Practical Application For Designing Quality House (Case Study)

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Abstract

Quality Function Deployment (QFD), as came in definition ,is a systematic thinking process for product planning that enables businesses to consider the characteristics of product to ensure that products satisfy customer requirements for it is a customer –driven quality management and product development system for achieving higher customer satisfaction . (QFD) has become a widely used tool in the product development process. It helps design teams gather the wants and needs of the customer and organize and utilize this data so that a product which satisfies the customer will be developed. It addresses dimensions including customer desire, quality characteristics, functions, parts, and failure modes. One of the reasons for the success and acceptance of QFD is that it is a very versatile tool. The traditional matrices and process can be modified in many different ways to fit the needs of the product team. Like any innovation, however, QFD in practice has been implemented with varying degrees of success. QFD is a system engineering process, which can be applied to large systems. It can be extended to a project functions, project phases, project resource utilization, and other areas such education. QFD utilizes the house of quality (HOQ) as a method of understanding customer requirements, establishing the priorities of design requirements, and product segmentation and positioning.

The research presents how to build the house of quality through a real case study. The aim of this research is emphasis that such techniques should be strongly considered for inclusion in any Total Quality Management effort and specially can be applied to practically any manufacturing or service industry. So we applied the new techniques even in representing the House of Quality matrix by using Auto Cad program. that we consider an electrical motor (1/4 HP) in our case study because of its wide use, especially at summer season in the air coolers, by consulting the specialists from engineers and technicians especially in our field "Mechanical Engineering' as well as consumers by the huge field study in industry as well as markets with focusing on some main customer requirements, then comparing our results with other foreign products.

In short the organizations should recognize such tools and techniques in the context of total Quality Management in order to increase the knowledge and personal efficiency. as we concluded in our case study by taking many different variables.

Keywords: quality Function Deployment (QFD), house of quality (HOQ), case study, customer requirements

التطبيق العملي لتصميم بيت الجودة في احدى الشركات الصناعية

الخلاصة

ان نظام انتشار الجودة (QFD) Quality Function Deployment وكما جاء عند تعريفها في مصادر عدة هي عملية تحليل و تقييم بشكل متسلسل و مترابط في تخطيط الأنتاج بحيث تلبي

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متطلبات و احتياجات الزبون بما يرضيه من مواصفات و بعد اجراء التحسينات الضرورية لضمان الجودة.
وبذلك أصبح هذا النظام كأداة واسعة الانتشار في عملية تطوير المنتج حيث أنها تساعد المصممين للربط بين متطلبات و احتياجات كل من الشركة المنتجة والزبون, بحيث يمكن الحصول على منتج مطابق للمواصفات المرغوبة , ومن أسباب نجاحها باعتبارها كأداة متعددة و مختلفة الأمكانيات في التقويم و القياس بما يتضمن رغبات الزبون , فضلا عن امكانية تحوير العملية والمصفوفات بطرق مختلفة بحيث تلائم متطلبات الانتاج كذلك.
ومع ذلك فأن (QFD) مثل أي اجراء اخر تتفاوت في درجة ودقة تحقيق الأهداف ويمكن تطبيقها بأعتبارها كعملية نظام هندسية لمجالات مختلفة و على وجه الخصوص للشركات و المشاريع الكبيرة والضخمة بحيث من الممكن ان تتعدى و تمتد الى مختلف أطوار ومراحل المشاريع وحتى عند عمل دراسات الجدوى وأكثر من ذلك في اختصاصات مختلفة اخرى مثل العمليات التعليمية و غيرها.
ومن هذا النظام تم الأفادة من طريقة بيت الجودة House of Quality (HOQ) باعتباره اداة تحليلية متطورة لمساعدة فرق العمل في الشركات الكبرى لترجمة رغبات الزبون في تصميم المنتج و هذا من خلال نظام هندسي متكامل على شكل مصفوفات لدراسة جميع المتغيرات المؤثرة على المنتج التقنية منها والهندسية التي تخص الزبون ايضا بهدف التطوير و التحسين للجودة عن طريق المقارنة مع مثيلاتها من المنتجات الاجنبية.
تضمن البحث دراسة الحالة العملية (case study) لمنتج من نوع المحرك الكهربائي المستخدم في مبردات الهواء و الذي يتم انتاجه في شركة الصناعات الكهربائية في الوزيرية بعد اجراء الدراسات الميدانية و الأستفسار من المختصين من مهندسين و فنيين وعلى وجه الخصوص في مجال الهندسة الميكانيكية (مجال اهتمامنا),وذلك لسعة استخدامه و خاصة في فصل الصيف ,ثم جرت مقارنته بالمنتجات المماثلة له و المتوفرة في الاسواق المحلية وذلك بأستشارة و ألأخذ باراء العديد من المستهلكين بأجراء البحوث الميدانية , باستخدام نظام بيت الجودة و بالاستعانة ببرنامج ال(auto cad) لرسم المصفوفة و ايضاح المتغيرات المؤثرة على المنتج بما يخص المواصفات و الخصائص الميكانيكية من وجهة نظر هندسية بالاضافة الى متطلبات الزبون و بما يهدف الى تطوير هذا المنتج و زيادة كفاءته و بالتالي ارضاء الزبون.
و من ابرز ما توصلنا اليه من نتائج بعد تصميم و بناء أركان بيت الجودة الخاص بالمنتج المذكور و بالاستناد على استخدامنا لعدد كبير من المتغيرات التقنية و بعد مداخلتها لاحتياجات الزبون ان هناك بعض المتغيرات التي تستلزم الاهتمام بها اكثر من الاخرى و عكس ما هو متوقع او تقليدي في سبيل تطوير المنتج.

Introduction

Every successful company has always used data and information to help in its planning processes. In planning a new product, engineers have always examined the manufacturing and performance history of the current product. They look at field test data, comparing their product to that of their competitor's product.
They examine any customer satisfaction information that might happen to be available. Unfortunately, much of this information is often incomplete. It is frequently examined as individual data, without comparison to other data that may support or contradict it. By contrast, Quality Function Deployment (QFD) uses a matrix format to capture a number of issues that are vital to the planning process. [10].

Increased global competition, rapid technological change, and market fragmentation have all reduced product life cycles. Consequently, corporations must understand customer requirements and effective product positioning strategies to remain competitive.

Over the past few years, two issues have become mantras for corporations throughout the world: "mass customization "and "meeting or exceeding the customer's needs". Companies have rushed to offer a range of products that covered almost every configuration their target market might want. However, as the number of products being offered by companies grew larger, it became evident that the cost estimates used to determine the profitability of these new product offerings did not fully account for all the costs associated with providing this variety. Increased inventories above what was expected, additional setups, and the complexity of managing the increased variety were not always included in the original cost estimates, and the expected profits did not follow because of these factors. These additional cost drivers were not included because of the difficulty in estimating their effects.[6]

(QFD) is a method that uses matrices to show the relationship between two or more sets of concepts. QFD directly facilitates a customer-focused product and process design by making explicit the relationship between design characteristics and customer requirements. [2]

QFD translates customer requirements into technical specifications appropriate for each stage of product development and production.[5]

According to Hauser and Clausing, it is "a kind of conceptual map that provides the means for interfunctional planning and communication."[10]

(QFD) is a methodology for building the voice of the customer into product and service designs. It is a team tool, which captures customer requirements and translates those needs into characteristics about a product or service. [2]

The origins of QFD come from Japan. In 1966, the Japanese began to formalize the teachings of Yoji Akao on QFD.[2,13]

QFD was born as a method or concept for new product development under the umbrella of Total Quality Control, to flourish business, designing products and services that excite the customer and creating new markets is a critical strategy.

Growth can be achieved in many different ways to create customer delight.[10].

Japanese industries broke from their post-World War II mode of product development through imitation and copying and moved to product development based on originality. QFD was born in this environment as a method or concept for new product development under the umbrella of Total Quality Control. The subtitle "An Approach to Total Quality Control" added to *Quality Function Deployment.* [4]

Since the late 1980's, QFD has become widespread throughout many industries, including automotive, electronics, and defense.[3]

QFD was developed in the manufacturing industry and its purpose is primarily to find out customer requirements systematically and structurally and to translate them into specific design and manufacturing requirements.

Surveys, content analysis, interviews with customers and visits to the *gemba* are generally used in order to complete the process of gathering the Voice of the Customer (VoC). [11]

(QFD) is a well-known tool for identifying customer needs and translating customer requirements into a technical response.
The translation of customer needs into manufacturing
Requirements are supported by sequence of four „Houses of Quality“:
1- Customer requirements are translated into product specifications
2- Product specifications are translated into component characteristics
3- Component characteristics are translated into production process characteristics
4- Process characteristics are translated into manufacturing specifications [8]
A "full" QFD consists of four phases:
Phase 1, Product Planning: Building the House of Quality. Led by the marketing department, Phase 1, or product planning, is also called The House of Quality.
Many organizations only get through this phase of a QFD process. Phase 1 documents customer requirements, warranty data, competitive opportunities, product measurements, competing product measures, and the technical ability of the organization to meet each customer requirement. Getting good data from the customer in Phase 1 is critical to the success of the entire QFD process.
Phase 2, Product Design: This phase 2 is led by the engineering department.
Product design requires creativity and innovative team ideas. Product concepts are created during this phase and part specifications are documented. Parts that are determined to be most important to meeting customer needs are then deployed into process planning, or Phase 3.
Phase 3, Process Planning: Process planning comes next and is led by manufacturing engineering. During process planning, manufacturing processes are flowcharted and process parameters (or target values) are documented.
Phase 4, Process Control: And finally, in production planning, performance indicators are created to monitor the production process, maintenance schedules, and skills training for operators. Also, 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 Phase 4.[12]
The 3 main goals in implementing QFD are:
1. Prioritize spoken and unspoken customer wants and needs.
2. Translate these needs into technical characteristics and specifications.
3. Build and deliver a quality product or service by focusing everybody toward customer satisfaction.[12].

The House of Quality

The House of Quality Matrix is the most recognized and widely used form of this method. It translates customer requirements, based on marketing research and benchmarking data, into an appropriate number of engineering targets to be met by a new product design. Basically, it is the nerve center and the engine that drives the entire QFD process.

A simplified matrix for interaction between potential customer needs and engineering design elements has been termed the house of quality (HOQ). QFD utilizes the HOQ as a construct for understanding customer requirements and prioritizing design requirements. The HOQ aims to design a product or modify a product design so as to meet or exceed customer expectations.[5]

This matrix is especially powerful because of the amount of information that can be documented and analyzed. It requires that the team ask specific questions about customer needs, competitors, and how their organization will meet the challenges of providing products that delight the customer. [2]

(QFD) is a widely used Industrial Engineering technique for systematically focusing on customers' requirements. Usually, cross-functional teams within the business use it to identify and resolve issues involved in product development, process control, services, etc. Here, we introduce its first step, which is called the "House of Quality". It organizes important activities and information (Figure 1).

The six components are:

1. Customer Requirements: A structured list of customer requirements for a product, usually described in their words (also called Voice of Customer). Fig. (1-a)
2. Planning Matrix: A matrix quantifying the customers' requirement priorities and their perceptions of the performance of existing products. These priorities can be adjusted based on the issues that the design team identifies. Fig. (1-b)
3. Technical Requirements: A set of engineering characteristics to meet the customer needs. It describes the product in the terms of the company (thus called the Voice of the Company). Fig. (1-c)
4. Interrelationships matrix: A matrix that relates customer requirements and technical requirements to identify issues, and group these issues into different sectors according to their importance and priorities. Fig. (1-d)
5. Roof: A display of where the technical requirements that characterize the product support or impede one another, Considers impact of technical requirements on each other, and make Feature to feature comparison.Fig. (1-e)
6. Targets: A summary of the conclusions drawn from the data contained in the entire matrix and the team's discussions. Fig. (1-f)

In our data mining context, we are primarily interested in the first four components of the House of Quality:

1. Customer Requirements: Application requirements expressed as the classes that are important to the user (or customer).
2. Planning Matrix: A matrix quantifying the user's requirement priorities.
3. Technical Requirements: Attributes and values (other than the class attribute and its class values) that can be used to deal

with the problems of certain classes.

4. Interrelationships matrix: Linkages between classes and attributes to identify issues and opportunities for problem solving. This will be discussed in greater detail below within the case study. [1, 10]

The parts of The House of Quality is expressed more extremely in Fig.(2) ,with noticing that the design priorities is the percentage of total that showing the importance of requirements.

We can observe the effect of customer's requirement to develop the product as shown in Fig.(3) through the following stages:-

1. Customer requirements are translated into product specifications.
2. Product specifications are translated into component characteristics.
3. Component characteristics are translated into production process. characteristics
4. Process characteristics are translated into manufacturing specifications.

Case Study

The initial steps in forming the House of Quality include determining, clarifying, and specifying the customers' needs. These steps lay the foundation for a clearly defined venture and will ensure a project or process is well thought out prior to any further development. In our case study we consider an electrical motor (1/4HP) , because of its wide use, especially at summer season in the air coolers , while the company produce other motor types(1/2HP,1HP).

As mechanical engineers we focused basically on some features such as (wire type, Horse power, Manufacturing of stator ,the ball bearing and screws features ,Manufacturing of covers,……cost,etc.) because of their importance in our field.

Past research and practical implementations by business have generally used focus group opinion, expert opinion, and Analytic hierarchical process (AHP).

1) Focus group opinion: A group of managers meet and collectively develop a competitive evaluation. The focus group summarizes the customer surveys (including users, consignees, and engineers), which are conducted either by questionaire or interview. A scale of 1 to 9 is generally employed, with 1 representing low importance and 9 symbolizing high importance. The QFD team also employs the "degree of importance" values obtained by evaluating customer demands, where 5 means "very important", 4 indicates "important",3 is "less important",while 2 means "not so important", and 1 denotes "not important".

2) Expert opinion: Various experts are asked to survey product technology, market environment, and marketing strategy to rank their relative importance. The Delphi method determines their relative ranking by circulating a series of questionnaires among individuals with relevant knowledge or abilities.

3) AHP: AHP is a widespread decision model for handling multi-criteria problems. AHP is an effective and efficient method for ranking importance since it

combines the advantages of the subjective judgment and personal preference methods, as well as the risk attribute weighting method. AHP is an excellent technique for modeling complex decisions, since it effectively prioritizes alternative variables in many studies. A pair-wise comparison of all criteria with respect to customer satisfaction is conducted to obtain the AHP rating for each criterion, using a nine-point scale that compares participants' judgments or preferences. AHP ranks the various alternatives under consideration. With this method, consistency refers to transitivity and magnitude. If the consistency ratio is higher than 0.1, then it may indicate that the model is unspecified, a key variable has been omitted, a clerical error has occurred, or the judge was not conscientious in making the paired comparisons.[5]

1- Clarifying Customer Requirements (voice of costumer)

Customers buy benefits and producers offer features. This seems like a relatively simple notion; however, unless customers and producers are perfectly in tune with one another, it may be very difficult to anticipate these features, or each underlying benefit from each producer. It is of utter(absolute) importance to translate the wishes of each and every customer into some tangible values that can be turned into engineering specifications.[9]

Specifying the Customer Needs After determining what items are most important to the customer, organizations must translate them into particulate specifications. Nothing can be produced, serviced or maintained without detailed specifications

This QFD process is identifying what the customer wants and what must be achieved to satisfy these wants. In addition, regulatory standards and requirements dictated by management must be identified. Once all requirements are identified it is important to answer what must be done to the product design to fulfill the necessary requirements.

In our case study the customer requirements were put according to the usage of the device in the best way.

These parameters can be derived from several locations. Organizations can use known data from market research, or conduct new studies to gather necessary information. In any event, the needs, which were clarified and then explicitly stated, should be satisfied to the best of that organization's ability. as shown in fig.(4).

2- Customer Importance Ratings

The next step in the QFD process is forming a planning matrix. The main purpose of the planning matrix is to compare how well the team met the customer requirements compared to its competitors. The planning matrix shows the weighted importance of each requirement that the team and its competitors are attempting to fulfill. Customer ratings, typically ranging from 1 to 5, are given to each company under each requirement. As in Fig.(5)

5= very important
4= important
3= less important
2= not so important
1= not important

3- costumer Evaluation to product

This step aim is to compare the product with other companies products to see how much this product is useful , in our case study we put degrees from 1-5 to evaluate each requirement as shown:

5= excellent
4= very good
3= good
2= not so good
1= poor

And this is shown in the matrix as for our product, as competitor's product. this can be noticed in Fig.(6).

4- Project Objectives

This step shows what requirements should be developed according to customer needs and the other companies products , as shown in the table below

The attributes got these values because they are lesser the competitor's product values so we had to improve them to these values, while the other attributes (fits over different sizes, finishing) stayed as they were because they didn't need improvement. These target values are shown in Fig. (7).

According to get the Improvement Rate we can use the following equation:

Improvement Rate = Target value / Evaluation score ……(1)

By applying the above equation using Fig.(7) we get the results in table (2)

After getting these results the QFD team can make the right decisions to improve and develop the attributes.

Then we have to find the (weight) or the importance of each attribute or costumer requirement by using the following equation:

Weight = Improvement rate * the relevant importance weight factor ……(2)

by applying this equation we could find the weight for each attribute as following:

Easy to fix: 2 * 3= 6
Low noise and vibration:1.7 * 5 = 8.5
Etc. as shown in Fig. (8).

The sum of the weights is 51.7, so we can find the percentage of weight for each attribute, taking the example below:

(Weight %) for (Easy to fix) attribute = 6*100/51.7= 12% ……………etc.

5- Technical parameters (voice of engineer)

In this step the QFD team of the company should put the main technical requirements for this product that would be interrelated with the customer requirements in the matrix. These requirement are displayed in Fig.(9).below.

3- Direction of Improvement

As the team defines the technical descriptors, a determination must be made as to the direction of movement for each descriptor to state if it has to be improved in which way as shown in Fig.(10) by arrows.

6- Interrelation matrix

The main function of the interrelationship matrix is to establish a connection between the customer's product requirements and the performance measures designed to improve the product. With this customer overview, the company can begin to formulate a strategy to improve their product. In doing this, the strengths and weaknesses of the company are weighted against the customer priorities to determine what aspects need to be changed to surpass the competition, what aspects need to change to equal the competition, and what aspects will be left unchanged. The optimal combination is desired.

Knowing what improvements need to be made allows the list of performance measures to be generated and displayed across the top of the interrelationship matrix. By definition, a performance measure is a technical measure evaluating the product's performance of a demanded quality. In other words, the company must take the voice of the customer and translate it into engineering terms. The matrix will have At least one performance measure for each demanded quality.

After setting up the basic matrix, it is necessary to assign relationships between the customer requirements and the performance measures.

These relationships are portrayed by symbols indicating a strong relationship, a medium relationship, or a weak relationship. The symbols in turn are assigned respective indexes such as 9-3-1, 4-2-1, or5-3-1.

When no relationship is evident between a pair a zero value is always assigned.

- Strong Relationship = 9

- Medium Relationship = 3

- Weak Relationship = 1

While the empty cell means there is no relationship between the customer need and the product technical requirement.

For example there is strong relationship between the maintainable feature and the manufacturing of covers, while the relationship between the noise and the wire type is weak.

After putting these relationships we can show the importance of the project by points using the following equation with regard of results that we got before from Fig.(8):

Cell score = Relationship's strength * weight (%) ……(3)

By applying the above equation on our case study we obtain the points of the matrix's cells:

Easy to fix ------------ to the manufacturing of stator: 1*12 = 12

Low noise and vibration ------------- to the horse power 3*16= 48 Etc. as shown in Fig.(11).

After filling the cells we notice that the sum of points of each requirement could be count easily , as we notice that the points of the horse power(48+12+36+12+12=120),while the sum of all points equals 3382, according to these points we can expect the most important requirements that satisfy the customer , so we can get the percentage of each technical requirement (21% for manufacturing of covers ,19% for the ball bearing and screws features) which put them as the most important requirements to deal with in designing this product because they got the highest priority percentage.as we can see in Fig.(12)

7- Interaction between product specification

Performance measures in existing designs often conflict with each other. The technical correlation matrix, which is more often referred to as the Roof, is used to aid in developing relationships between customer requirements and product requirements and identifies where these units must work together otherwise they will be in a design conflict. The following symbols are used to represent what type of impact each requirement has on the other. These symbols are then entered into the cells where a correlation has been identified. The objective is to highlight any requirements that might be in conflict with each other. as in Fig.(13).

Any cell identified with a high correlation is a strong signal to the team, and especially to the engineers, that significant communication and coordination are a must if any changes are going to be made. Many technical requirements are related to each other so working to improve one may help a related requirement and a positive or beneficial effect can result. On the other hand, working to improve one requirement may negatively affect a related requirement as mentioned above. One of the principal benefits of the Roof is that it flags these negative relationships so they can be resolved. If these issues aren't settled satisfactorily, some aspects of the final product will dissatisfy the customer.

The technical properties matrix uses specific items to record the priorities assigned to technical requirements. It also provides a technical performance achieved by competitive products and the degree of difficulty in developing each requirement. The final output of the matrix is a set of target values for each technical requirement to be met by the new design. In some cases, organizations are not able to create the most optimum design because of constraints related to cost, technology, or other related items.

Technical analysis (Setting Design Targets & Benchmarks)

The customer requirements are distributed across the relationships to the quality characteristics. This gives an organization prioritized quality characteristics. High priority quality characteristics usually indicate that working on this technical issue will deliver great value to the customer. A high quality characteristic weight indicates strong relationships with high priority demanded quality items.

An organization's current products can be benchmarked technically with competitors' products on the high priority quality characteristics. In many cases, organizations should not be surprised to learn that competitors are better at a given task or characteristic. QFD assists organizations to identify technical areas and to develop areas where they can achieve the most cost effective customer satisfaction. Organizations can then examine the Customer Context for usage concerns that must be accounted for, and set design target specifications for our quality characteristics. At a minimum, current performance standards should be maintained. So we need to put the units, cost , or the type of each requirement so that we can compare it with the competitor's product. with regard our local product wire type is (A) and the competitor's is (B)…etc. As shown in table (3).

So the final form of the house of quality for this case study can be seen in Fig.(14).

Conclusions

In few words QFD is: *The voice of the customer translated into the voice of the engineer.*

Sometimes importance levels and requirements may mislead the designers if they only listed in a table. Thus, the requirements should be considered as concepts and the relationships between the concepts should be examined visually. Concept mapping provides the tool needed in this situation. Concept mapping can reveal the requirements which are hidden behind the words.

As in our case study the engineer or the team of work may pay more attention to some variables more than others such as wire type, or diameter of the wire but the house of quality showed that the more important variables are manufacturing of covers(21%) and the ball bearing features(19%) because they got the highest points and percentage of total as we showed before after taking the customer needs with regard to these technical requirements by the interrelationship between these two variables. Then comes the importance of cost which took (17%)and this requirement has an important position within the practical thinking in the designing process. and so on till we reach the horse power requirement which took (4%) as importance ,while it took a great attention for the engineers and technicians ,but it did not get this great effect to the customer requirements .

While comparing the local product with the competitors' (Syrian and Persian) we noticed that there are some features needed to be improved such as(easy to fix, low noise and vibration)requirements, some of them are better such as (maintainable , low cost)and the other requirements are most similar in general such as electrical safety, but we proposed that some requirements should be improved to higher values such as (easy to fix, maintainable,…….etc.).

Because of this focus, the process leads to improved customer understanding and the ultimate outcome = a satisfied customer.

Recommendations

As what had been taken in this case study, it can be recommended the following:

∗ We propose to the company to regard our study and the conclusions we got to improve the product in efficiency, maintenance, safety and cost to satisfy the customer's demands.

∗ It is strongly needed for using the house of quality in the institutes specially the ones that are dealing with the customers directly.

∗ Take other variables and more technical requirements for the same product or any others.

∗ The House of Quality functions as a living document and a source of ready reference for related products and future upgrades. While it is a great communication tool at each step in the process, the matrices are the means and not the end. Its purpose is to serve as a vehicle for dialogue to strengthen vertical and horizontal communications.

Through customer needs and competitive analysis, the House of Quality helps to identify the critical technical components that require change. Issues are addressed that may never have surfaced before.

These critical issues are then driven through the other matrices to identify the critical parts, manufacturing operations, and quality control measures needed to produce a product that fulfills both customer needs and producer needs within a shorter development cycle time.

∗ The house of quality can be applied to different multiple issues other than industry such as education, banks, and transportation.

∗ The house of quality must be redesigned after every while to gain the developments in technology and to pay more attention to the customer needs.

∗The house of quality can be automized using Exel program to get the results of all calculation within the matrices easily and more accurate.

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Table (1) Target Values

Target value	Product attribute
4	Easy to fix
5	Low noise and vibration
4	maintainable
3	Low electrical consuming
5	Electrical safety
4	efficiency
3	Low cost

Table (2) Calculating Improvement Rate

Improvement Rate	Customer requirements
4/2 = 2	Easy to fix
5/3 = 1.7	Low noise and vibration
2/2 = 1	fits over different sizes
4/3 = 1.3	maintainable
3/2 = 1.5	Low electrical consuming
5/3 = 1.7	Electrical safety
3/3 = 1	finishing
4/3 = 1.3	efficiency
3/2 = 1.5	Low cost

Table (3) Technical analysis

Units	type	HP	type	type	type	type	mm	$
Our product	A	$\frac{1}{4}$	x	K	A	x	0.3	30
Competitor A's product	B	$\frac{1}{4}$	X	L	B	X	0.3	40
Competitor B's product	B	$\frac{1}{4}$	Y	K	B	Y	0.3	55
Target Value	B	$\frac{1}{4}$	X	L	B	X	0.3	25

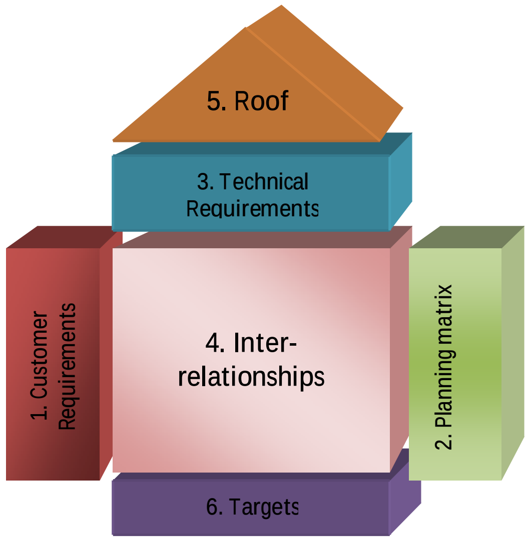


Figure (1)

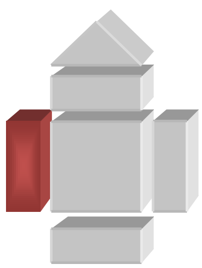
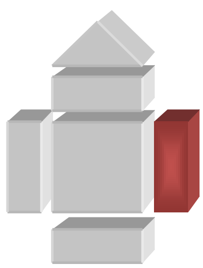


Fig. (1-a)



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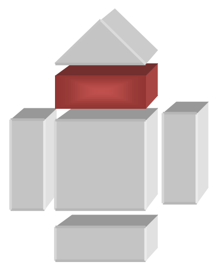

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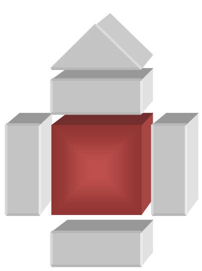

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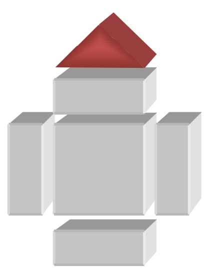

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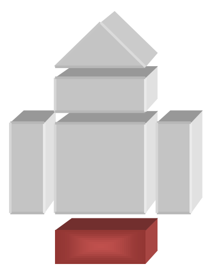

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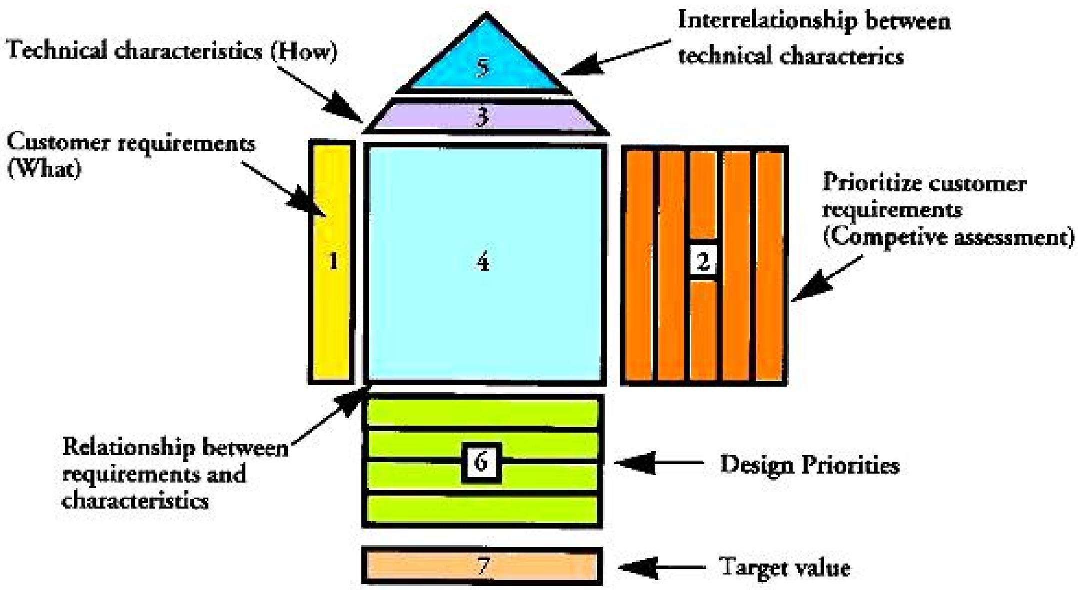

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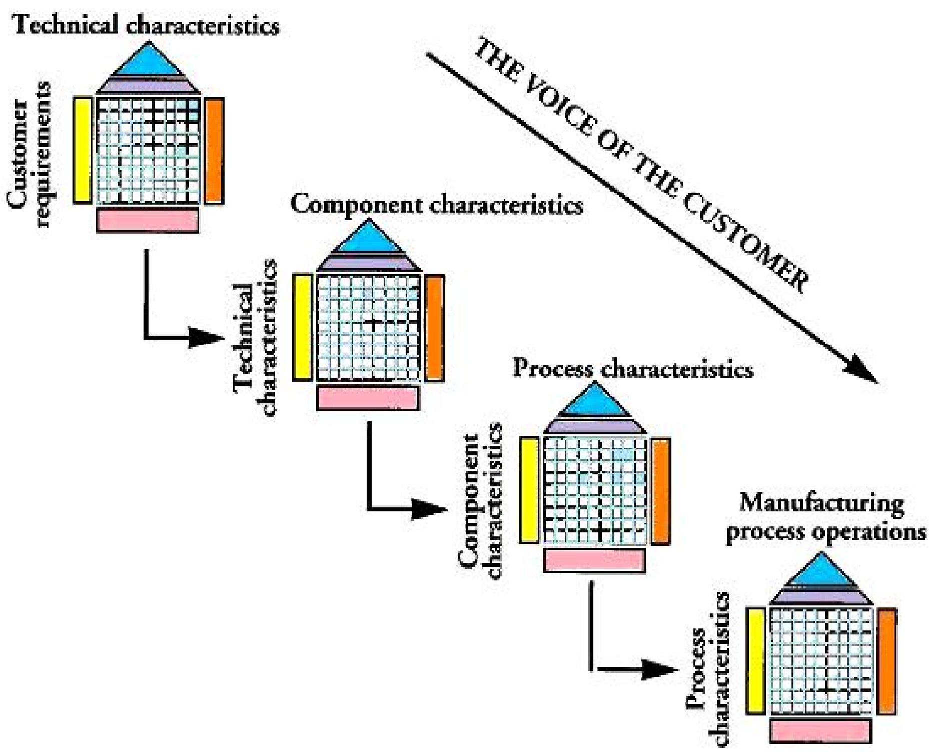

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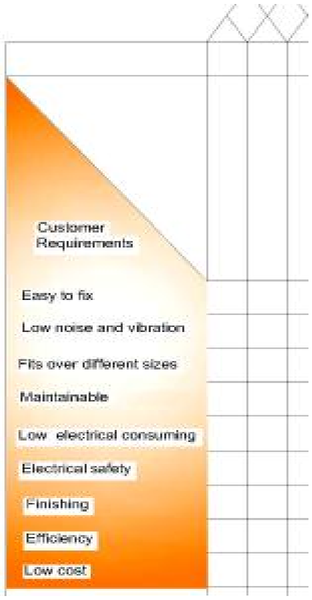

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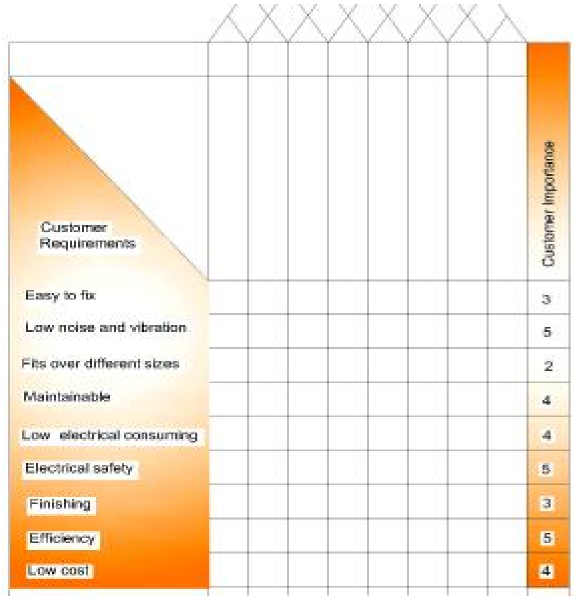

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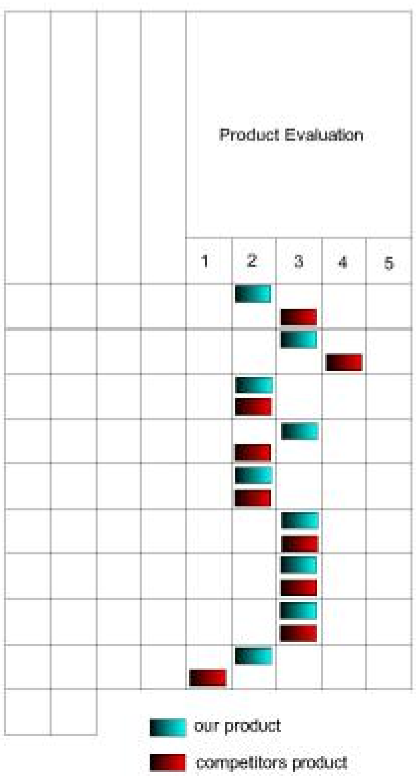

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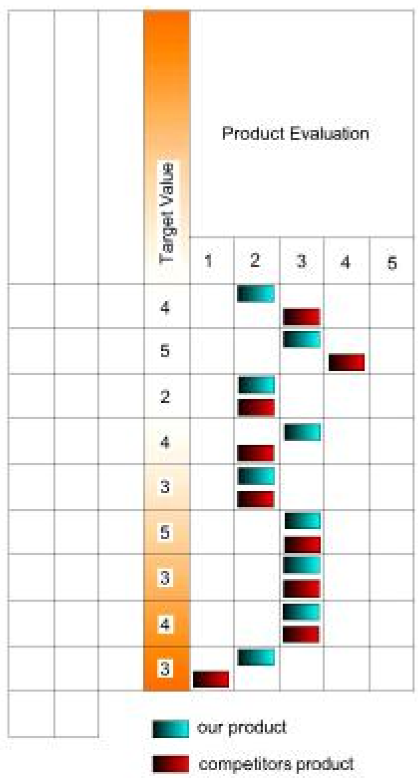

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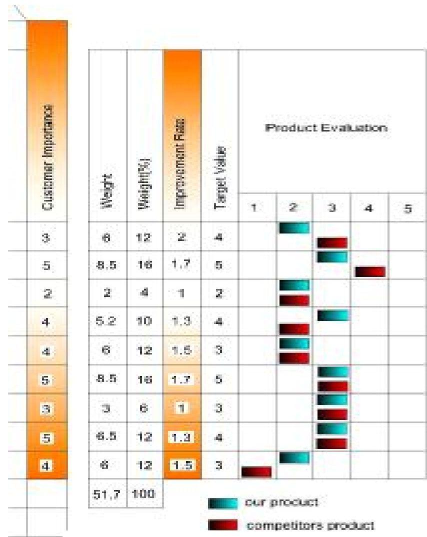

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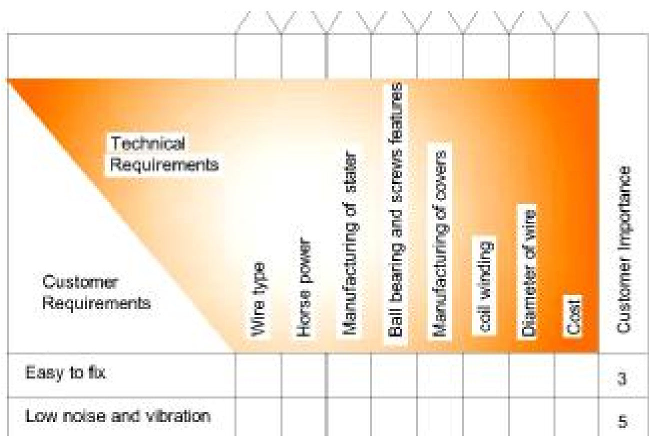

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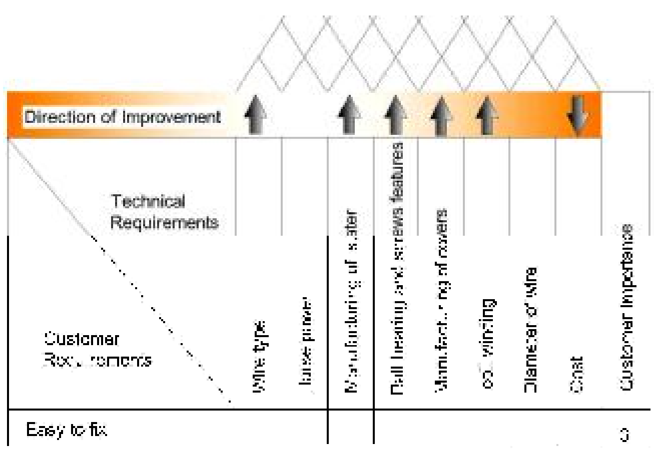

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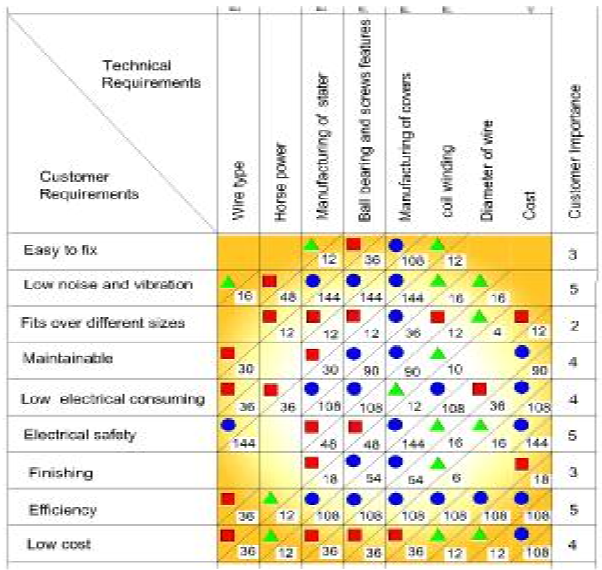

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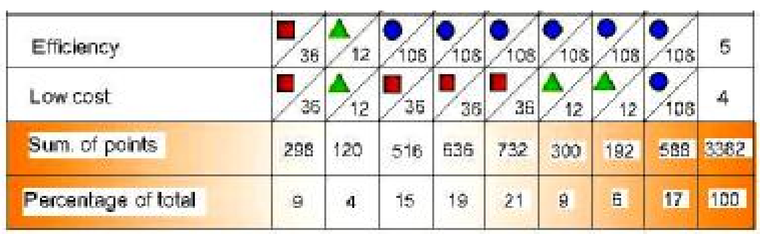

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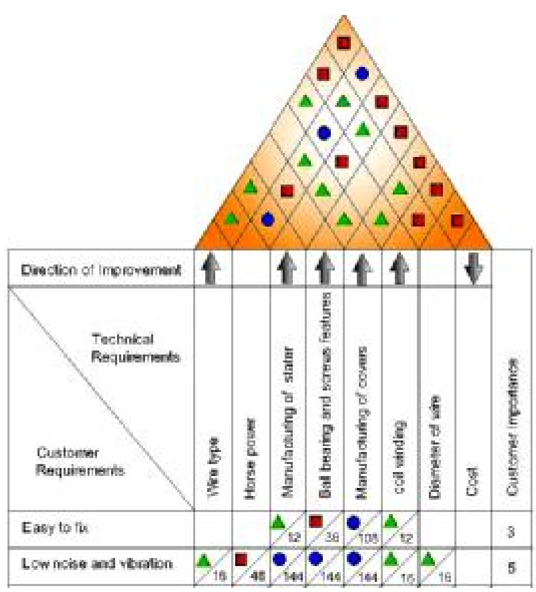

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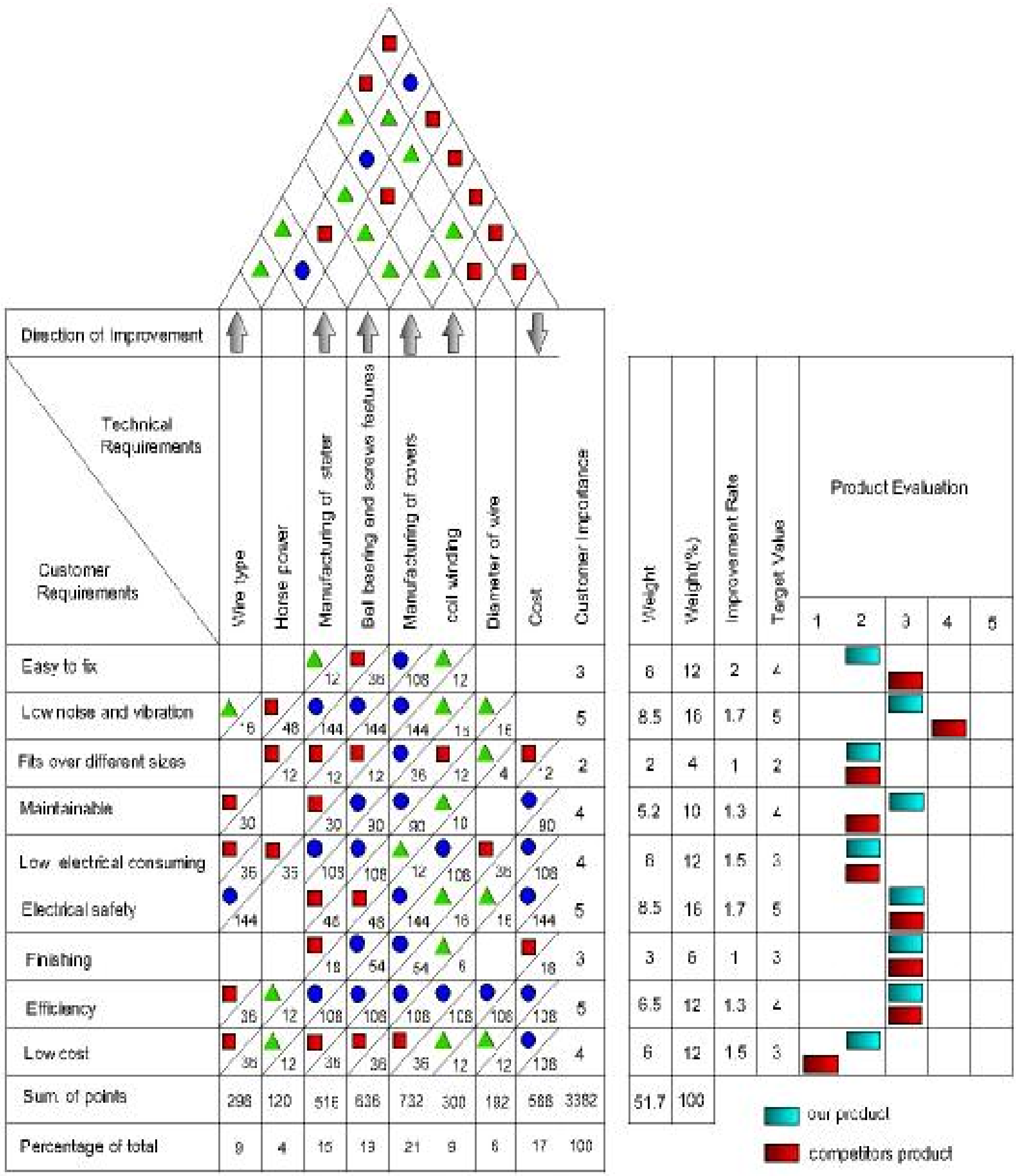

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Competitor A's product	B	$\frac{1}{4}$	X	L	B	X	0.3	40
Competitor B's product	B	$\frac{1}{4}$	Y	K	B	Y	0.3	56
Target Value	B	$\frac{1}{4}$	X	L	B	X	0.3	25

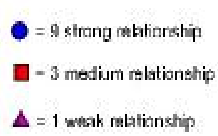

Figure (14)