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Quality Function Deployment in Continuous Improvement

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1. Introduction

Six Sigma is a customer focused continuous improvement strategy and discipline that minimizes defects. It is a philosophy to promote excellence in all business processes with aggressive target goals. Six Sigma is a five phase methodology for continuous improvement which uses a metric based on standard deviation. It is also a statistic which describes the amount of variation in a process. Six Sigma is focused on customer satisfaction and cost reduction by reducing variation in processes.

At the core of the method, Six Sigma utilizes a discipline that strives to minimize defects and variation of critical variables towards an achievement of 3.4 defects per million opportunities in product design, production, and administrative processes. Customer satisfaction and cost reduction can be realized by reducing variation in processes that produce products and services which they use. While focused on reducing variation, the Six Sigma methodology uses a well-defined problem solving approach with the application of statistical tools. The methodology uses five phases including Define-Measure-Analyze-Improve-Control (DMAIC). The purpose of the five phases are to define the problem, measure the process performance, analyze the process for root causes, improve the process by eliminating or reducing root causes, and control the improved process to hold the gains.

The goals of Six Sigma include developing a world-class culture, developing leaders, and supporting long-range objectives. There are numerous benefits of Six Sigma including a stronger knowledge of products and processes, a reduction in defects, an increased customer satisfaction level that generates business growth and improves profitability, an increased communication and teamwork, and a common set of tools. Six Sigma is commonly credited to Bill Smith, an engineer at Motorola, who coined the term in 1984. The concept was originally developed as a safety margin of fifty percent in design for product performance specifications. This safety margin was equivalent to a Six Sigma level of capability. Since it's first introduction, Six Sigma has continued to evolve over time and has been adopted throughout the world as a standard business practice.

In order to achieve Six Sigma, an organization must understand the customer's wants and needs, also known as the voice of the customer (VOC). The voice of the customer is defined as the identification, structuring, and prioritization of customer needs. Within the Six Sigma DMAIC methodology, gathering the voice of the customer falls within the define phase. This enables the team to fully understand the customer's expectations at the beginning of

the project. Prior to initiating any project or process improvement initiative, the organization or team must determine how the customer defines quality. The customer is typically surveyed or interviewed (among other techniques) to determine their expectations and these are then analyzed using quality function deployment (QFD). A critical aspect of a QFD analysis is gathering the voice of the customer to assess how a product or service measures against what the customer wants or expects.

Customers continually want more reliable, durable products and services in a timely manner. In order to remain competitive, all organizations must become more responsive to customers, strive for Six Sigma capability, and operate at world class level.

Quality function deployment has been widely used to capture the voice of the customer and translate it into technical requirements in the development of products and services. It is a link between product or service development and technical specifications to achieve customer satisfaction. Applications of QFD range from product development, service development, and product re-projecting (Miguel & Carnevalli, 2008).

QFD was developed by Yogi Akao in 1966 and was initially introduced in Japan in the late 1960s and early 1970s. QFD was first implemented in Mitsubishi's Kobe shipyard in 1972. Following QFD's introduction in Japan, it was then implemented primarily in manufacturing settings in the United States. Since then, it has been successfully used in many industries and various functional areas, including product development, quality management, customer needs analysis, product design, planning, engineering decision making, management, teamwork, timing, costing and other areas (Chan and Wu, 2002).

Assessing customer requirements is a complex task. Traditional approaches have focused on present customer needs; however, Wu, Liao, and Wang (2005) have concluded that, since customer needs are dynamic and may vary drastically over time, analyzing future customer needs is critical to an organization's long-term competitiveness. Customer needs may vary depending on various factors, the most important and complex of which is human nature. Other factors may include cultural setting, work environment, age, sex, etc. The most common way to determine customer requirements is through direct customer interaction, but surveyors must consider what a customer means rather than what he or she says.

Quality function deployment is a systematic process to integrate customer requirements into every aspect of the design and delivery of products and services. Understanding the customers wants or needs from a product or service is crucial to the successful design and development of new products and services. QFD is a system that utilizes customer demands to meet client missions by outlining what the customer wants in a service or product. QFD involves the construction of one or more matrices, called quality tables, which ensure customer satisfaction and improved quality services at every level of the service and product development process. QFD is a planning process that translates customer needs into appropriate company requirements at each stage, from research and product/service development to engineering, manufacturing, marketing/sales, and distribution.

It is crucial for any organization to understand their customers' requirements and service expectations as they represent implicit performance standards used by the customers in the assessment of service and product quality. A significant relationship between the relative quality, as perceived by the customers, and the organization's profitability has been shown.

The opportunities to apply QFD in service and business sectors are rapidly expanding. QFD has been used to enhance a wide range of service aspects in healthcare, chemical, and telecommunications industries as well as the typical product design applications. It is vital for companies to identify the exact needs of the customers and to measure their satisfaction toward a Six Sigma level to survive in the current competitive market. QFD focuses on designing in quality rather than inspecting in quality which reduces development times, lowers startup costs, and promotes the use of teams.

QFD maintains the integrity of the VOC and generates innovative strategies to achieve an organization's vision. In addition, it leads directly to policy deployment for implementation and performance management. Overall, QFD is a service planning and development tool, that facilitates service providers with an organized way to assure quality and customer satisfaction while maintaining a sustainable competitive advantage (Akao, 1990). QFD aims at enhanced customer satisfaction, organizational integration of expressed customer wants and needs, and higher profit levels (Griffin and Hauser, 1991).

QFD is a comprehensive quality system aimed specifically at satisfying the customer. It concentrates on maximizing customer satisfaction by seeking out both spoken and unspoken needs (Helper and Mazur, 2006). QFD displays the notation of customer orientation for designing products and services. Its purpose is to listen to the customer and translate their requirements back in any business process so that the end product or service will satisfy their needs and demands (Chan et al., 2006).

Since its introduction, QFD has been used in conjunction with various techniques such as the Kano model (Sauerwein, Bailom, Matzler, & Hinterhuber, 1996), SERVQUAL (Parasuraman, Zeithaml, & Berry, 1988), analytical hierarchy process (AHP), and maximum difference (MaxDiff), among others.

The mission of this chapter is to provide an overview of QFD, the various approaches, goals/purpose of QFD, a step-by-step procedure for performing QFD, and interpreting QFD.

2. Background

The opportunities to apply QFD in service and business sectors are rapidly expanding. QFD has been used to enhance a wide range of service aspects in healthcare, chemical, and telecommunications industries as well as the typical product design applications. It is vital for companies to identify the exact needs of the customers and to measure their satisfaction to survive in the current competitive market. QFD focuses on designing in quality rather than inspecting in quality which reduces development times, lowers startup costs, and promotes the use of teams (Fisher and Schutta, 2003).

Quality Function Deployment:

QFD is a planning process that translates customer needs into appropriate company requirements at each stage, from research and product/service development to engineering, manufacturing, marketing/sales, and distribution (Pawitra and Tan, 2003). The quality function deployment method was first originated in Japan and is used to select the design features of a product to satisfy the expressed needs and preferences of the customer as well as to prioritize those features and select the most important for special attention further down the design process (Fisher and Schutta, 2003). Maritan and Panizzolo (2009) proposed

that when used in the strategic planning process, QFD maintains the integrity of the VOC and generates innovative strategies to achieve an organization's vision. They also argue that it leads directly to policy deployment for implementation and performance management. Overall, QFD is a service planning and development tool, that facilitates service providers with an organized way to assure quality and customer satisfaction while maintaining a sustainable competitive advantage (Akao, 1990). QFD aims at enhanced customer satisfaction, organizational integration of expressed customer wants and needs, and higher profit levels (Griffin, 1992).

QFD differs from traditional quality systems that aim to minimize negative quality such as poor service (Mazur, 1993). QFD provides an organized, systematic approach to bringing customer requirements into product and service design (Helper and Mazur, 2006). QFD focuses on delivering "value" by seeking out both spoken and unspoken customer requirements, translating them into actionable service features and communicating them throughout an organization (Mazur, 1993, 1997; Pun et al., 2000). It is driven by the voice of the customer and because of that, it helps service providers to address gaps between specific and holistic components of customer expectations and actual service experience. In addition, it helps managers to adopt a more customer-driven perspective, pointing out the differences between what managers visualize as customer expectations and the actual customer expectations. It provides a way to more objectively address subjective needs yet demonstrates the belief in customer focus and employee involvement for every party involved in the supply chain.

QFD is developed by a cross-functional team and provides an interdepartmental means of communication that creates a common quality focus across all functions/operations in an organization (Stuart and Tax, 1996). The unique approach of QFD is its ability to integrate customer demands with the technical aspects of a service. It helps the cross-functional team make the key tradeoffs between the customers' needs and the technical requirements so as to develop a service of high quality. Hence, QFD is not only a methodological tool but also a concept that provides a means of translating customer requirements in each stage of service development (Chan and Wu, 2002).

Voice of Customer (VOC):

A critical aspect of a QFD analysis is gathering the voice of the customer to assess how a product or service measures against what the customer wants or expects. The voice of the customer is defined as the identification, structuring, and prioritization of customer needs (Griffin and Hauser, 1991). Customer needs are measured in terms of consequences, which are determined by asking customers directly what they are looking for in a product or service. Then, the customer consequences are assessed and technical requirements are developed by knowledgeable professionals associated with the specific field of the product or service being assessed. The technical requirements are design dimensions that are specifically made to meet the customer consequences developed from the VOC. For example, if a customer consequence was better fuel economy (associated with a vehicle), perhaps a technical requirement would be the fuel type or weight of the vehicle that would directly be associated with the customer consequence.

The VOC is obtained primarily by two methods, namely through interviews or focus groups, which are then used to develop a survey questionnaire to distribute to potential and/or existing customers. Griffin and Hauser (1991) suggest that interviews with 20-30

customers should identify 90% or more of the customer needs in a relatively homogeneous customer segment. Multiple analysts (4-6) should review the transcripts of the focus groups to identify group synergies. Once the interviews and/or focus groups are conducted, an affinity diagram can be used to group the similarities in responses from the participants to develop a questionnaire that addresses all the topics important to the participant. The survey then asks the participant to rate an existing product or service on a scale of 1 to 5 on how well they view the product or service performs on each customer consequence. The participant is also asked to weight how important each customer consequence is to them for the product or service. A weighted rating can then be obtained by multiplying the rating and weight assigned to each customer consequence so that prioritization can be assessed. For example, a customer consequence could be discovered to be very important to a participant, but they view the product or service as performing poorly. This consequence would have priority to address over a consequence that the participant viewed as having a high rating on performance yet it was not seen as important.

The next discussion refers to the House of Quality, which is the tool used for organizing the customer consequences and subsequent technical requirements developed to address those consequences.

House of Quality (HOQ):

Olewnik and Lewis (2008) report that the HOQ is a design tool that supports information processing and decision making in the engineering design process. They note that for companies just implementing QFD and the HOQ, there is undoubtedly an improvement in information structure, flow, and direction. Hauser and Clausing (1988) state that the principal benefit of the HOQ is increasing the quality focus of the organization. That is, the HOQ gets people within an organization thinking in the right direction and thinking together.

QFD uses a set of interrelated matrix diagrams. The first matrix is the HOQ, which converts the customer consequences into technical requirements that must be fulfilled throughout the supply chain. The starting point on the left of the house is the identification of basic customer consequences. The next step is the definition of the priority levels that customers assign to these needs. These priorities are translated into numeric values that indicate relative importance, as discussed earlier. Customer ratings, shown on the right side of the house, enable benchmarking with competitors' services. The section just below the roof states the technical requirements used to meet the customer consequences. The relationship between the customer consequences and technical requirements constitutes the main body of the HOQ, called the relationship matrix. This matrix helps identify certain technical requirements that should be given priority if one addresses multiple customer consequences. The correlation matrix defines the relationships among technical requirements, which is represented by the roof of the HOQ. The bottom of the house evaluates the competition in terms of technical requirements in which the target values are defined by the researcher in this matrix (Tan and Pawitra, 2001). The construction of each of the sections in the HOQ is discussed in the following sections. Figure 1 depicts a standard HOQ.

The following section of this paper will outline a standard generic methodology for conducting a QFD analysis, which includes obtaining the VOC and translating it into meaningful data using an HOQ.

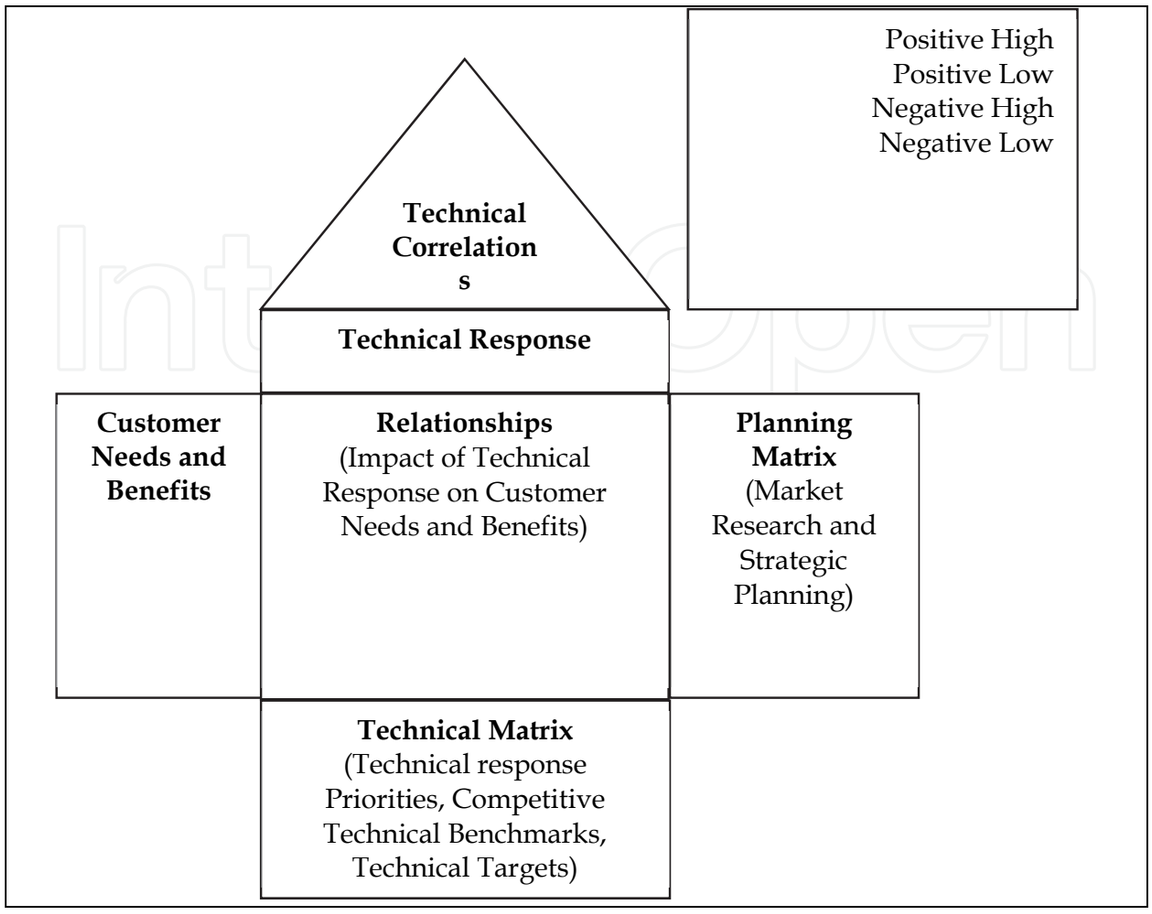


Fig. 1. HOQ Model (Cohen, 2007)

3. Methodology

QFD involves the construction of one or more matrices, called quality tables, which ensure customer satisfaction and improved quality services at every level of the service development process. The House of Quality, one of the most commonly used matrices in the QFD methodology, is a toolbox of decision matrices and the customer requirements and competitive benchmarks are utilized for decision-making (Andronikidis *et al*., 2009).

The QFD methodology requires the development of a survey to understand the customer consequences for a product's or service's potential, current, or past customers regarding its functions to these demographics, and translates these consequences using quality function deployment into technical requirements to improve service offerings. The final deliverable of the methodology is an HOQ that is constructed by integrating customer consequences gathered via a survey, developing technical requirements to address each customer consequence, benchmarking competitors on similar design structures, and comparing the product or service to its competitors and prioritizing actions based on customer wants and competitors' successes and/or failures. The step-by-step process for the development of the HOQ is discussed in detail in the following sections.

Understanding Customer Choice Decisions: The Voice of the Customer

One of the essential strategies for successful functioning of any organization is delivering superior service or product quality to their customers. Understanding what exactly the customer's needs and wants (voice of the customer) are is a key criterion in total quality management (Griffin and Hauser, 1991). The first step towards understanding customer needs is to identify attributes and customer consequences. Attributes are defined as the physical or abstract characteristics of a service or product. They are objective, measurable, and reflect the provider's perspective. Consequences are a result of using attributes; basically, an end result in what a customer "gets" from using a service or product. Customers judge services and products based on their consequences, not their attributes. In other words, customers judge a service or product on its outcome, or affect of use on them. A service or product has many attributes, and each may have more than one consequence (Fisher and Schutta, 2003).

To gather the VOC, a cross-functional team must conduct focus groups or interviews with a select group of potential, existing, or past customers and ask them what is important to them in the service or product being offered. "Why" is asked numerous times until the respondent responds with the same answer each time. This is the fundamental customer consequence that the customer wants from using the service or product. These responses are grouped using an affinity diagram and used to develop a meaningful survey questionnaire that captures all things important to the customers. To ensure that the appropriate number of responses is gathered (90%), a standard sample size calculation can be performed.

Development of Customer Consequences

During the survey, the respondents are asked to evaluate the particular product or service provider on each customer consequence on a standard 5 point Likert scale. The respondent is also asked to weight each consequence on how important it is to them on a 5 point Likert scale. These ratings and weightings will be multiplied to derive a weighted rating to encompass both the performance rating and the importance for each consequence. With this information, the team can determine which of the consequences are the most important and also the worst in performance and assign priorities.

If respondents for other similar types of products or services are available, the same survey can gather data regarding customer consequences for those competitors. If respondents are not available, the team will use available data (i.e., website published information, annual reports, technical reports, financial statements) to determine which competitor being evaluated is "best" and assign it a value of "5". The team will also identify which competitor is "worst" at each consequence and sign them a value of "1". All competitors will be assigned a value relative to "best" and "worst" using team or industry expertise in the subject area. This information will be used to "benchmark" the product or service being directly evaluated by the team to see how they compare to similar competitors.

Development of Technical Requirements

After the customer consequences are analyzed, the next step in the construction of the HOQ is the development of the technical requirements. The technical requirements are the design specifications that satisfy customer consequences. These technical requirements are on the top of the HOQ and are referred to as the "how" of the HOQ. They describe "how" to meet the customer consequences and improve a product or service. The technical requirements must be within the control of the product or service provider and must be measurable (i.e.,

quantitative measurements, "yes/no"). Each customer consequence can have more than one technical requirement, and each technical requirement may fulfill the need of more than one customer consequence.

The development of technical requirements often requires expertise in the area regarding the service or product and requires creativity to develop. This area of the HOQ is the "thinking outside the box" aspect and there is no definite "right or wrong" answer. Any reasonable technical requirement should be considered. Often times ambiguous research and information collected from many sources (i.e., experts, websites, technical reports) may be used to spark brainstorming and creativity to develop technical requirements.

Relationship Matrix: The Body of the House of Quality

Once the customer consequences are developed, survey results are gathered, and the technical requirements are developed, a matrix to highlight relationships between the customer consequences and the technical requirements is constructed. This matrix is the "body" of the House of Quality. The matrix defines the correlations between the customer consequences and technical requirements as strong, moderate, or weak using a 9-3-1 scale. For this scale the following notations are used Strong (H) = 9, Moderate (M) = 3, and Weak (S) = 1. Each customer consequence is matched with any applicable technical requirement; make note that relationships should not be forced, leaving a blank if no relationship is determined. Here again, this assignment of relationships requires the expertise of the researchers or industry members. Normally only the strongest relationships are specified leaving approximately 60-70% of the matrix blank (Griffin and Hauser, 1991). Although some indicate that ideally in the QFD analysis, no more than 50% of the relationship matrix should be filled, and a random pattern should result (Fisher and Schutta, 2003). This matrix identifies the technical requirements that satisfy most customer consequences. The technical requirements that address the most customer consequences should be a main priority in the design process to ensure a product or service that satisfies the stated customer expectations.

Planning Matrix (Customer Competitive Analysis)

After the completion of the relationship matrix, the focus of the analysis shifts to the construction of the planning matrix. The planning matrix defines how each customer consequence has been addressed by the competition. It provides market data, facilitates strategic goal setting for the new product, and permits comparison of the customer desires and needs. It also compares the service to its key competitors. For the competitive analysis, research should be conducted regarding similar products or services. Researchers may have to assert a level of expertise in drawing meaningful information from the information available, as many competitors will not openly aid their competition by providing market data and design specifications. The researchers will use available data (i.e., website published information, annual reports, technical reports, financial statements) to determine which competitor being evaluated is "best" and assign it a value of "5". The researchers will also identify which competitor is "worst" at each consequence and sign them a value of "1". All competitors will be assigned a value relative to "best" and "worst" using researcher or industry expertise in the subject area. This information will be used to "benchmark" the product or service being directly evaluated by the researcher to see how they compare to similar competitors.

Technical Correlations

Following the completion of the relationship and planning matrices, the technical correlations are determined. These correlations are depicted in the roof of the HOQ. The

roof maps the relationships and interdependencies among the technical requirements. The analysis of which informs the development process, revealing the existence and nature of service or product design bottlenecks. The relationships among technical requirements are plotted and given a value. Relationships among the technical requirements are important to evaluate, as one technical requirement could either aid or hinder the success of another crucial technical requirement in meeting customer consequences. Past experience and publicly available data (i.e., website information, technical reports, financial reports) can be used to complete the roof of the HOQ. Symbols are used to represent the strength of the relationship between the technical requirements and are assigned by the team.

Technical Matrix

The last step in the formation of the HOQ is the foundation or bottom of the house. This foundation is referred to as the technical matrix. This matrix depicts the values assigned by the team of the direction of improvement and/or standard values of each technical requirement needed to be competitive in the industry. Often times, if a numerical value cannot be absolutely determined, the team and/or industry experts use judgment based on expertise in the subject area to assign "targets." The direction of improvement indicates the type of action needed to ensure that the technical requirements are sufficient to make the product or service competitive for each entity evaluated. For example, if a technical requirement's target value is 5, and a product or service provider's mean for that requirement is 4, the direction of improvement would be up to aim for the higher target value.

Prioritizing Resource Allocations: The Importance/Performance Grid

The collected information from the above methods enables the development of strategic decisions, one of which is the allocation of resources. An importance-performance grid can be developed to prioritize the usage of resources to improve the most critical customer benefits. The mean importance ratings (gathered from the survey) can be plotted on the vertical axis (importance) and the mean customer competitive ratings (gathered from the survey) on the horizontal axis (performance). Using the importance rating values, the mean importance rating (for all consequences) should be calculated. The consequences with an importance rating higher than that of the mean importance rating should be placed above the horizontal line and those lower should be placed below this line. After these values are plotted, the focus can shift to the distribution of consequences on either the left or right side of the vertical line. For this purpose, the mean performance rating is used and labeled for the vertical axis. Each consequence with a lower mean should be plotted to the left of the axis, and each consequence with a performance mean higher than the mean should be plotted to the right of the vertical axis. Using this grid, the level of priority can be assigned to each consequence from the customer's point of view, and subsequently resource allocation decisions can be influenced.

4. QFD tools

There are two main tools utilized in quality function deployment: the Kano model and SERVQUAL. This section describes each of these tools in detail.

The Kano model is a theory of customer satisfaction developed in the 1980s by Noriaki Kano (Kano et al., 1984). During interviews and focus groups, it can be difficult to elicit from customers clear expressions of the consequences that are important to them. Attributes are

the physical or abstract characteristics of the product or service where as consequences are the results of using the service. Sometimes customers are not even aware of important consequences (Fisher and Schutta, 2003).

The Kano model is a theory of product development and customer satisfaction. Kano et al. (1984) distinguish three types of product or service requirements that influence customer satisfaction in various ways: ''must be,'' ''one-dimensional,'' and ''attractive'' quality requirements. Must be requirements can be defined as the basic attributes of quality in terms of customer satisfaction. In other words, they are a necessary but insufficient condition for customer satisfaction (Busacca and Padula, 2005).

One-dimensional requirements are related to product or service performance; they create customer satisfaction when present and dissatisfaction when absent (Redfern and Davey, 2003). The higher the perceived product or service quality, the higher the customer's satisfaction and vice versa. One-dimensional requirements are both a necessary and sufficient condition for customer satisfaction (Busacca and Padula, 2005).

Attractive requirements can be defined as the product or service attributes that satisfy or even excite customers when present but do not dissatisfy when absent (Berger et al., 1993). Such attributes have the greatest influence on customer satisfaction with a given service (Matzler et al., 1996). They are a sufficient, but unnecessary condition for satisfaction (Busacca and Padula, 2005). Attractive attributes can be used as an element of an aggressive marketing strategy to attract competitors' customers. QFD normally deals with satisfiers not delighters.

Zhao and Dholakia (2009) have reported that although one-dimensional (i.e., linear) relationships are common, other relationships between attribute-level performance and customer satisfaction also exist that change dynamically over time and with user experience. Figure 2 illustrates the three different consequences and indicates the extent to which they can affect customer satisfaction.

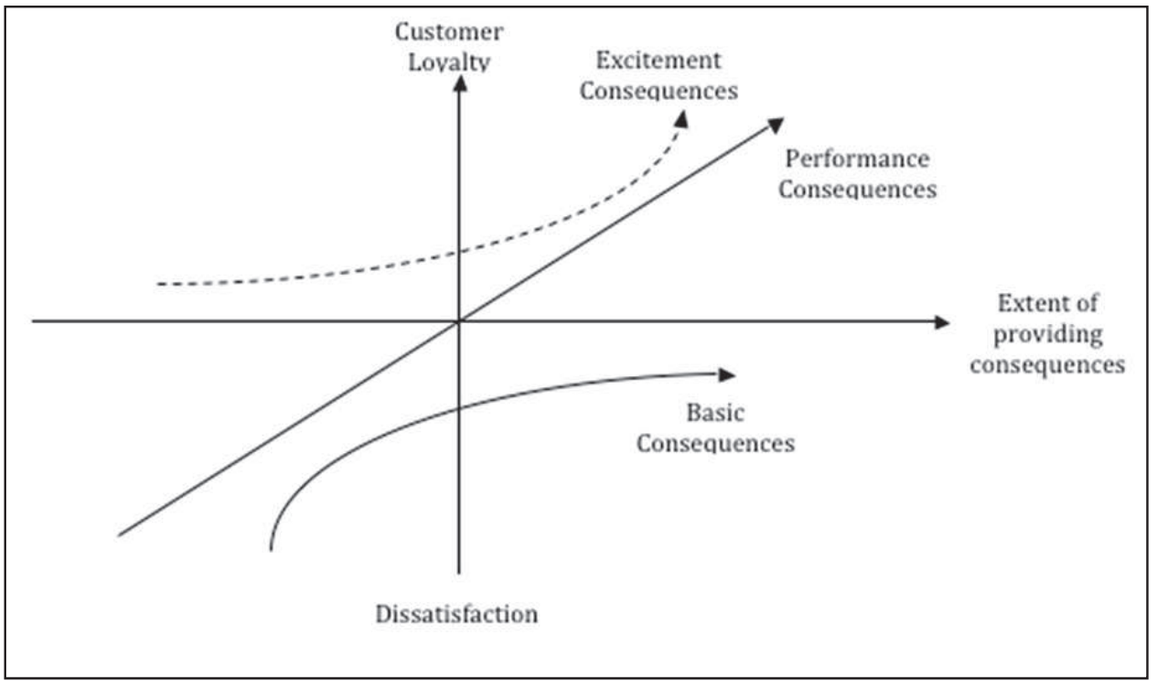


Fig. 2. Kano Model

Berry, Parasuraman, and Zeithaml developed SERVQUAL in 1988. It is a service quality tool based on the customer's perceptions of and expected performance. It is one of the most widely used models for the evolution of service quality (Pawitra & Tan, 2003). Initially, Parasuraman et al. (1985) proposed ten service quality attributes: reliability, responsiveness, competence, access, courtesy, communication, credibility, security, understanding/knowing the customer, and tangibles. However, in the early 1990s, these were condensed into five. The five dimensions of service quality, commonly known as RATER, include (Lim, Tang, & Jackson, 2003):

1. Reliability - ability to perform the promised service dependably and accurately.
2. Assurance - knowledge and courtesy of staff and their ability to convey trust and confidence.
3. Tangibles - physical facilities, equipment, and appearance of staff.
4. Empathy - caring, individualized attention provided to its customers.
5. Responsiveness - willingness to help customers and provide prompt service.

With the help of SERVQUAL, customer satisfaction can be measured in terms of the difference, or gap, between the expected and perceived level of performance. This approach can be applied to any service organization to evaluate the standards of quality for the services provided. "Services are different from goods in many ways: they are intangible, require participation of the customer, simultaneous production and consumption" (Oliveira et al., 2009).

Research conducted by Baki et al. (2008) concluded that the integration of SERVQUAL, the Kano model, and QFD could serve as an effective tool in assessing quality of services provided by an organization. The linearity assumption in SERVQUAL can be eliminated by integrating SERVQUAL with the Kano model and QFD to develop a way to satisfy customer needs, thus leading to increased customer satisfaction and higher profits.

SERVQUAL is a reliable and valid scale used to measure the perceived and expected levels of performance in any service organizations and thus results in improved service offerings. SERVQUAL is most effective when administered periodically to monitor new trends in the service quality. By calculating the average of the differences between the scores on the questions that make up a given dimension, and by calculating an average across all dimensions, an organization's quality standards can be administered (Parasuraman et al., 1988).

SERVQUAL has also been used in the house of quality design process to evaluate customer satisfaction with an organization's services. It can be used to identify and analyze customer requirements and thus forms the first stage in the construction of an HOQ. As noted by Parasuraman et at. (1988), the SERVQUAL dimensions can be modified based on the requirements and needs of an organization to make them more relevant to the context in which they are used (Paryani et al., 2010).

The following sections present two case studies for the Kano model and SERVQUAL methodology.

5. Kano model case study

This case study integrates quality function deployment and the Kano model to examine the application of quality function deployment in the new product development process by using the production of a fuel efficient vehicle. An integrated team of marketers, design engineers, and business experts developed a House of Quality for the fuel efficient vehicle

that provided an insight into the customer preferences to be concentrated on and the technical requirements that helped achieve desired results in the prototyping of a Hydrogen Fuel Cell Vehicle (HFCV).

The product that was being developed was a plug-in hybrid. The vehicle's power source consists of a battery and a hydrogen fuel cell. The first step in obtaining the VOC for this case study was to conduct interviews, which was used to derive a customer survey. The interviews were one-on-one conversations conducted with customers to determine their expectations from a vehicle. Only 30 interviews were conducted, as past research has shown that this captures 90% of customer consequences for the general customer base (Griffin and Hauser, 1991).

The interview questions included:

1. What do you look for in purchasing a vehicle?
2. What is your main need in a vehicle?
3. What is your main use for your car now?
4. What is important to you in your current vehicle?
5. What brands of vehicles are you currently familiar with?
6. What brands of environmentally friendly vehicles are you familiar with?
7. Of those vehicles, what do you know about them?
8. What is your opinion of environmentally friendly vehicles?
9. What would be your ideal environmentally friendly vehicle?
10. Name, Age, Occupation?

The purpose of the interview process was not to ask each customer all ten questions, but to promote the customer to talk. When the subject stopped talking, the next question would get the conversation flowing again. To elicit consequences from a customer, the interviewer used a probing technique repeatedly by asking "why" to determine the attributes responsible for making a specific feature appealing to them. Seventeen customer consequences were developed from the interview data.

Affinity Diagram

After the VOC had been gathered via the interview process, the collected data was organized using affinity diagrams. Affinity diagrams group the consequences gathered based on similarity to clarify customer input. The 17 consequences were grouped into six similar categories, and each category was given a title. The left side of the HOQ was completed with customer consequences and attributes. The affinity diagram is shown in Table 1.

Survey

The next step was to obtain the importance rating and rankings of each consequence from the customer base. A survey was conducted of 104 customers regarding the relative importance of the 17 consequences. The reason behind this was to avoid misinterpretation of the customer's overall attitude or satisfaction towards the product that could lead to poor prediction of the customer's purchase behavior. Customers do not place equal importance on all consequences. Three vehicles were chosen for this purpose including a Toyota Prius (Vehicle A), a BMW 335 advanced diesel (Vehicle B), and the HFCV (Vehicle C). In addition, the survey respondent's current car was used to allow comparison. The identities of the three vehicles were not disclosed to the survey respondents. A brief description of each vehicle was provided however, to allow them to make a nonbiased decision on ratings and

rankings of each consequence, relative to each vehicle. Each respondent was asked to read the descriptions and provide rating and rankings for each vehicle.

Attributes	**Consequences**
Safety	The vehicle provides accurate safety warnings.
	The vehicle has high safety and standard ratings.
Efficiency	The vehicle gets good mileage.
	The vehicle is energy efficient.
	The vehicle has high horsepower.
Cost	The vehicle is affordable.
	The vehicle has an extensive warranty.
	The vehicle is a hybrid (i.e., it splits power between electric and gas).
Performance	The vehicle has towing capabilities.
	The vehicle does not compromise speed and handling.
	The vehicle can be driven for longer distances (>400 miles).
Comfort	The vehicle provides a comfortable ride.
	The vehicle has a quality audio system.
	The vehicle is climate controlled.
	The vehicle comfortably fits a sufficient number of people.
Eco-friendliness	The vehicle has low emissions.
	The vehicle is environmentally friendly.

Table 1. Affinity Diagram

The survey was conducted in two parts. First, the respondents were asked to identify the most important consequence to them and label it as "10". All other consequences were to be assigned a value (rank) between 1 and 10, relative to the consequence labelled as most important. Therefore, some consequences may be just as important as the first consequence assigned a value of "10", and they too would be assigned a value of "10." Consequences that were almost as important as the first consequence assigned a value of "10" may be assigned values of "9" or below, relative to how important the customer felt they were in relation to the first "10" consequence. The mean of the rankings was calculated for the results of each consequence that constituted the importance column in Table 2.

The second part of the survey involved rating each consequence as it applies to each of the four vehicles on a Likert scale from 1 to 5. The mean of the ratings was calculated for each consequence and noted in the rating column in Table 2. The weighted rating values were obtained by multiplication of the importance (rank) and rating together. The weighted rating is a means of obtaining an optimal solution by evaluating both what is important to a customer and how well the customer thinks each product is doing on what is important to them. This is also used as a means to evaluate resource allocations, as if the customer base feels that a company is lacking on a consequence that they deem very important, more focus can be applied to improving this, which may ultimately improve market share. Conversely, if a customer base feels that a product excels on consequences that are of no importance to them, resources can be directed away from these areas and applied to areas needing improvement. The survey's main purpose was to gather more specific information on potential customer desires and needs. The results of the survey are tabulated in Table 2.

			Vehicle A		Vehicle B		Vehicle C		Current Vehicle	
		Importance	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating
1	This vehicle is climate controlled.	6.6	4.2	27.51	4.2	27.51	3.6	23.58	4.0	26.20
2	This vehicle has a quality audio system.	6.7	3.4	22.64	3.5	23.31	3.3	21.98	3.7	24.64
3	This vehicle provides a comfortable ride.	7.5	3.3	24.65	3.9	29.13	3.6	26.89	3.7	27.64
4	This vehicle gets good gas mileage.	7.6	4.4	33.44	3.9	29.64	4.4	33.44	3.3	25.08
5	This vehicle has low emissions.	4.7	4.2	19.57	3.5	16.31	4.4	20.50	2.9	13.51
6	This vehicle has low emissions.	5.4	4.2	22.64	3.5	18.87	4.4	23.72	2.9	15.63
7	This vehicle is good for the environment.	5.1	4.1	20.87	3.6	18.32	4.3	21.89	2.8	14.25
8	This vehicle has a lot of horsepower.	6.5	2.3	15.04	3.8	24.85	2.9	18.97	3.0	19.62
9	This vehicle has towing capabilities.	5.2	1.9	9.79	3.1	15.97	2.5	12.88	2.7	13.91

10	This vehicle does not compromise speed and handling.	7.1	2.9	20.51	3.4	24.42	2.9	20.58	3.5	24.78
11	This vehicle is affordable.	8.0	3.7	29.77	2.5	19.87	2.3	18.03	3.7	29.77
12	This vehicle has an extensive warranty.	6.2	3.2	20.06	3.3	20.49	3.0	18.69	2.9	17.70
13	This vehicle can drive for long distances (>400 miles).	7.1	3.7	26.66	3.6	25.60	3.0	21.68	3.7	26.52
14	This vehicle has a high safety and standard rating.	7.0	3.8	26.63	3.8	26.56	3.7	25.65	3.5	24.12
15	This vehicle provides accurate safety warnings.	5.7	3.6	20.51	3.7	21.13	3.6	20.51	3.5	19.78
16	The vehicle is a hybrid (split powers between electric and gas).	3.2	3.6	11.70	2.1	6.74	3.8	12.21	1.7	5.44
17	This vehicle comfortably fits a family of all sizes.	4.7	2.4	10.95	3.7	17.06	3.3	15.56	2.8	13.23

18	Overall, I am satisfied with this type of vehicle.		3.2		3.6		3.4		3.9	
	Sum	104.07	62.15	362.93	62.74	365.77	62.39	356.76	58.16	341.82
	Average			3.49		3.51		3.43		3.28

Table 2. Importance Rating

Development of Technical Requirements

After the customer consequences were analyzed, the next step in the construction of the HOQ was the development of technical requirements. The technical requirements are the design specifications that satisfy customer needs. This aspect of QFD is directly in the organization's control, and focuses on designing specific, measurable design aspects that ensure the end product meets the customer wants and needs. The technical requirements are called the 'hows' and are placed on the top of the house. Each consequence can have one or more technical requirement. Technical requirements must be within the control of the manufacturer. It must also be measurable to enable designers to determine if the customer's needs are fulfilled. Brainstorming among marketers and product designers was used to develop the technical requirements, along with various Internet sources for references to industry standards. Thirty technical requirements were developed and organized using tree diagrams. One of the seven management tools, the tree diagram is a hierarchical structure of ideas built from the top down using a logic and analytical thought process.

A customer design matrix log was then developed that created a product development log that provided a history of the design process. It contained the design concepts derived from the customer's voice and the corresponding technical requirements that were designed, their measurement units and values. The column 'Measurement units' in Table 3 was placed at the bottom of the HOQ indicating how each technical requirement would be measured. Table 3 shows the customer design matrix log.

Relationship Matrix

Once the customer consequences and the technical requirements were developed, a relationship matrix was constructed. The matrix defines the correlations between customer attributes and technical attributes as weak, moderate, or strong using a standard 9-3-1 scale. For this scale the following notations are used Strong (H) = 9, Moderate (M) = 3, and Weak (S) = 1.

Each customer consequence was matched with each technical requirement. The relationship between them was then determined and placed in the relationship matrix that constitutes the of the HOQ. This matrix identifies the technical requirements that satisfy most customer consequences and determines the appropriate investment of resources for each. The technical requirements that addressed the most customer consequences should be dealt into the design process to ensure a customer-approved product. Ideally in the QFD analysis, no more than 50% of the relationship matrix should be filled, and a random pattern should result (Fisher and Schutta, 2003). Relationships were determined here on the basis of

research conducted using resources available on the Internet. Appendix A displays the relationship matrix developed for the HOQ.

No	Customer's Voice	Technical Requirements	Measurement	Measurement Units
1	Climate control	Level of temperature change	Boolean Value	Yes/No
		Time taken to attain the changed temperature	Time	Minutes/Seconds
2	Audio System	Power of speakers	Power	Watts
		No. of operability modes in an audio system	Number	Integer value
3	Comfort	Seating Capacity	Capacity	Integer value
		Distance between front and rear seat	Length	Inches
4	Fuel Efficiency	Engine Power	Power	Horsepower
		Air compression ration	Volume	Cubic cms (cc)
		Size of exhaust pipes	Diameter	Inches
5	Environmental friendly	Lower Emissions (Nitrogen, Carbon-dioxide, Carbon-monoxide)	Weight/Distance	Grams/Km
		Hybrid	Boolean Value	Yes/No
6	Safety	Size of side & rear view mirror	Ratio	Ratio
		Size of damping sheets		
		Suspension/steering stability	Spring frequency	Cycles/minute (cpm)
		No. of airbags	Number	Integer value
		Air bag response time	Time	Seconds
		Alignment of tires	Toe-in (Distance)	Fractions of an inch
		Crash warning system	Boolean Value	Yes/No
7	Long distance travel	Tank capacity	Capacity	Gallons
		Tire quality	UTQG standards	Grades
8	Warranty	No. of parts covered under warranty	Number	Integer value
		Validity of warranty	Time	Years
		Cost of extended warranty	Boolean Value	Yes/No
9	Performance	Torque transmission	Force	Foot-pounds
		Cylinder size	Volume	Liters
		No. of valves/cylinder	Number	Integer value
		Weight of engine	Weight	Grams

Table 3. Customer Design Matrix

Planning Matrix (Customer Competitive Analysis)

After completion of the relationship matrix, the focus of the project shifted to the construction of the planning matrix. This matrix defines how each customer consequence has been addressed by the competition. It provides market data, facilitates strategic goal setting for the new product, and permits prioritization of the customer desires and needs. It also compares the product to its key competitors. A standard 5-point Likert scale was used. Each vehicle was represented by different symbol. A square symbol was used for the Toyota Prius, a circle for the BMW 335d, and a triangle for the HFCV. The ratings were based from the customer survey. Customers rated the three vehicles for each of the 17 customer consequences included in the planning matrix. Appendix A shows the planning matrix in the HOQ.

Technical Correlations

Following completion of the planning matrix, technical correlations were determined. These form the roof of the HOQ. The roof maps the relationships and interdependencies among the technical requirements. The analysis of which informs the development process, revealing the existence and nature of design bottlenecks. The relationships among technical requirements were plotted and given a value. Past experience and test data were used to complete the roof of the HOQ. Symbols are used to represent the level of the relationship between technical requirements. Appendix A shows the completed roof of the HOQ, with all relationships identified between the technical requirements.

Technical Matrix

Next, a technical matrix was constructed to form the foundation of the HOQ. This matrix addresses the direction of improvement, standard values, units of measurement, the relative importance of technical requirements, and technical evaluation.

The customer design provides information regarding consequences, technical requirements, and their units and values. It contains design concepts derived from the VOC and detailed design considerations. The column 'Measurement Units' from Table 3 was placed at the bottom of the HOQ, indicating the units of measurement for each technical requirement.

The relative importance of each technical requirement was calculated by multiplying the value assigned to its relationship with a specific consequence (9, 3, 1) multiplied by the importance of that consequence; the values of all consequences were then added to yield the final weight. These weights were placed in a row at the bottom of the HOQ. A final weight is a comprehensive measure that indicates the degree to which the specific technical requirement relates to the customer consequences.

The technical evaluation of the competition and the product to be developed is carried out by the engineering and technical staff who would design the product. The process establishes strategic goals for the product development process to ensure the satisfaction of the customer. For each technical requirement, the product was compared to its competitors and a technical evaluation was performed. Thus, the construction of the HOQ was completed. Appendix A shows the completed HOQ with the roof.

Prioritizing Resource Allocations

The collected information from the above methods helped in the development of strategic decisions, one of them being the allocation of resources. An importance-performance grid was developed to prioritize the usage of resources for improvement on the most critical

customer benefits. The relative importance ratings were plotted on the vertical axis (importance) and the median importance rating on the horizontal axis (performance). Using the values from the column 'Importance' from Table 2, the median importance rating was found out to be 6.5. Consequences with rating higher than that of the median importance rating were placed above the horizontal line and the others below the median. After this decision was made, the focus shifted to the distribution of consequences on either the left or right side of the vertical line. For this purpose, the median was calculated for each consequence and if the mean brand rating was higher than that value it was placed on the right side of the vertical line otherwise on the left side. Using this grid, the level of priority was assigned to each consequence from the customers point of view. Figure 3 shows the Importance-Performance grid for Vehicle C (HFCV).

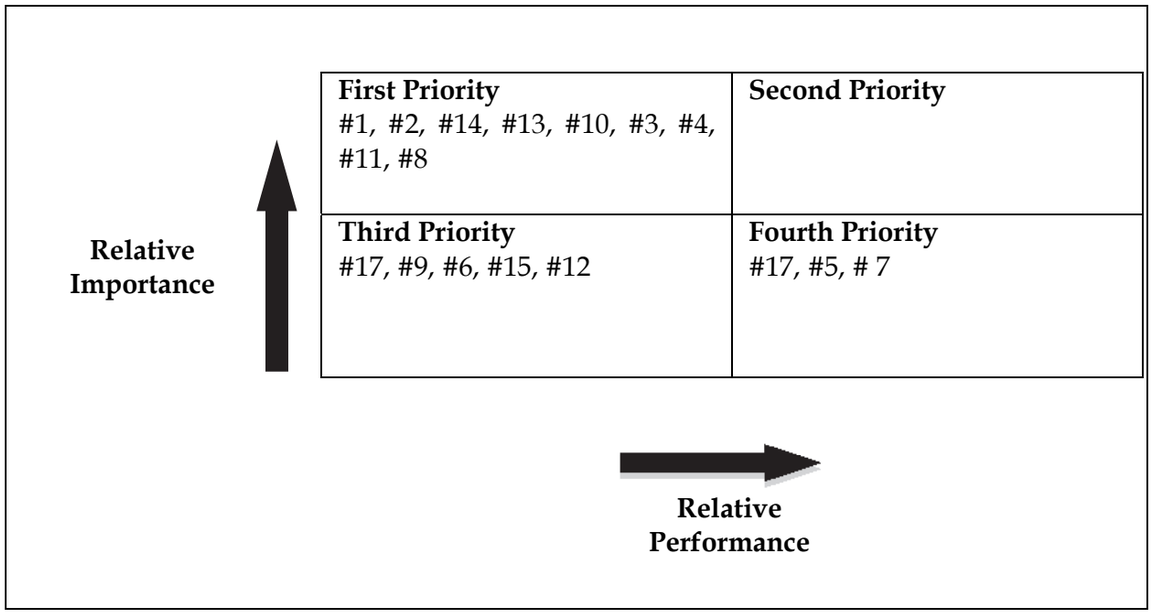


Fig. 3. Importance-Performance Grid

Recommendations and Conclusions

This study has illustrated how QFD can successfully be applied to new product development efforts via the application to the prototyping of a fuel-efficient vehicle. This study was deemed a success, as the results were reasonable per the design team that is currently in progress prototyping the product. For this particular application, the results showed that the first and utmost priority should be given to the following customer benefits/consequences: climate control, quality audio control, high safety and standard rating, long distance travel, high speed and handling, comfortable ride, good gas mileage, substantial horsepower, and affordability. These benefits are ones that must be accomplished in order to appeal to the customers in the market, and thereby give the new product a chance for success as a sellable product. The consequences were identified as priority because they are of high importance to the customer, but have poor performance according to the prototype description given to the respondent group in the study. These are the areas of design that must be addressed so as to create a product that appeals to the consumer. If resources are limited, consideration should be given to shifting resources to

these priorities in the design phase. Conversely, the fourth priority benefits include low emissions, environment-friendly, and power split between electric and gas. These benefits are performing well and not of high importance, so no improvement needs to be made with these benefits currently. In fact, resources can actually be shifted away from these aspects and reinvested elsewhere where the design needs improvement to meet customer expectations.

The results presented in this study aided the design team of the HFCV and provided them with an insight into what customers were really looking for in an environmentally friendly vehicle. The application of QFD to the prototyping of a HFCV proved to be beneficial, as the voice of the customer was gathered, analyzed, and factored into the design process to ensure a product that will meet customer expectations.

It has been demonstrated that the QFD methodology can be successfully applied in a new product development process. It also aided the HFCV design team in developing a proprietary knowledge base about their customers' needs and wants which allowed them to make the best design efforts in the early development stages that lowered the development costs and increased profit levels. Although this study focused on the production of HFCV, the QFD methodology presented could serve as a powerful reference to the development of a new product of any kind. The authors hope that this study could attract more new product development teams and organizations to adopt QFD in the NPD process and develop better and successful products and achieve high customer satisfaction with increased profit levels.

6. SERVQUAL case study

This case study integrates quality function deployment and SERVQUAL to evaluate a university career opportunities center (COC) and recommends service standards to increase its benefits to students. A university COC seeks to bridge the gap between students and employers. It equips students with the professional skills they need to find employment. The staff keeps the students regularly informed about various events such as the career fair, and it can help them make major career decisions. A COC should maintain high standards of quality and serve students efficiently. To do so, its staff must understand student needs and constantly monitor feedback to improve their performance.

The mentioned methodology has been applied to a COC at a university. Detailed steps are listed for the construction of the HOQ, with SERVQUAL being incorporated into QFD in this application. A step-by-step procedure for this case is discussed in this section.

SERVQUAL dimensions for a COC

The main goal of applying QFD to a university COC was to identify how the COC could better serve students. This work sought to identify expectations of the students and the measures necessary to meet them. Here, SERVQUAL was applied to identify the key customer needs and requirements. Table 4 presents the SERVQUAL dimensions and their definitions as they relate to their application to the COC case study.

To make the dimensions more relevant to a COC, a few SERVQUAL items were modified or removed based on the responses obtained through student interviews. A total of 15 customer requirements were identified. Table 5 provides the modified SERVQUAL dimensions and customer requirements.

Dimensions	Description
Reliability	The ability of the COC staff to deliver the promised services dependably and precisely.
Assurance	Knowledge and courtesy of the COC staff and their ability to communicate trust and confidence in the students.
Tangibles	Physical aspects of the COC including the appearance of personnel and communication services.
Empathy	Ability to provide individualized attention and care by the COC staff to the students.
Responsiveness	Willingness of the COC staff to serve the students and provide them with prompt services.

Table 4. SERVQUAL: Five Dimensions

Dimensions	Customer Requirements
Empathy	I get a job that fits me
	I have a job that I enjoy
	I know what different jobs are available
	I can work overseas
Reliability	I get job offers
	I get a job that pays well
	I get opportunities with potential employers
	I have my resume easily accessible to companies
Assurance	I stand out to a potential employer
	I am prepared for an interview
	I am comfortable during an interview
Responsiveness	I have interviewing experience
	I get a resume evaluation
Tangibles	I have a professional resume
	I have a professional appearance for an interview

Table 5. SERVQUAL Adjusted Items Description

These SERVQUAL items are the customer consequences that were obtained by conducting interviews with 30 students. The intention behind interviewing these students was to keep the conversation flowing. To elicit the consequences from a customer, the interviewer used a probing technique repeatedly by asking "why" to determine the reason responsible for making a specific aspect appealing to them. When the student stopped talking, the next question would get the conversation flowing again.

Survey conducted for a COC

A survey of 99 students was the primary source of information for this study. The survey asked the students to express their thoughts on various aspects of the COC and to indicate what changes would increase their satisfaction. Customers do not assign equal importance to all requirements. The survey was administered in two sections. First, the students were asked to identify the most important consequence, assigning to each a rank from 1 to 10, with 10 indicating the highest level of importance. The mean rank was calculated for each customer consequence. To determine the quality of COC services, respondents were also asked if they would recommend the service to other students. In the second part of the survey, students were asked to indicate the degree to which each of the consequences was true of an ideal COC and of the specific university COC on a scale from 1 to 5, where 5 indicated strongly agree and 1 indicated strongly disagree. The mean ratings were calculated for each consequence as shown in Table 6. The survey results obtained were analyzed using SERVQUAL by performing a gap analysis that is discussed in the following section. The questionnaire developed for this study is included in Appendix B.

Customer Requirements	Importance Ratings	Current COC Rating	Ideal COC Rating
I have a professional appearance for an interview	6.8	3.6	4.5
I am comfortable during an interview	7.3	3.5	4.6
I stand out to a potential employer	8.1	3.5	4.7
I am prepared for an interview	7.7	3.5	4.5
I have interviewing experience	6.9	3.5	4.5
I get opportunities with potential employers	7.7	3.5	4.6
I can work overseas	3	2.5	3.7
I know what different jobs are available	7.7	3.5	4.6
I have a professional résumé	7.7	3.6	4.6
I get a résumé evaluation	6.6	3.4	4.5
I have my résumé easily accessible to companies	7.5	3.7	4.6
I get a job that fits me	8.4	3.3	4.7
I get a job that pays well	7.8	3.5	4.6
I have a job that I enjoy	8.4	3.3	4.6
I get job offers	8.5	3.3	4.7

Table 6. Survey Results (Averages of all the ratings)

6.3 Prioritizing SERVQUAL dimensions for a COC

The five SERVQUAL dimensions: reliability, assurance, tangibles, empathy, and responsiveness were prioritized based on the gap score calculated for each dimension. There were four items under reliability, three under assurance, two under tangibles, four under empathy, and two under responsiveness for a COC. For each customer requirement, the perceived level (P) and expected level (E) of service were obtained from the survey data. The difference (gap score) between them was calculated, as was the average gap score for each of

the five dimensions. The five RATER dimensions for a COC were prioritized based on the value of the average gap scores; i.e. the dimension with the highest average gap score was the one given the highest priority for improvement. Empathy had the highest average gap score (-1.25), making it the highest priority. The dimensions were prioritized in the following order starting with the highest priority: reliability (-1.12), responsiveness (-1.1), and assurance (-1.1), and tangibles (-0.95).

Based on the gap scores calculated for each customer requirement, the importance ratings obtained from the survey data, and the priority level of each SERVQUAL dimension, the customer requirements were prioritized. When two consequences have the same gap score, their mean importance ratings obtained from the survey results could be used to determine their priority level. The results showed that students identified the following requirements, listed in priority order from the highest to lowest:

1. I get a job that fits me
2. I have a job that I enjoy
3. I know what different jobs are available
4. I can work overseas
5. I get job offers
6. I get a job that pays well
7. I get opportunities with potential employers
8. I have my resume easily accessible to companies
9. I stand out to a potential employer
10. I am prepared for an interview
11. I am comfortable during an interview
12. I have interviewing experience
13. I get resume evaluation
14. I have a professional resume
15. I have a professional appearance for an interview

6.4 Development of service characteristics for a COC

After analyzing the survey results using SERVQUAL, the focus shifted to the development of service characteristics that are the design specifications that would satisfy customer needs. Each customer consequence can have one or more service characteristic. Various strategies were developed to reduce or eliminate low customer satisfaction and increase the quality of service. The service characteristics are called the how's. These characteristics appear on top of the HOQ and constitute the technical response matrix. They are the measurable steps to ensure that all customer requirements are met. The service characteristics defined in QFD are within the organization's direct control. These characteristics focus on specific, measurable aspects of service.

Brainstorming was used to develop the service characteristics using various Internet sources which provided references to industry standards. Tree diagrams were used to organize these service characteristics. Tree diagrams are hierarchical structures of ideas built from the top down using logic and analytical thought. A customer design matrix log was then developed to create a service process development log that provided a history of the development process. This log contained the design concepts derived from the VOC, along with the corresponding service characteristics and their values. Twenty service characteristics were developed which are listed in Appendix C.

Dimension	No.	Customer Requirements	Expectation Score (E)	Perception Score (P)	Gap Score (P-E)	Average for Dimension
Tangibles	1	I have a professional appearance for an interview	4.5	3.6	-0.9	-0.95
	2	I have a professional resume	4.6	3.6	-1.0	
Reliability	3	I get opportunities with potential employers	4.6	3.5	-1.1	-1.12
	4	I have my resume easily accessible to companies	4.6	3.7	-0.9	
	5	I get a job that pays well	4.6	3.5	-1.1	
	6	I get job offers	4.7	3.3	-1.4	
Responsiveness	7	I get a resume evaluation	4.5	3.4	-1.1	-1.1
	8	I have interviewing experience	4.6	3.5	-1.1	
Assurance	9	I am comfortable during an interview	4.6	3.5	-1.1	-1.1
	10	I stand out to a potential employer	4.7	3.5	-1.2	
	11	I am prepared for an interview	4.5	3.5	-1.0	
Empathy	12	I can work overseas	3.7	2.5	-1.2	-1.25

Table 7. Calculation of Unweighted SERVQUAL Scores

Dimensions	Priority Level	Customer Requirements	Gap Score	Importance Rating
Empathy	1	I get a job that fits me	-1.4	8.4
	2	I have a job that I enjoy	-1.3	8.4
	3	I know what different jobs are available	-1.1	7.2
	4	I can work overseas	-1.2	3
Reliability	5	I get job offers	-1.4	8.5
	6	I get a job that pays well	-1.1	7.8
	7	I get opportunities with potential employers	-1.1	7.7
	8	I have my resume easily accessible to companies	-0.9	7.5
Assurance	9	I stand out to a potential employer	-1.2	8.1
	10	I am prepared for an interview	-1.0	7.7
	11	I am comfortable during an interview	-1.1	7.3
Responsiveness	12	I have interviewing experience	-1.1	6.9
	13	I get a resume evaluation	-1.1	6.6
Tangibles	14	I have a professional resume	-1.0	7.7
	15	I have a professional appearance for an interview	-0.9	6.8

Table 8. Prioritizing Customer Requirements

6.5 Relationship matrix for a COC

Once the customer consequences and the service characteristics were developed, a relationship matrix was constructed. This matrix defines the correlations between customer attributes and technical attributes/service characteristics as strong, moderate, or weak using a 9-3-1 scale. For this scale the following notations are used: Strong (H) = 9,

Moderate (M) = 3, and Weak (S) = 1. Each of the fifteen customer consequences was matched with each of the twenty service characteristics for a COC. The relationship between them was then determined and placed in the relationship matrix that constitutes the center of the HOQ. This matrix identifies the technical requirements that satisfy most customer consequences and determines the appropriate investment of resources for each. The technical requirements that addressed the most customer consequences should be addressed in the design process to ensure a product that satisfies the stated customer expectations. Ideally in the QFD analysis, no more than 50% of the relationship matrix should be filled, and a random pattern should result (Fisher and Schutta, 2003). Relationships were determined here on the basis of research conducted using resources available on the Internet. Appendix C displays the relationship matrix developed as a part of the HOQ for a COC.

6.6 Planning matrix (customer competitive analysis) for a COC

After completion of the relationship matrix, the focus of this study shifted to the construction of the planning matrix, which defines how each customer consequence has been addressed by the competition. This matrix provides market data, facilitates strategic goal setting for the new service, and permits prioritization of customer desires and needs. In this methodology, where we incorporated SERVQUAL into the HOQ, the competitive analysis is done between the current COC and an ideal COC. For the competitive analysis, a survey was conducted to determine the characteristics of an ideal COC, and this ideal COC was compared to a university COC. The survey respondents judged the ideal COC and the current COC against each of the fifteen consequences on a scale of 1 to 5, where '5' indicated strongly agree and '1' indicated strongly disagree. The mean for each consequence was calculated and placed in the columns to the right of the HOQ. A triangle was used for the ideal COC, and a square was used for a university COC. Appendix C shows the planning matrix in the HOQ.

6.7 Technical correlations matrix for a COC

Next, the technical correlations were determined after the completion of the planning matrix. These form the roof of the HOQ. The roof maps the relationships and interdependencies among the service characteristics. The analysis of these characteristics informs the development process, revealing the existence and nature of service design bottlenecks for a COC. The relationships among service characteristics were plotted and given a value. Past experience and test data were used to complete the roof of the HOQ. Appendix C shows the correlations developed for the roof of the HOQ for a COC.

6.8 Technical matrix for a COC

A technical matrix was constructed to form the foundation of the HOQ. This matrix addresses the direction of improvement, target values, the final weights of service and quality characteristics, and the level of difficulty to reach the target values. The direction of improvement indicates the type of action needed to ensure that the service characteristics are sufficient to make the service competitive; this direction is typically indicated below the roof of the HOQ.

Dimension	No.	Customer Requirements	Service Requirements	Measuring Units	Values
Tangibles	1	I have a professional appearance for an interview	No. of workshops conducted on professionalism	Number	Integer value
			No. of formal outfits that could be rented	Number	Integer value
	2	I have a professional resume	No. of workshops conducted on resume and cover letter writing	Number	Integer value
Reliability	3	I get opportunities with potential employers	No. of career fairs held	Number	Integer value
			No. of companies participating in the career fairs	Number	Integer value
			Number of companies invited to hold seminars	Number	Integer value
			Number of alumni invited to be connected to the university	Percentage	Percentage
	4	I have my resume easily accessible to companies	Provide companies with online access to resumes of all students	Boolean value	Yes/No
	5	I get a job that pays well	Expected salary amount	Money	Dollars
	6	I get job offers	No. of interview calls received	Number	Integer value
Responsiveness	7	I get a resume evaluation	No. of staff members appointed for resume evaluation	Number	Integer value
			Waiting time to get an appointment for resume evaluation	Time	Days
	8	I have interviewing experience	No. of mock interviews conducted	Number	Integer value

Table 9. Customer Design Matrix

The quality and service characteristics were analyzed and a standard or limit value was determined for each. These are the industry standard values. These values were established based on well-informed assumptions, and they are believed to be within reach for a university COC. The final weight of each service characteristic was calculated by multiplying the value assigned to its relationship with a specific consequence (9, 3, 1) multiplied by the importance of that consequence (obtained from the survey results); the values of all consequences were then added to yield the final weight, that is a comprehensive measure that indicates the degree to which the specific service characteristic relates to the customer consequences. These final weights are shown in a row along the bottom of the HOQ.

The engineering and technical staff that would design the service process evaluates the level of difficulty involved in achieving each service characteristic. This evaluation becomes the basis for development of strategic goals for the development of the service process to ensure customer satisfaction. The level of difficulty involved in reaching the target values for each service characteristic was determined on a scale of 0 (easy) to 10 (difficult). Thus, the HOQ was completed for a COC; it is shown in Appendix C. Twenty service characteristics were developed that would fulfill customer requirements.

6.9 Results and discussion for a COC

With the help of QFD and SERVQUAL methodologies, the SERVQUAL dimensions, customer consequences/requirements and the service characteristics were prioritized. The priority order of the five RATER dimensions based on their gap scores were determined as: Empathy (-1.25) followed by reliability (-1.12), responsiveness (-1.1), and assurance (-1.1), and tangibles (-0.95). The overall gap score for the five dimensions was -1.1 indicating a scope for improvement for a COC. A few of the customer requirements that ranked higher than the others were: I get a job that fits me, I have a job that I enjoy, I know what different jobs are available, I can work overseas, I get a job that pays well, I get opportunities with potential employers, etc.

Establishing a team for career guidance and counseling team to provide students with individual attention and care would increase the performance of the COC. Hosting more career fairs with the participation of a large number of companies would provide students with more opportunities to interact with employers and to secure suitable jobs. Establishment of a resume evaluation team with sufficient staff would increase student confidence and help them face interviews. Conducting periodic workshops on writing resumes and cover letters, interviewing, business ethics, and professionalism would increase student knowledge and improve their professional skills. Conducting frequent mock interviews would equip students with practical experience that could help them to perform better in interviews.

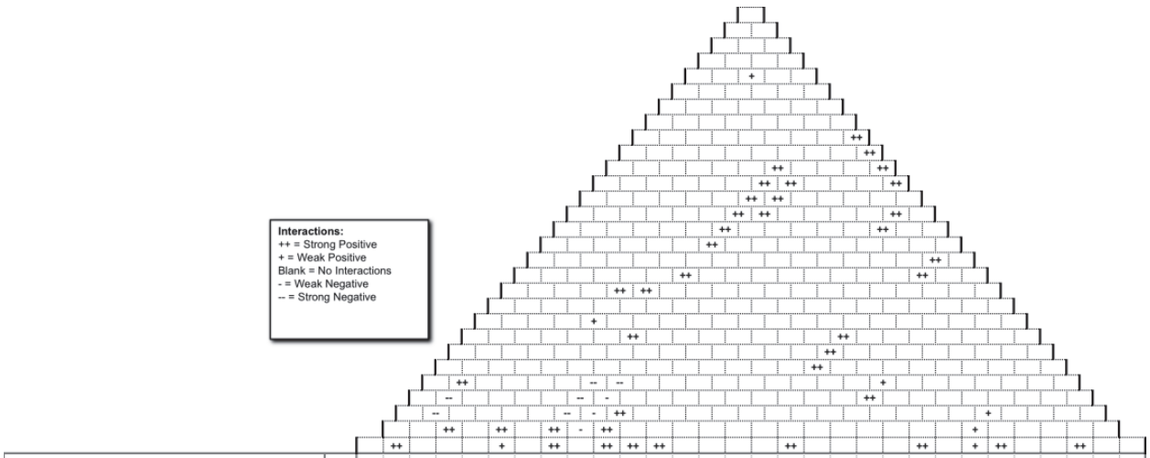
The service characteristics were also prioritized that help the design team in development of better services and reduce the service development costs. The number of mock interviews conducted received the highest priority along with number of staff appointed for conducting mock interviews, followed by the number of staff members on the career guidance and counseling team, the number of interview calls received, the number of staff members appointed for resume evaluation, the number of workshops conducted on setting up, and accessing online job accounts. Also important were expected salary

amount, employer access to online resumes, number of workshops on interviewing and business ethics, the number of international companies participating in the career fair, and the number of formal outfits that could be rented. A focus on implementing these service characteristics in order of their priority would improve the function of the COC.

Priority Level	Service Characteristics	Weight/Importance
1, 2	Number of mock interviews conducted	179.8
1, 2	Number of staff appointed for conducting mock interviews	179.8
3	Number of staff members in career guidance and counseling team	171.1
4	Number of interview calls received	157.4
5	Number of staff members appointed for resume evaluation	138.5
6, 7	Number of companies participating in the career fairs	133
6, 7	Number of career fairs held	133
8	Number of workshops conducted on resume and cover letter writing	85.4
9	Number of workshops conducted on professionalism	83.9
10	Number of companies invited to hold seminars	87.0
11	Waiting time to get an appointment for resume evaluation	75.3
12	Number of workshops conducted on setting up and accessing online job accounts for students	66
13	Expected salary amount	64.1
14	Provide companies with online access to resumes of all students	61.6
15	Number of job e-mail alerts sent	59.1
16	Number of workshops conducted on interviewing and business ethics	47.3
17	Number of alumni invited to be connected to university	35.8
18	Number of international companies participating in the career fairs	24.6
19	Number of etiquette dinners offered	22.2
20	Number of formal outfits that could be rented	18.6

Table 10. Prioritizing Service Characteristic

7. Appendix A – house of quality for HFCV case study



Relationships:
9 = Strong
3 = Moderate
1 = Weak
0 or Blank = No Relationship

	Importance Rating	Level of temperature change	Time taken to attain the changes in temperature level	Power of the speakers	# of operability modes in audio system	Seating capacity	Distance between front and rear seat	Engine power	Air compression ratio	Size of exhaust pipes	Nitrogen emissions	Carbon monoxide emissions	Carbon dioxide emissions	Size of side and rear view mirrors	Size of damping sheets	Suspension/steering stability	# of airbags	Airbag response time	Alignment of tires	Engine crash warning system	Tank capacity	Tire size	Tire quality	Transmission torque	Cylinder size	Weight of engine parts	# of valves per cylinder	Cost of extended warranty	# of parts covered under warranty	Validity of warranty	Hybrid
The vehicle provides accurate safety warnings	6.55																			9											
The vehicle has high safety and standard ratings	6.97													9		3	3	9	3	9											
The vehicle gets good gas mileage	7.60							9	1													9		9	3	1	9				9
The vehicle is energy efficient	5.39							9	9	3														9							9
The vehicle has high horsepower	6.54							9	9	9													1	3	9	9	9				
The vehicle is affordable	7.98					3																									9
The vehicle has an extensive warranty	6.21																											9	9	9	
The vehicle is hybrid (split power between gas and electric)	3.24										9	9	9																		9
The vehicle has towing capabilities	5.15							9	9															9							
The vehicle does not compromise speed and handling	7.12							9	3							9			9					9							
The vehicle can drive for long distances (>400 miles)	7.13							9	3	1											9		3								
The vehicle provides a comfortable ride	7.47	3	1			9	9								9	9															
The vehicle has a quality audio system	6.66			9	9																								3		
The vehicle is climate controlled	6.55	9	9																												
The vehicle comfortably fits a family of all sizes	4.66					9	9																								
The vehicle has low emissions	4.66	1						9		1	9	9	9																		9
The vehicle is environmentally friendly	5.09										9	9	9																		9
Raw score		86	66	60	60	133	109	392	204	87	117	117	117	63	67	152	21	63	85	122	64	68	28	247	82	66	127	56	76	56	306
Relative %		3%	2%	2%	2%	4%	3%	12%	6%	3%	4%	4%	4%	2%	2%	5%	1%	2%	3%	4%	2%	2%	1%	7%	2%	2%	4%	2%	2%	2%	9%
Importance Rank		2	1	1	1	2	2	5	3	2	2	2	2	1	1	2	1	1	2	2	1	2	1	3	2	1	2	1	2	1	4
Target Value/Specs		Yes/No	29.95 BTU/h/cu. Ft.	125 Watts	4	5	Yes/No	134 HP	13/1 Ratio	2.5 inches	gm/mile	gm/mile	gm/mile	2/30 Ratio	3 inches	1.49 Hz	6	60 miliseconds	0.03 inches	Yes/No	11.9 gallons	inches	1195/65R15 Grade	161 ft lbs	2.2 litres	Yes/No	4	Yes/No	Yes/No	4 years	Yes/No

8. Appendix B – survey questionnaire for COC case study

Part A – Questionnaire

Find the benefit of using the Career Opportunities Center in the list below that is most important to you. Assign it 10 points. Then, assign from 0 to 10 points to the other benefits to indicate how important they are to you in comparison to the most important one. You may assign the same number of points to more than one benefit.

_____ I have a professional appearance for an interview
_____ I am comfortable during an interview
_____ I stand out to a potential employer

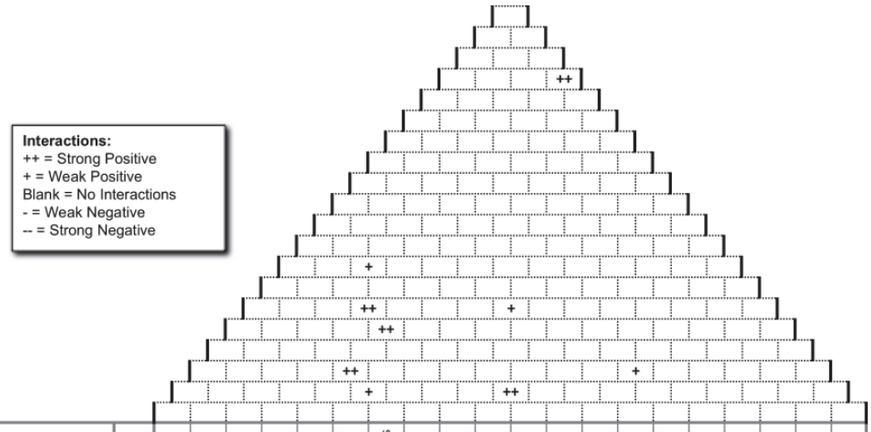
_____ I am prepared for an interview
_____ I have interviewing experience
_____ I get opportunities with potential employers
_____ I can work overseas
_____ I know what different jobs are available
_____ I have a professional résumé
_____ I get a résumé evaluation
_____ I have my résumé easily accessible to companies
_____ I get a job that fits me
_____ I get a job that pays well
_____ I have a job that I enjoy
_____ I get job offers

Part B - Questionnaire

Please rate how well the university's Career Opportunities Center delivers each of these benefits when you use it. Circle the number below that best indicates how well you feel the university's COC satisfies each of the benefits. For comparison purposes, please rate your ideal career center on the same benefits. Use a scale of:
1= Strongly Disagree
2= Disagree
3= Neutral
4= Agree
5= Strongly Agree

	COC	**Ideal COC**
I have a professional appearance for an interview	1 2 3 4 5	1 2 3 4 5
I am comfortable during an interview	1 2 3 4 5	1 2 3 4 5
I stand out to a potential employer	1 2 3 4 5	1 2 3 4 5
I am prepared for an interview	1 2 3 4 5	1 2 3 4 5
I have interviewing experience	1 2 3 4 5	1 2 3 4 5
I get opportunities with potential employers	1 2 3 4 5	1 2 3 4 5
I can work overseas	1 2 3 4 5	1 2 3 4 5
I know what different jobs are available	1 2 3 4 5	1 2 3 4 5
I have a professional résumé	1 2 3 4 5	1 2 3 4 5
I get a résumé evaluation	1 2 3 4 5	1 2 3 4 5
I have my résumé easily accessible to companies	1 2 3 4 5	1 2 3 4 5
I get a job that fits me	1 2 3 4 5	1 2 3 4 5
I get a job that pays well	1 2 3 4 5	1 2 3 4 5
I have a job that I enjoy	1 2 3 4 5	1 2 3 4 5
I get job offers	1 2 3 4 5	1 2 3 4 5
Would you recommend this service to your peers?	1 2 3 4 5	1 2 3 4 5

9. Appendix C - house of quality for COC case study



Relationships:
9 = Strong
3 = Moderate
1 = Weak
0 or Blank = No Relationship

	Importance Rating	# of workshops conducted on professionalism	# of formal outfits that could be rented	# of workshops conducted on resume & cover letter writing	# of mock interviews conducted	# of career fairs held	# of companies participating in the career fairs	Provide companies with online access to resumes of all students	Expected salary amount	# of interview calls received	# of staff members appointed for resume evaluation	Waiting time to get an appointment for resume evaluation	# of workshops conducted on interviewing and business ethics	# of international companies participating in the career fairs	# of workshops conducted on setting up and accessing online job accounts for students	# of staff members in career guidance and counseling team	# of companies invited to hold seminars	# of etiquette dinners offered	# of alumni invited to be connected to university	# of job email alerts sent	# of staff appointed for conducting mock interviews
I have a professional appearance	6.8	9	3										1								
I am comfortable during an interview	7.3				9								3								9
I stand out to a potential employer	8.1			3						9								3	3		
I am prepared for an interview	7.7	3			9						3		3								9
I have interviewing experience	6.9				9																9
I get opportunities with potential employers	7.7					9	9			3							3		1		
I can work overseas	3.0													9		1					
I know what different jobs are available	7.2														9		9		1	9	
I have a professional resume	7.7	1		9							9	3									
I get a resume evaluation	6.6										9	9									
I have my resume easily accessible to companies	7.5							9							1		1				
I get a job that fits me	8.4															9					
I get a job that pays well	7.8								9							1					
I have a job that I enjoy	8.4															9					
I get job offers	8.5					9	9			9						3					
Raw score		92	20	94	197	146	146	68	70	173	152	83	52	27	72	188	95	24	39	65	197
Relative %		5%	1%	5%	10%	7%	7%	3%	4%	9%	8%	4%	3%	1%	4%	9%	5%	1%	2%	3%	10%
Importance Rank		3	1	3	5	4	4	2	2	4	4	2	2	1	2	5	3	1	1	2	5
Target Value/Specs		3 workshops per month	≥35	3 workshops per month	3 sessions per month	2 per year	≥200	Yes	$67,567	≥7	Minimum of 5 people	≤2 days	3 workshops per month	≥30	3 workshops per month	Minimim of 5 people	Minimum 10	5 per semester	100%	2 per semester	Minimim of 5 people
Technical Difficulty (0=Easy, 10=Hard)		3	7	3	6	6	7	2	3	7	4	5	3	5	3	4	5	2	5	3	1

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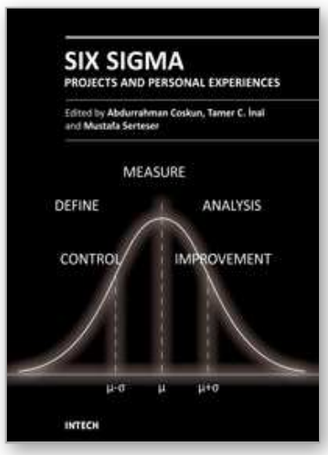

Six Sigma Projects and Personal Experiences

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In the new millennium the increasing expectation of customers and products complexity has forced companies to find new solutions and better alternatives to improve the quality of their products. Lean and Six Sigma methodology provides the best solutions to many problems and can be used as an accelerator in industry, business and even health care sectors. Due to its flexible nature, the Lean and Six Sigma methodology was rapidly adopted by many top and even small companies. This book provides the necessary guidance for selecting, performing and evaluating various procedures of Lean and Six Sigma. In the book you will find personal experiences in the field of Lean and Six Sigma projects in business, industry and health sectors.

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