and this room is helpful for design engineers in the next phase of the comprehensive QFD project. Team members must examine how each of the technical descriptors impacts each other. The team should document strong negative relationships between technical descriptors and work to eliminate physical contradictions.

Figure 12: Target values for technical descriptors

12. Step 12, Absolute Importance:

Lastly the team calculates the absolute importance for each technical descriptor. This numerical calculation is the product of the cell value and the customer importance rating. Numbers are then

added up in their respective columns to know the importance for each technical descriptor. Here one knows which technical aspects of their product matters the most to customer.

Figure 13: Correlation Matrix

Figure 14: Absolute Importance in matrix

Figure 15: The QFD Matrix or 'House of quality'

13. Next Stage:

The above all process is repeated in simplified way for next three project phases. A simplified matrix involving steps 1, 2, 3, 5, 6, 7, 9 & 11 are involved. The main difference with the different phases is that in phase 2 the process becomes a translation of the voice of the engineer in the voice of the part design specifications. Then in phase 3, the part design specifications get translated into the voice of manufacturing planning. Finally, in phase 4 the voice of manufacturing is translated into the voice of production planning. QFD is a systematic means of ensuring that customer requirements are accurately translated into technical descriptors throughout each stage of the product development. So, meeting customer demands means more than just maintaining or improving

product performance. So, it means that designing and manufacturing products that makes customer happy and fulfills their unclear desires. Companies growing into 21st century will be enterprises that promote the needed innovation to create new markets.

FUZZY LOGIC FUNCTION DEPLOYMENT APPROACH:

For QFD charts, various inputs in the form of judgments and evaluations are needed. These inputs are gathered through questionnaires, deep interviews, and focus groups. This give rise to uncertainties when try to quantify the information. To reduce the uncertainty of data, Fuzzy logic can be used. Fuzzy logic and Fuzzy sets were introduced in 1965 by Prof. L.A. Zadah. Fuzzy logic uses human linguistics (word or sentences) understanding to express the

knowledge of a system. This knowledge consists of facts, concepts, theories, procedures, relationships and it is expressed in the form of IF-THEN rules. These linguistic variables are characterized by ambiguity and multiplicity of meaning. Specifying good linguistic variables depends upon the knowledge of expert. E.g. 'age' is a linguistic variable if its values are 'young', 'not so young', 'old', and 'very old'. In fuzzy logic theory, a linguistic variable can be a member of more than one group like someone who is 27 years old belongs to both the 'young' and 'not so young' group at a different degree as can be seen in stated figure.

Figure 16: Linguistic Variable

Fuzzy logic shows some useful features for exploitation in QFD and these are:

1. It uses human linguistic to express the knowledge of the system.
2. It allows decision making with estimated values under incomplete or uncertain information.
3. It is suitable for uncertain or appropriate reasoning.
4. With this interpretation of its rules is simple and easy to understand.
5. It deals with multi input and output system.

INTEGRATION OF FUZZY LOGIC WITH QFD

In this approach, crisp values are translated into fuzzy numbers which is considered as probability distribution (Zimmermann, 1986) used to test the significance of the coefficients. So mathematically it becomes,

$$A_{ij} = [\alpha_{1ij}, \alpha_{2ij}] \quad (2)$$

Where A_{ij} is a symmetrical triangular fuzzy number (TFN) and it is defined by the interval $(\alpha_{1ij}, \alpha_{2ij})$. Using the same information, a typical membership function for a symmetrical TFN, A_{ij} can be expressed as;

$$\mu_{A_{ij}}(a_{ij}) = 1 - \frac{\left| a_{ij} - \frac{\alpha_{2ij} + \alpha_{1ij}}{2} \right|}{\frac{\alpha_{2ij} - \alpha_{1ij}}{2}}, a_{ij} \in A_{ij} \quad (3)$$

The scalar multiplication of TFN and the sum of two symmetrical TFNs can be shown as follows (Kaufmann and Gupta, 1985);

$$\lambda \circ [\alpha_1, \alpha_2] = [\lambda \cdot \alpha_1, \lambda \cdot \alpha_2] \quad (4)$$

$$[\alpha_1, \alpha_2] \circ [\beta_1, \beta_2] = [\alpha_1 \times \beta_1, \alpha_2 \times \beta_2] \quad (5)$$

Where λ denotes the scalar quantity and (α_1, α_2) and (β_1, β_2) are the intervals of the two symmetrical TFNs respectively. Individual rating equations can be generalized as:

$$\text{Individual rating} = \sum_j^n A_{ij} X_j \quad (6)$$

$$A_{ij} = [\alpha_{1ij}, \alpha_{2ij}] \quad (7)$$

Where A_{ij} and X_j shows the relative importance of the i th characteristics with respect to the j th customer need in the relationship matrix and importance of the j th customer need recognized by the customer, which are customer rating respectively. Comparison between crisp individual ratings and fuzzy individual ratings, normalized individual ratings (Cole 1990) are used. The normalized individual rating for each characteristic is determined as:

$$\text{Normalized Individual Rating}_i = \frac{\text{Individual Rating}_i}{\text{Maximum Individual Rating}} \quad (8)$$

The relative importance and customer rating can be crisp or linguistic variable. As it is mentioned, linguistic variable like strong relation (s), moderate relation (m), and weak relation (w) are used to describe the relative importance. These linguistic variables first translated into TFNs numbers like;

Table 1: Definition of linguistic variables

Linguistic variables	Fuzzy Number
Strong Relation (s)	[0.6-1.0]
Moderate Relation (m)	[0.3-0.7]
Weak Relation (w)	[0.0-0.4]

This table shows customer rating and relative importance using linguistic variables. The ranges of linguistic values for quantifying the relationship were predetermined by intuition. The ranges of rating were than derived from calculated rating and predetermined uncertainty value. The uncertainty value is fixed. In FQFD approach, demand weight is calculated in the range of 10.27-10.47. With this approach, individual rating is calculated and then translated into normalized individual ratings.

TAGUCHI METHOD

QFD is powerful because it ranks critical items to help determine where quality technology and engineering effort should be applied. QFD also identifies design requirements and in these instances, Taguchi methods are providing very good results. While Taguchi methods are integral part of QFD are integral part of QFD, they are also used outside of the QFD framework. Dr. Genichi Taguchi, highly acclaimed Japanese engineer and the winner of four Deming Prizes, began developing these methods in the year 1950s. his most important contribution has been the combination of engineering and statistical method to achieve rapid product and process design optimization. Taguchi methods form a comprehensive integrated quality engineering system including number of special techniques. Taguchi approach is distilled into three areas;

1. Quality evaluation.
2. Cost effective quality improvement.
3. Cost effective quality maintenance.

Figure 17: Counterpart Characteristics

1. **Quality Evaluation:**

Taguchi defined quality by his 'loss function'. Loss refers to costs incurred or profits foregone relative to baseline performance. The underlying principle is that quality loss is proportional to the deviation from the target value or the ideal performance level over the life of a product. Therefore conformance to arbitrary specification limits is an irrelevant measure of quality. The loss function quantifies potential savings by reducing variation around the target value. Taguchi's loss function contradicts concept that everything within specs is equally good and that everything outside of specs is equally bad. A simple example is variation around a scheduled flight departure time. Customer dissatisfaction and potential loss will grow at an increasing rate as departure time deviates, early or late, from the published schedule. We can assign no arbitrary limits to distinguish zones of total satisfaction (no loss) from total dissatisfaction.

Assume that our standard on the 'late' side is 'no greater than 30 minutes'. A delayed passenger sees no black and white difference between a delay of 29.5 minutes and 30.5 minutes and our 'spec' is a useless measure of customer satisfaction. As a product e.g. consider the colour density of a picture tube. It is not reasonable to assume that customers are equally satisfied with all levels of density within a given specification interval only to become totally unsatisfied when the density reaches some discrete point. Suppose that two plants producing the same picture tube shipped units with the same average density and all were within specifications. Both plants' customers should be equally satisfied. The Sony Corporation found it differently. Customer satisfaction is higher and warranty claims are lower for units produced in its Japanese plant than those produced in its American plant.

The difference is deviated from target value. Average density is the same but dispersion in density values is much greater for American produced units. This example is a case where 'nominal is best'. The loss function also applies to 'larger is better' situations like tread life, weld strength and to 'smaller is better' like fuel consumption, CO content of exhaust gas. Using the loss function, all quality improvements are

measured in terms of cost savings. Cost and quality improvement becomes same. Quality projects may be undertaken even though no out of spec material is being produced. We can also reject an improvement project in favour of others even when some out of spec material is being produced. This opinion of quality promotes the increase never-ending devotion to reducing variation and continuous improvement which accounts for Japan's rise as a global quality and cost leader.

2. **Cost Effective Quality Improvement:**

The improvement consists of three steps applied to both the product design and production processes:

2.1. System Design: This is non-statistical process of surveying and selecting appropriate design technology and concepts to produce a prototype design that possesses the functions required by the product plan.

2.2. Parameter Design: These are experimental design methods to find the optimal levels of the individual system parameters which were determined during the system.

2.3. Tolerance Design: These are experimental design methods used only after parameter design to set the tolerances of the parameters, if necessary. According to Taguchi, narrow tolerances should be the weapon of the last resort to be used only when parameter design gives insufficient results.

Taguchi refers to them as off line quality control. US companies have applied parameter design most extensively. The premise behind parameter design is simple that it is much easier and less costly to design a product insensitive to manufacturing variables than to control all of those variables. Similarly, parameter design can improve product's field performance so that it is less subject to environmental variables and deterioration. The objective is to have a robust design. For e.g. Taguchi cited a case of the Ina Tile Company in 1953. Ina knew that uneven temperature distribution in the tunnel kiln was an assignable cause of size variation in the fired tiles. Rather than controlling the kiln temperature which would have been expensive, they performed a design experiment. The experiment studied the effect of varying 7 factors involved in the tile mixture. They found that changing the lime content from 1% to 5% reduced tile size

variation by a factor of ten, preventing the need for expensive temperature controls.

Taguchi modified the conventional statistical methods of experimental design for parameter design. The basic strategy is straight forward which says that, identify which factors are controllable and which are 'noise' means not controllable or very expensive to control. Find the levels for controllable factors such that highest performance is achieved in spite of noise. The power of Taguchi methods is ability to improve design or production processes in a short time using a small number of experiments or combinations. Traditional techniques for checking the effects of only 4 factors each at three different settings, demands 81 combinations. A corresponding Taguchi experiment uses only 9 combinations. This difference grows exponentially as more factors are added to the analysis. By using Taguchi method, a small number of confirmation experiments are usually performed to check initial experimental conclusions. Companies have applied Taguchi parameter experimentation to the controllable factors in an existing production process without modifying the product design itself.

Ford body and Assembly Division improved door fits under existing production constraints in one of its

plants. They had only 4 factors with which to work like latch plate location yet they managed to improve on 3 out of 5 targeted quality characteristics with no capital investment or design changes. **ITT** used Taguchi methods to increase the weld splice strength in wire harness assemblies until it exceeded the core strength of the wire. They saved \$300,000 per year by discounting a destructive pull test. It also reduced field failures and discarded proposals for costly alternative processes like ultrasonic welding.

3. *Cost Effective Quality Maintenance:*

People make mistakes and materials also vary even when product and process design are completely optimized. To maintain quality during production, Taguchi developed On-line quality control. It relies on different formulas to cost effectively minimize losses due to piece-to-piece variation, scrap, adjustment, inspection, and manufacturing related performance variation. The basic principle is to weight the cost or loss of reducing variation around the target against the loss due to the variation itself. This form of quality control does not involve any charts but a systematic method of checking and adjusting. Online quality control is not practiced in US and it is poorly understood even though it is well

Figure18: Relationship among QFD, Taguchi Method, and JIT/TQC operating principles.

Relationships Among QFD, Taguchi Methods, and JIT/TQC Operating Principles

fitted to operations like as metal stamping.

Some criticize Taguchi method as statistically incorrect or inefficient and sometimes gives the wrong or not the best answers. The argument may represent the difference of like 50% improvement in two months versus a 90% improvement in two years. In reality, the full conventional experimental protocol is never performed and seat of the pants judgments suffice with a complex product or process. Taguchi had made statistical experimental design usable by a wide range of non statisticians so his methods are having a great impact on US manufacturing. For example, ITT used Taguchi methods in over 2000 cases and reported cost saving of \$35 million. Akashi Fukuhara's analysis of the sources of quality management at Toyota from 1977 to 1985 is based on Taguchi method.

QFD BASED ON VOICE OF CUSTOMER USING NEURAL NETWORK

QFD is a customer oriented design tool with cross functional team members reaching the agreement in developing a new or improved product to increase customer satisfaction. Customer happiness is influenced by product development outcome which are influenced by the technical and organizational dimensions. QFD is a supporting tool for process and product development which converts the voice of customer (VOC) into engineering characteristics (EC) and prioritizes the ECs based on the customer's requests. Conventional QFD evaluates these targets for brittle weights of the customer attributes (CA) identified from the VOC's. Quality management and product development are achieved in QFD through customer needs analysis. It is always a first step of QFD process and it is an important functional field of QFD. In QFD two main things are focussed like aspects of customer needs analysis, collecting and translating customer needs.

QFD is referred to as designed in quality rather than traditional inspected in quality in the sense that it helps a company shift from inspecting the product's quality to designing quality into the product through customer needs analysis. QFD analyses the voice of customer at the initial level of product development and arranges it throughout the firm. It is the voice of the customer, which aligns the company's resources to focus on maximizing customer satisfaction.

Engineering systems have become even more than complex than before to design and build while the demand the quality and effective development at lower cost and shorter time continues. To implement the QFD, customer requirements (CR) need to be identified and analyzed. E.g. Wang and Chin (2011) proposed a linear goal programming (LPG) approach to analyze the relative important weights of CRs.

Customers often have various requirements and preferences on a product. To achieve the optimal target setting of engineering characteristics (ECs) of a new product, QFD technology can be made to maximize the overall customer satisfaction by considering the weights of the importance of different segments. The weights and development costs in the model have been stated as triangular fuzzy numbers in order to describe the imprecision caused by human subjective judgment (Luo, Kwong & Tang, 2010).

QFD provides a comprehensive, systematic approach to ensure new products to meet or exceed the customer expectations. It reduces time to market, improved quality and increased customer satisfaction (Vatthanakul et al., 2010). Customer surveys, customer demands, engineering characteristics and engineering solutions are interconnected as in Neural Network architecture (Zhang et al., 1996). In the figure 19, engineering solutions represent the input and the customer satisfaction as the output for back propagation algorithm. Here the customer requirements become the input to neural network and the output is the voice of customer. The hidden layer represents the engineering characteristics.

Neural network and statistical tools are employed for analysis. The approach for building forecasting model is adopted from integrated QFD model methodology which was introduced by San Myint (2003). The neural network technique is used to overcome QFD weakness in subjective judgments of relationship values with the help of human expert.

CONCLUSION

The various benefits of using the QFD method includes

- 1. Customer focussed product development:** The system and product design requirements to include system supportability requirements and objectives can be found out from customer

Figure 20: Neural Network architecture

Figure 21: Architecture for analysing QFD for Customer Voice

Figure 22: Step To Carry Out For Building Forecasting Model

requirements. This includes the 'voice of customer' into early system design process.

2. **Shorter system development cycles:** The application of QFD helps to avoid the need for 'fire fighting' during detail system design. There is more emphasis on 'before the fact', rather than 'after the fact'. The overall system or product development cycle time is likely to be reduced by a factor of 33% to 50% through proper and time implementation of QFD.
3. **Enhanced early system design efficiency:** QFD facilitates a proactive rather than reactive approach to system and product design and development. This directly impacts design efficiency through fewer, earlier, and easier to

incorporate design changes. This is important since the ease and cost of implementing a design change is a function of the system design phase. The ease of effecting a system design change reduces progressively as one proceeds through the life cycle. Below stated figure shows a comparison and reduction of the number of design changes necessary with or without proper application of QFD. Here the numbers of design changes made by Japanese company during product design with QFD are compared to the number of design changes made by a US company which do not use QFD.

Figure 23: Comparison of design changes necessary with and without QFD.

Figure 24: Toyota production start-up problems before and after QFD.

4. **Effective early system design tradeoffs:** The integrated representation of information from diverse sources within the QFD matrix promotes greater visibility and facilitates fulfillment of effective design tradeoff. Tradeoff decisions can be used to utilize strategic opportunities identified as a result of the customer benchmarking exercise. Correlation of requirements with DDPs provides insight into necessary product strengths.
5. **Fewer production start up problems:** The proactive approach inbuilt within the QFD method involves early consideration of downstream issues leads to manufacturing, distribution, installation, operation, and sustaining support. This reduces start up problems. As shown in below graph, the Toyota Company in Japan initially experienced lot of problems at production start. This was controlled through proper implementation of QFD. This resulted in reduced number of problems across the board.
6. **Lower start up costs:** Fewer start up problems converts into reduced start up costs. Figure 21 shows two curves depict the result of applying QFD at Toyota Auto Body over 7 year period. The cost index of the program reduced from 100 in 1977 to 39 in 1984. This shows 61% reduction in start up costs over this 7 year period.
7. **Reduced deployment and support costs:** Benefits of QFD can be derived event after production start in the form of reduced problem for customer's leads to reduced warranty costs and sustaining support costs.

Figure 25: Startup and pre-production costs at Toyota before and after QFD

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