European Journal of Business and Management www.iiste.org
ISSN 2222-1905 (Paper) ISSN 2222-2839 (Online)
Vol.9, No.6, 2017

An Integration of Kano Model, QFD and Six Sigma to Present a New Description of DFSS

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Abstract
Business competitiveness is no longer a choice but a matter of survival in global market place. For any company, the continuous and timely development of new products and services, which include creative features that are expected to satisfy customers, is essential to remain competitive. At present, the companies not only focus on customer satisfaction, but also want to please them that ultimately lead them towards loyalty in future. Therefore, in-depth and quick understanding of the dynamic needs of customers can be important in the development of products and markets through a short period of time. However, there have been numerous failures in product development efforts leading towards enormous waste of time and resources. One of the reasons for this is the lack of a structured and comprehensive process for product development that utilizes powerful models and methodologies, such as Kano model, QFD and modern QI methodologies as well as the principles of concurrent engineering including cross-functional teams and timely communication. As all these methodologies share the same goals of pursuing customer satisfaction thus their integration into a common model is possible and beneficial Kano model strengthens the modern QI methodologies such as Six Sigma or Lean Six Sigma approach and further enhances customers' satisfaction level. Six Sigma is used to achieve high-levels of stability through reduction in process and product variation. This directs to an almost defect free level which is also the focus of DFSS (or DMADV) building quality upstream for existing products and new product development methods. This level is essential to the customer, but not necessarily economic. Therefore, it is important to understand the customer's needs and requirements of the target, and understanding about company's own capabilities and costs. In addition to integrating Kano model and QFD into Six Sigma, the proposed approach extends previous works on these models. This paper presents a new description of the DFSS structured approach including a simple way for calculating the degree of importance for customer requirements with the adoption of Kano factor (K).An integrated approach for DFSS is proposed for practitioners to strategically understand the VOC. It included the use of different powerful tools such as Kano model, QFD, Taguchi's QLF, TRIZ, AHP, DOE, SIPOC and FMEA. All of these tools are relevant and have consensus in terms of solving customer problems to achieve customer satisfaction. They also complement each other and can be integrated together, within DFSS, to form a better methodology. Therefore, the integration of these tools for the DFSS method is considered to be possible and useful. This work extended the previous works regarding these tools, included new ideas and incorporated them in a new model. Kano model lies in the center of the framework as it forms a basis for a profound understanding of the customer needs. The DFSS methodology utilizes Deming's PDCA cycle through the DMADV phases for Cl. Kano model strengthens DFSS and brings an intelligent approach to understand and prioritize customer requirements. In addition, a generic case study is used to demonstrate some of the steps in the proposed methodology about how it can be implemented.
Keywords: Kano model, QFD, QI, Six Sigma, VOC, DFSS, QLF, FMEA, CI, DMADV, SIPOC, Customer satisfaction, product development

1. Introduction

Business competitiveness is no longer a choice but a matter of survival in global market place. This competitiveness demands new products and services development models to be realigned and recalculated in the light of new culture of customer satisfaction and perceived quality. Perceived quality is based on the customer opinion and customers fill products and services with their understanding of their goodness (Foster 2007). For any company, the continuous and timely development of new products and services, which include creative features that are expected to satisfy customers, is essential to remain competitive. Currently, companies are not only aiming at satisfying customers, but also at delighting them. In fact, some companies even aim at winning their customers' loyalty so that they only buy their products as well as recommend no other company to other potential customers. Therefore, it is important to achieve a comprehensive and profound understanding for the dynamic requirements and needs of the customers. One of the key models that can be used to achieve this goal is the Kano model.

At present companies are facing competitions not only from local organizations but also across the globe. It is important to effectively identify customer needs so that companies would be able to develop the products and market them in a short time through their SC. Companies which efficiently introduce new products have a competitive advantage over competitors. However, there have been numerous failures in product development efforts leading to a enormous waste in time and resources. One of the reasons for this is the lack of a structured and comprehensive process for product development that utilizes powerful models and methodologies, such as Kano model, QFD and modern QI methodologies as well as the principles of concurrent engineering including cross functional teams and timely communication.

Kano model and QI methodologies share the same goals of pursuing customer satisfaction. Thus, it is possible and beneficial to integrate them into a common model. Kano model strengthens the modern QI methodologies such as Six Sigma or Lean Six Sigma approach or further enhances customers' satisfaction level. Six Sigma is used to achieve high levels of stability by reducing the variability of processes and products. This leads to an almost defect-free level which is also the focus of the DFSS (or DMADV) approach to building quality upstream into existing products and new product development. This level can be essential to customers but not necessarily be economic. Therefore, it is important to understand and target the customer needs and requirements and also to understand the company's own capabilities and costs

Quality means providing customers with what they want and satisfying their needs. However, due to the fierce competition in the global market, the goal should be to exceed satisfaction by the innovation of delighting product features (attractive attributes) and exciting non-ordinary products and features. This will enable customers to be satisfied, happy, and then loyal.

Customer satisfaction provides an indication of the quality of a product. Highly satisfied customers are more likely to be retained than those who are just satisfied. There is a big difference in loyalty levels if the customer is "satisfied" or "very satisfied" (Finkelman and Goland 1990; Heskett and Schlesinger 1994). Customer needs are becoming more sophisticated as a result of the global exposure (Plsek 1997). Satisfaction levels differ by individual customers (Magnusson et al. 2003). The VOC is a description of what product problems the customer wants to be solved (Matzler and Hinterhuber 1998). It has two types: qualitative, which includes what customers want, and quantitative, which is about how they prioritize their wants (Tan and Shen 2000). The American Marketing Association estimates that the cost of acquiring a new customer is five to six times higher than to keep the existing one (Matzler and Hinterhuber 1998). In addition, the cost of customer satisfaction is threatening around 8.5% of the total revenue according to the research by (Hepworth 1998). Customer satisfaction represents a defensive strategy as opposed to market share (offensive strategy). Market share improvements result from the improvement of customer satisfaction rates (Matzler and Hinterhuber 1998).

Table 1.1: Definitions of quality as adapted from (Hassan, Shariff Nabi Baksh, and Shaharoun 2000)

Quality guru/authority	**Definition**
Juran	Fitness for use and conformance to specifications (Juran and Gryna 1988)
Crosby	Conformance to requirements (Crosby 1980)
Feigenbaum	Total composite which will meet the expectations of customers (Feigenbaum 1991)
Deming	Targeting the present and future needs of the customer (Deming 1986)
Taguchi	Loss to society (Taguchi 1986)
ISO 9000	Totality of products characteristics to satisfy the stated or implied needs of the customers (ISO 9000, 1992)

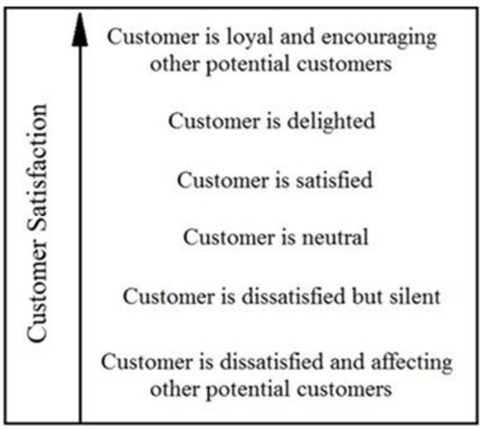


Figure 1.1: Levels of Customer satisfaction

The traditional way to design a product used to be based on trial and error (Breyfogle III 2003). Concurrent engineering method with cross functionality, guaranteed that design is considering the different aspects simultaneously as in the following examples: design for manufacturing, design for safety, design for maintainability, design for assembly, design for quality, design for performance, design for reliability, etc. These design aspects consider voices of both, external and internal customers. From the initial matrix, often referred to as the house of quality, the QFD approach focuses on the attributes or qualities of the most important products or services. These are composed of customer wows, wants, and musts (i.e. Kano model of customer perception). Once you have prioritized the attributes and qualities, QFD deploys them to the appropriate organizational function for action. A set of house of quality (HOQ) is better than a conventional single house of quality (HOQ). Thus, QFD is the deployment of customer-driven qualities to the responsible functions of an organization. Many QFD practitioners claim that using QFD has enabled them to reduce their product and service development cycle times by as much as 75 percent with equally impressive improvements in measured customer satisfaction.

2. Literature review

Kano model (Kano et al. 1984) is an effective technique to gain a deep understanding of customer needs. Product performance refers to the efficiency with which a product achieves its intended purpose(Foster 2007). Kano model enables a creative understanding of customer needs and which ones are more critical to satisfaction. It is used to deeply analyze the Voice-Of-the-Customer (VOC). It is an intellectual model which provides a systematic approach to understanding customer needs (Shen, Tan, and Xie 2000). It has been applied to new product development (Matzler and Hinterhuber 1998) as well as new service creation (Bhattacharyya and Rahman 2004). Kano et al. (Kano et al. 1984; Kano 1993) classified product characteristics into three types (i.e. must be attributes(expected), one dimensional attributes (proportional) and attractive attributes (value-adding)).However, there are situations where three other categories may result (Kano et al. 1984) i.e. indifferent, reverse and skeptical or questionable.

It is recommended to complete all must-be attributes (priority), be competitive on the one-dimensional attributes and then include some of the attractive attributes (Kano 1993; Robertshaw 1995). Kano model helps in understanding the unspoken needs of customers (Magnusson et al. 2003). Customer needs are dynamic and what is currently attractive may become a priority in the near future. The Kano questionnaire helps practitioners to classify customer needs (see Table 2.1). It is based on a pair of a negative and a positive question with multiple choices for each.

Kano model has the following advantages: it provides a better understanding of customer needs and a better tailoring of solutions to optimally satisfy different customer segments, it helps in requirements trade-off decisions, it helps to fulfill the attractive and differentiating requirements, and in creating an optimal prerequisite for establishment of QFD (Matzler and Hinterhuber 1998). At the same time, it requires little mathematical calculation and related information can easily be obtained (Lee, Sheu, and Tsou 2008). Customer's needs are different and the improvement in one may not grant the same satisfaction level as in another one. Therefore, weighing them is important. However, the traditional weighing methods may not be sufficient to explain the relationship between needs and satisfaction. Kano model classifies the influences of the needs on customer satisfaction. Therefore, it is a very effective tool that can be used to establish some priority level of needs by setting-up some importance ranks of individual product characteristics in multiple-criteria decision-making to optimize the product development process by readjusting the conventional raw weights focusing on customer satisfaction (Chen and Chuang 2008).

Kano model is criticized to provide limited decision support in engineering design if used alone (it does not classify requirements that are within the same category), focusing on the customer view with limited consideration of the manufacturer's capacity (to make and afford; the value chain converges when the two overlap), and for not being equipped with quantitative assessment of customer needs (Xu et al. 2009). It lacks the consideration of human uncertainty and the fuzzy thinking patterns of customers (Lee and Huang 2009).

Table 2.1: Kano assessment template as adapted from (Matzler and Hinterhuber 1998)

Functional form of the question	Dysfunctional form of question				
	1. like it that way	2. must be that way	3.neutral	4. can live with that	5. dislike it that way
1. like it that way	Questionable	Attractive	Attractive	Attractive	One-dimensional
2. must be that way	Reverse	Indifferent	Indifferent	Indifferent	Must-be
3.neutral	Reverse	Indifferent	Indifferent	Indifferent	Must-be
4. can live with that	Reverse	Indifferent	Indifferent	Indifferent	Must-be
5. dislike it that way	Reverse	Reverse	Reverse	Reverse	Questionable

Quality of products and processes is a critical success factor in manufacturing industry. The selection of a QLF is an important issue in quality engineering to relate the product's key quality characteristics to its quality performance. QLF depends on customer specifications and it quantifies the quality loss on an economic scale. It includes costs incurred during production and use. It recognizes the needs of producers and customers.

In order to minimize the loss of product quality, the variance and deviation must be reduced. The exact QLF form is unknown (Teeravaraprug. Jirarat 2004). Different QLFs have been discussed in the literature (Randolph 1970; Taguchi and Wu 1980; Taguchi 1986; Spiring 1993; Drain and Gough 1996; Li 2003). However, a simple quadratic QLF may be reasonable in many cases(Taguchi, Elsayed, and Hsiang 1989; Teeravaraprug and Cho 2002). The approach for improving quality depends on the QLF type ((Teeravaraprug 2002). Clausing (Barker and Clausing 1984) defined quality loss in terms of a QLF as the financial cost imparted by the society after the product is shipped including the internal costs. To define the quality loss, Taguchi proposed a QLF in the form of a quadratic relationship which unites the financial loss with the functional specification. Taguchi's QLF represents a cost oriented element of company-wide quality control (CWQC). His QLF changed the way people think about quality and the effect of QI (Sullivan 1988).

Taguchi's QLF defines quality as 'uniformity around a target value', with the specification limits being irrelevant in this context as the overall loss caused by a product increases if the product deviates more and more from the target, regardless of whether it is within the specification limits or not. Products manufactured closer to the targets works well and are easily to assemble. The concept of conformance to specifications can become a barrier to QI. Taguchi's QLF can justify spending money to improve the capability of a process even when it is capable. Taguchi's QLF has the unique advantage of overcoming the system of cost control which is an internal company inhibitor to QI. Most American companies impose financial pay back guidelines which must be met by improvement actions and these guidelines often prevent QI. Figure 2.1 shows the step-loss function as well as Taguchi's three models.

An example from Nippondenso, a Japanese company that uses Taguchi's QLF in project or QI initiatives prioritization, showed that out of 43 characteristics in nine processes, the top priority was for a process with a 10-Sigma capability and not for other processes with less Sigma values. American companies never give priority to a process with 10-Sigma capability. They need to use Taguchi's QLF to translate the idea of process and product design optimization to improve cost and quality (Sullivan 1988).

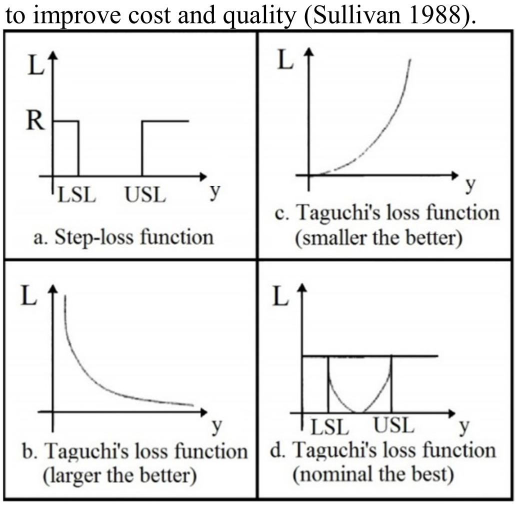


Figure 2.1: Step loss and Taguchi loss functions as adapted from (Teeravaraprug 2002)

According to Tan and Shen (Shen, Tan, and Xie 2000), QFD is a proactive design approach that was introduced by Akao in Japan in 1966 as a QI tool which spread later to be used in different fields in North American companies in the early 1980's. In a broad sense, QFD is a management philosophy which needs management commitment (Chen 2009). It is similar to Pareto law where 20% of considered items affect 80% of the problem and thus they are the most influential.

QFD is also a communication tool and a QM and planning approach. It is based on customer feedback and is used to implement TQM. It helps to interpret how the processes of an organization interact to drive customer satisfaction (Tan and Shen 2000). It is a structured way (using project management rules) for developing new products based on the assessment of customer requirements (Matzler and Hinterhuber 1998). It is also considered as a QMS that builds quality into the product from the early design stage and it translates customer demands into design targets (Bayraktaroglu and Özgen 2008).

A typical QFD form has four phases: the house of quality (HOQ), product characteristics design and parts deployment, process design and planning, and process control features and production planning. The HOQ is the most commonly used form and it connects several sub-matrices, links technical requirements with customer needs and ranks the technical characteristics to choose the most effective ones (ReVelle 2004). The HOQ is based on the belief that products should be designed to achieve total satisfaction (Tan and Shen 2000) through concurrent engineering of processes and products including reliability. The HOQ has been the focus of the QFD- related literature as it contains the most crucial company information regarding its customers and competitors (Chen 2009). It transforms customer requirements into product features, then to process reengineering design features and to control plans.

QFD is a structured method, with seven management and planning tools (i.e. Affinity Diagram, Relations Diagram, Tree Diagram, Matrix Diagram, Matrix Data Analysis, Arrow Diagram and Process Decision Program Chart) to identify and prioritize customer expectations quickly and effectively.

Once you have prioritized the attributes and qualities, QFD deploys them to the appropriate organizational function for action. A set of house of quality (HOQ) is better instead of a conventional single house of quality (HOQ). Many QFD practitioners claim that using QFD has enabled them to reduce their product and service development cycle times by as much as 75 percent with equally impressive improvements in measured customer satisfaction. It helps companies to minimize the Product Design Phase (Design Life Cycle) as well as also prevent from unnecessary product redesigning and modification so save lot of time and revenue. It also helps to make trade-offs between customer needs and manufacturer's capacity, improves communication between departments, builds quality upstream, increases customer satisfaction, considers the critical production control points, collects information for product development, shortens time to market (Jariri and Zegordi 2008).

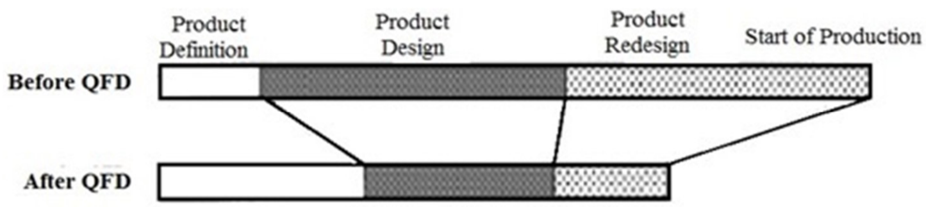


Figure 2.3: Advantages in the Successful Application of Quality Function Deployment (QFD) (Cristiano, Liker, and CC III 2001)

Six Sigma is a process improvement methodology developed at Motorola in the 1980's to minimize defects in its processes. Motorola's Six Sigma Quality Program was created by B. Smith in 1987 (Devane 2004). Also, W. Smith (Kumar et al. 2008) and Harry (Harry and Schroeder 2005) participated in the development of the concepts of Six Sigma. Motorola created six steps to achieve Six Sigma, which were later replaced by the four phases of measure, analyze, improve and control of General Electric (GE). After that, the define phase was added before the measure phase to form the well-known DMAIC process, i.e., Define, Measure, Analyze, Improve and Control. DMAIC may be regarded as a short version of the Deming cycle, i.e., Plan-Do-Check-Act or PDCA (Dahlgaard and Dahlgaard - Park 2006). Six Sigma measures the process capability in order to produce defect-free products and utilizes DMAIC to move to a revised process (Chen and Lyu 2009).

DMAIC is the term used to describe the phases of the approach taken in a Six Sigma project to achieve Cl. It is used when the product or process already exists but is failing to meet customer requirements (Bañuelas and Antony 2003). On the other hand, if the product or service taken into account is under major design change requirements or still at the early stages of development, DFSS (Design for Six Sigma) is the approach used and the five phases that are used become DMADV (Define, Measure, Analyze, Design and Verify) or IDOV (Identify, Design, Optimize and Verify). The goal of DMADV is to try hard to achieve a Six Sigma-level right from the early design stage and it generally applies the principles of concurrent engineering. According to Harry and Schroeder (Harry and Schroeder 2005), organizations that implemented Six Sigma and achieved five-Sigma levels (i.e. 233 defects per million opportunities or DPMO) need to implement DFSS to exceed those levels. They have also indicated that IDOV helps create stable, reliable, efficient and satisfying products. Banuelas and Antony (Banuelas and Antony 2004) have mentioned that DMAIC is concerned with Cl, whereas DMADV is concerned with continuous innovation.

DFSS is a structured methodology based on analytical tools for predicting and preventing defects in product design. It is used to create a reliable and defect-free new product and thus increase profits. It passes through five phases: define the design problem and customer requirements, measure the Critical-To-Quality (CTQ) characteristics, analyze the high-level technical design requirements to meet the customer's needs, develop the optimized design in detail and verify the design performance in satisfying customers.

Kano-based quality loss is a QLF generated based on Kano model. Cho and Leonard (Cho and Leonard 1997) proposed that the quality loss has a minimum value of zero at the customer specified target. However, the Kano-based QLF proposed by (Teeravaraprug 2002) has a zero value when the customers get what they asked for, a positive value when they are not satisfied and a negative one when they are delighted. Similar to Taguchi's three model types, the proportional attributes can be classified into three types: 'the larger the better' (where the customer feels neutral and the loss is zero when the targeted value is fulfilled, delighted when exceeded and dissatisfied when the targeted value is not fulfilled), 'the smaller the better' (where the customer feels neutral when the targeted value is fulfilled, dissatisfied when exceeded and delighted when a lesser value than the targeted value is achieved), and 'the nominal the best' (where the customer feels neutral when the targeted value is fulfilled and dissatisfied when the targeted value is not fulfilled). Figure 2.4 (a, b and c) shows a set of QLFs for these three QLF types. There are three factors that need to come up with an exact value for the QLF: the loss at any performance point, the targeted value, and the functional style of loss. For example, in 'the larger the better' case, the loss is R at zero performance, the targeted value is T, and the functional style is linear.

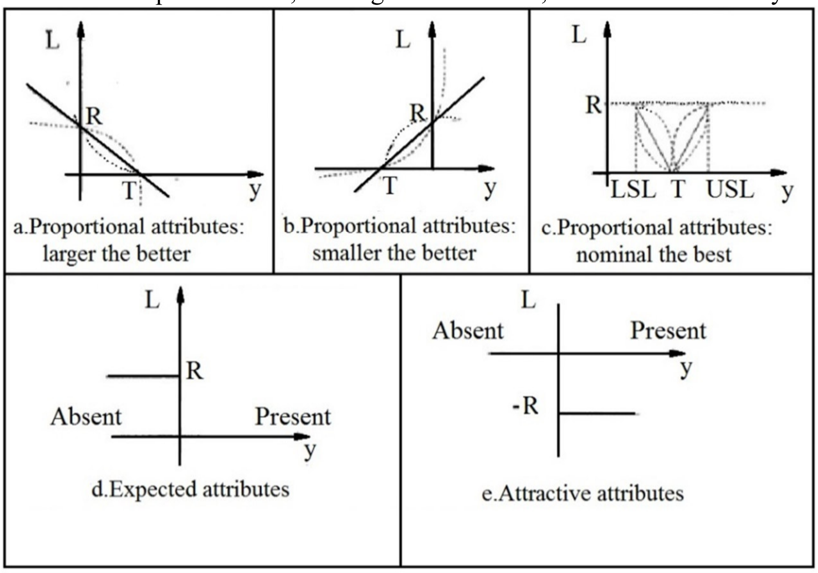


Figure 2.4: Kano based Taguchi loss functions as adapted from (Teeravaraprug 2002)

Other types can be approached in a similar way. The expected attributes and the attractive attributes act as a go/no-go requirement. For the expected attributes, when the characteristic exists, the customers feel neutral and the loss is zero. Whereas, when the characteristic is absent, the customers feel dissatisfied and the loss is positive (i.e., L=R if y exists and 0 if absent). For the attractive attributes, when the characteristic exists, the customers feel delighted and the loss is negative. Whereas when the characteristic is absent, the customers feel neutral and the loss is zero (i.e., L= -R if y exists and 0 if absent). Figure 2.4 (d and e) shows these two QLF types. Kano-based QLFs offer more flexibility but restrain the traditional and acceptable loss functions (Teeravaraprug 2002). Kano-based QLF can be used to link the product characteristics to its quality performance prioritize initiatives and quantify the quality loss to society.

3. Patterns of some integrated approaches from the literature

According to Magnusson (Magnusson et al. 2003), Clausing has proposed an iterative approach that can be used within DFSS for product development and it utilized Kano model, TRIZ and FMEA in three phases: product family, individual products and lower-level sub- systems. Shen (Shen, Tan, and Xie 2000) proposed an integrated approach to product development using Kano model and QFD. The integration between QFD and Kano model suggested by (Matzler and Hinterhuber 1998) is believed to have benefits such as fewer launch problems, better communication between departments, better competitive analysis and better planning. Tan and

Shen (Tan and Shen 2000) proposed using an approximate transformation function based on Kano's model, to calculate an adjusted customer satisfaction improvement ratio within the QFD planning matrix. This matrix reprioritized the customers attributes using an importance adjustment technique based on Kano-category factors, rather than traditional factors.

In QFD literature, Kano model is sometimes used to assign weights to the different customer attributes. An adjusted importance factor of each requirement is calculated by multiplying the raw importance factor by a weight. This weight or rank is sometimes calculated using an AHP (Tan and Shen 2000). Lee (Lee, Sheu, and Tsou 2008) presented an integrative approach by incorporating the Kano model into QFD and adjusting customer requirement weights to optimize the product design and enhance customer satisfaction. Also, Tontini (Tontini 2003) presented a modified Kano approach which is integrated into QFD.

In addition to integrating Kano model and QFD into Six Sigma, the proposed approach extends previous works on these models. This paper presents a new description of the DFSS structured approach including a simple way for calculating the degree of importance for customer requirements with the adoption of Kano factor (K).

4. Proposed Integrated Model for DFSS

The model proposed in this paper improves the implementation of different tools and provides a structured step-by-step DFSS method for product development. In addition, management commitment, concurrent engineering and cross-functional teams are needed to speed up the time to deliver new products into markets. Figure 4.1 shows a high-level map of the proposed framework. In addition, Figure 4.2 shows the phases of this proposed approach which follows the well-structured DMADV. Then a generic case study is used to demonstrate some of the steps in the proposed methodology about how it can be implemented.

4.1. Define

- Identify opportunities and initial product modification ideas which can appear due to reasons related to technology, market needs, competition, user solutions, own creativity, alliance, acquisition, licensing, etc., (Shen et al., 2000).
- Identify existing customers (if the product already exists and major design changes are needed) and potential customers.
- Evaluate risks and select the appropriate project. A selection matrix can be used to list the customers and evaluate them against the different product modifications.
- Draft the project; charter, time-line, financial case (COPQ and waste) and scope.
- Understand customer needs or VOC. Use SIPOC diagram to document the high-level process where each process output should meet customer expectations (see Table 5.1 for example).

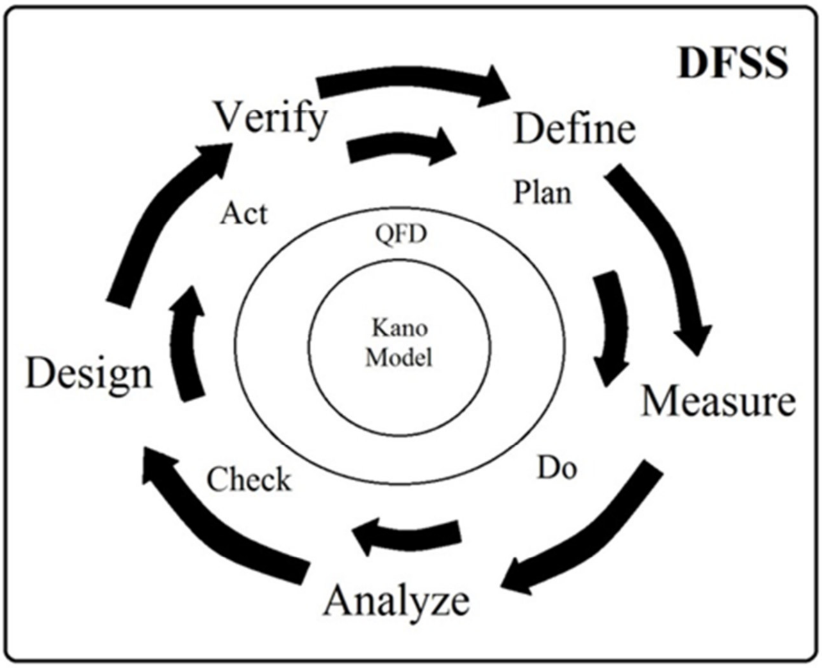


Figure 4.1: An Integrated framework of Kano, QFD and Six Sigma (following DFSS).

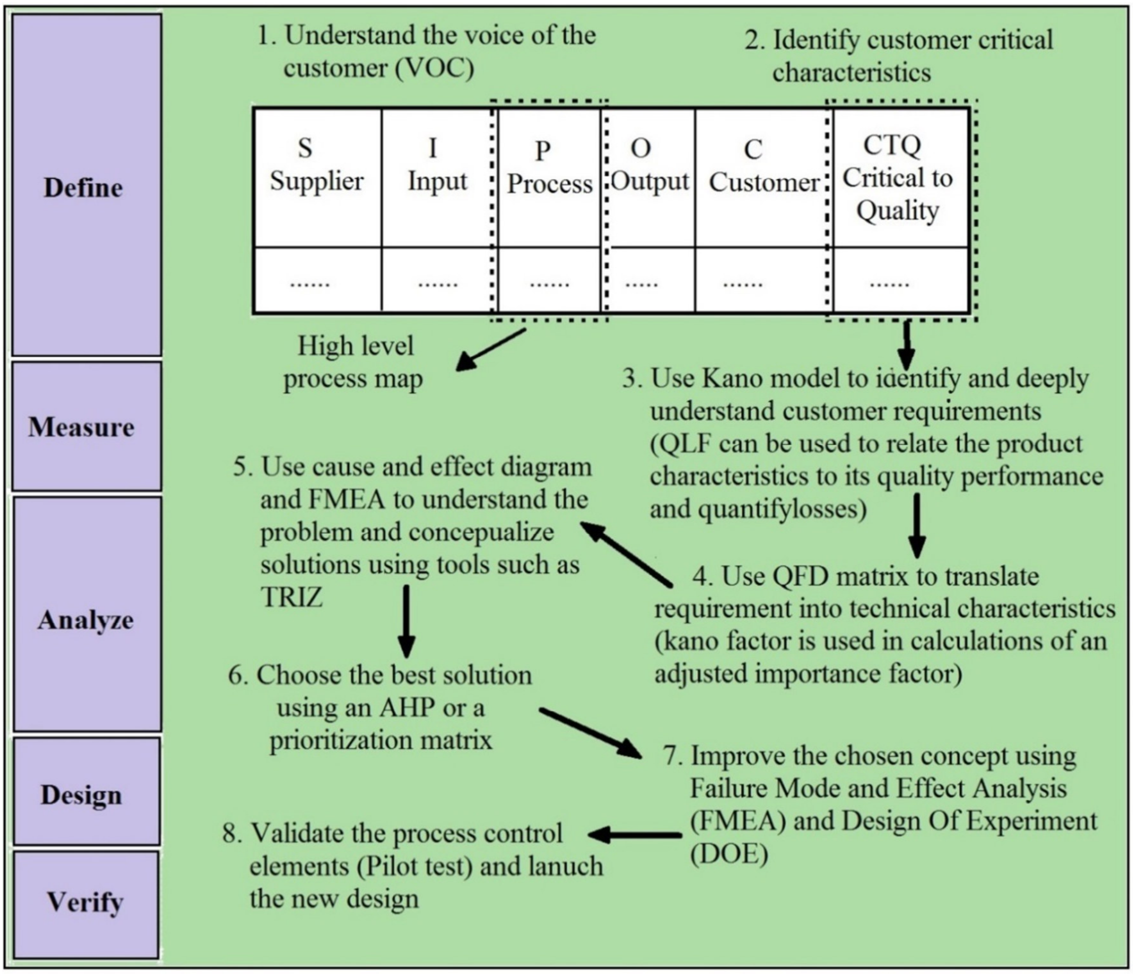


Figure 4.2: Phases of Integrated model of Kano, QFD and Six Sigma (following DMADV)

4.2. Measure:

- Identify the CTQ characteristics of the product so as to establish the VOC into the product (see Table 5.1). Customer requirements and the VOC are identified through interviews, market research, benchmarking, discussions, surveys, focus groups, customer specifications, observations, reports and warrantee claims. An affinity diagram can be used initially to brainstorm customer requirements and then organize them into different groups.
- Set up targets and specifications.
- Prioritize the CTQ characteristics. Use the Kano model to get a better understanding of what is critical to the customer (the different themes resulting from brainstorming the customer needs are Kano-categorized).Here, Kano-based QLF can be used to relate the product characteristics to its quality performance and to quantify quality losses.
- Use Kano Factor to rank the customer requirements according to their importance (see Table 5.2).

4.3. Analyze:

- Identify and prioritize key technical features by using HOQ (see Figure 5.1 for an example on the use of QFD matrix).
- Use the cause and effect diagram and FMEA to analyze the potential problems associated with the key technical features (see Figure 5.3 and Table 5.4 for example). These tools can help to ensure that the team has not missed any critical needs and they can minimize the number of KPIs.
- Conceptualize solutions using tools such as TRIZ and identify ‘how’ technical characteristics or design challenges (the ‘what’s’) identified by HOQ can be resolved. Also, identify new product features that will excite the customers.
- Use a selection matrix (see Table 5.6 for example), AHP or pursue feasibility study to find the best solution.

4.4. Design:

- Identify and prioritize process design changes.
- Identify potential process or design failures by using FMEA for a second time.
- Design modifications resulting from FMEA are performed for the items that represent the most critical risk. FMEA summarizes the risks to the customers through the design corrections for potential failures. TRIZ can also be used after FMEA identifies the failure modes to improve the design of the new products.
- Improve and optimize the chosen conceptual design by DOE. DOE is used to tweak and adjust process parameters. The goal of DOE is to optimize input variable settings for optimal output response. It can help to understand the sensitivity of the process and product characteristics, input and output variables and tolerances.
- Use benchmarking, regression analysis, processes simulation, DOE and other graphical tools such as box plots and control charts to optimize the settings of the critical inputs and process improvement.

4.5. Verify:

- Identify and prioritize the required process control elements.
- Validate and test the controls, process and the product (Pilot test).
- Establish continuous monitoring.
- Launch and implement new design and new product.

5. Discussion of implementation

The Kano model strengthens DFSS and provides a smart approach to understand and measure customer needs. To demonstrate the proposed integrated model, a generic case study is presented. From this study, it can be seen that the additional benefit for the integration of Kano model, QFD and Six Sigma lies in the use of DFSS innovative approach (which utilizes DMADV structure including various graphical and analytical tools of Six Sigma such as the ones used in Figure 4.2 as well as Table 5.4), the use of QFD to translate customer requirements into technical characteristics (and their ranks) as seen in Table 5.l, and the use of Kano model to deeply understand and quantify the customer requirements utilizing Kano factor which helps in the calculation of an adjusted degree of importance as seen in Table 5.2 and Figure 5.l.

5.1. A generic case study based on integrated proposed model for DFSS

This case study uses an example of Company A that buy rough green (wet) willow timber from sawmill. The timber is mainly dried, pressed and trimmed before being delivered to a customer. From sawmill it undergoes air or kiln drying process to reduce the moisture content. The next stage is pressing. The willow fibers have to be compressed in order to strengthen the timber sufficiently to withstand the impact of a cricket ball. The timber is pressed up to 2,000lb per square inch. Next stage is to correctly grade and trim it into the bat blade shape.

Company A led the supply of high grade bat blades to selected bat manufacturer who exports their products around the world. Making the finest quality cricket bats requires the careful selection of the world's best raw materials, the willow cleft. Only the highest grades of willow are hand selected by Company A. The density of the wood and consistency of the grain through the playing area of the bat is of vital importance to the end balance and performance. Here are the high-level steps of this DFSS (following DMADV) case study:

5.1.1.Define:

1. VOC is identified through interviews, market research, benchmarking, discussions, surveys, focus groups, customer specifications, observations, reports and warrantee claims. Existing customers as well as potential customers are identified.
2. Understand the VOC and identify customer CTQ characteristics (see Table 5..l)

Table 5.1: SIPOC and CTQ characteristics

S	I	P	O	C	CTQ
Sawmill	Properly sawn, end waxed and stacked bundles of logs	cutting	cut, sorted and stacked bundles of timber	Drying kiln	Properly cut, sorted and stacked bundles of timber
Drying kiln	cut, sorted and stacked bundles of timber	Dry	Dried bundles of timber	Press mill	Properly cut, sorted and stacked bundles. Moisture content and timber physical shape
Press mill	Dried bundles of timber	Press	Pressed timber pieces	Grading station	Specified thickness and width
Grading station	Dressed timber pieces	Grade	Graded timber pieces	Trimming station	Specified grade
Trimming station	Graded timber pieces	Trim	Trimmed bat blade pieces	Sorter	Specified length and bat blade shape
Sorter	Trimmed bat blades pieces	Sort	Sorted bat blades pieces	Packaging station	Proper sort
Packaging station	Trimmed bat blades pieces	package	Packaged bundles of bat blades	Customer	Specified grade, dimensions, moisture, quantity and good packaging

5.1.2. Measure

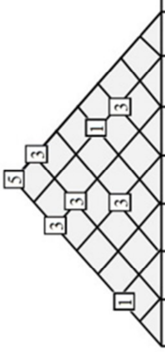
Use Kano model (see Table 5.2) to identify and understand customer requirements (or use a Kano-based QLF).

Table 5.2: Kano classification of customer requirements

Customer Requirement	Kano classification	Kano factor (K)
Moisture Content	Must-be	2.0
Specified grade	Must-be	2.0
Specified quantity	Must-be	2.0
Specified thickness	One-dimensional	1.0
Specified Width	One-dimensional	1.0
Specified length and shape	One-dimensional	1.0
Proper sorting	Attribute	0.5
Good packaging	Attribute	0.5

5.1.3. Analyze

Use QFD matrix to translate requirements into technical features. The Kano factor is used in the calculation of an adjusted degree of importance. This Kano adjusted degree of importance method allow different weighing factors such as Kano factor, sales point and improvement ratio (which is based on the target for the customer requirements and the customer perception of own company as a score). All scores of customer perception, target, degree of importance and technical characteristics inter-relationships are based on customer focused groups rating on a scale from 1 to 5 points and 1 to 2 points for sales point (as seen in Figure 5.1). The rest of the columns in Figure 5.1 are based on simple calculations according to the equations in the title of the table. The QFD matrix lists the customer and technical requirements and their rankings. Figure 5.2 shows that two customer requirements (i.e., specified grade and moisture content) stand for 73.8% of the total of the importance factors. Highest score (drying process) is the area of focus for the next period of time.



	Drying process	Grader training	Shipping operator training	Sorter accuracy	Pressing setup	Trimming setup	Rough material	Degree of importance	Customer perception of own company	Customer perception of competitor 1	Customer perception of competitor 2	Target	Sales point	Improvement ratio = Target / Customer perception of own company	Kano factor (K)	Kano weighted factor = improvement ratio* K * sales point	Kano adjusted degree of importance = Kano weighted factor * degree of importance	% importance
Moisture Control	9						3	4	2	2	3	4	2	2.00	2.0	8.00	32	33%
Specified thickness					9		1	3	2	3	3	3	1	1.50	1.0	1.50	5	5%
Specified width					9		1	3	3	4	3	4	1	1.33	1.0	1.33	4	4%
Specified length	1					9	1	4	2	2	4	4	1	2.00	1.0	2.00	8	8%
Specified grade	3	9			3		3	5	2	3	4	4	2	2.00	2.0	8.00	40	41%
Specified quantity			9					3	4	3	5	4	1	1.00	2.0	2.00	6	6%
Proper sorting				9				2	4	3	4	4	1	1.00	0.5	0.50	1	1%
Good packaging			9					2	3	2	3	3	2	1.00	0.5	1.00	2	2%
Customer perception of own company	2	2	4	4	2	2	2											
Customer perception of competitor 1	2	3	3	3	3	2	3											
Customer perception of competitor 2	3	4	4	4	3	4	4											
Relative importance of weight	416	360	72	9	197	72	233											
Relative factor	31 %	27 %	5 %	1 %	14 %	5 %	17 %											

Figure 5.1: QFD matrix

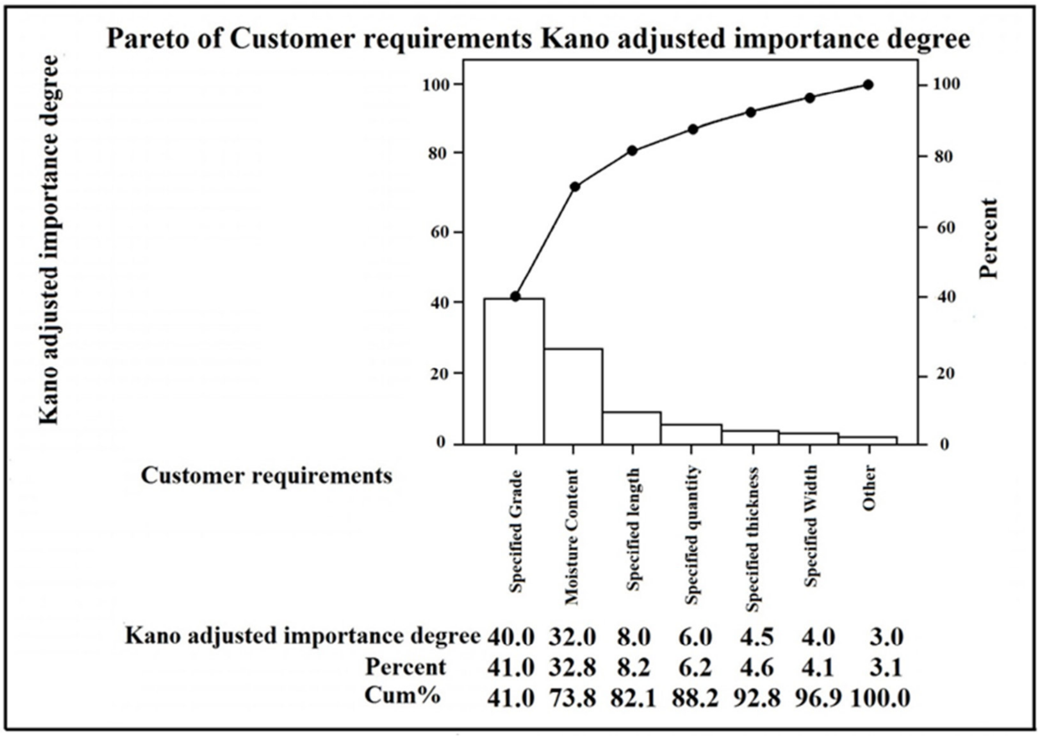


Figure 5.2: A Pareto of the Kano-adjusted importance degree via customer requirement

Use the cause and effect diagram and FMEA to understand the problem and start designing solutions (or use TRIZ).

I. In order to further analyze the leading problem from the previous steps (i.e., drying process defects), the cause and effect diagram (see Figure 5.3) is used to understand the problem. Table 5.3 shows a summary of the results sorted by a cross functional team. Each person was asked to rank the top eight items and calculate the score for each item by multiplying the ranks and dividing the result by the count of ranks. Similarly, FMEA is also used to understand the potential failure modes at the different steps of the process (as in Table 5.4). A Risk Priority Number (RPN) is calculated for every potential failure mode cause which is the result of the multiplication of severity, occurrence and detection rates filled by the team. Table 5.5 shows a summary of potential sources of problems from these two brainstorming knowledge tools. The four most important issues to focus on are: old kilns, drying procedure, kiln operator training and loader operator training (timber arrangement and bundle sizes). The main concern is the old kilns and its FMEA-identified corrective action (the feasibility study).

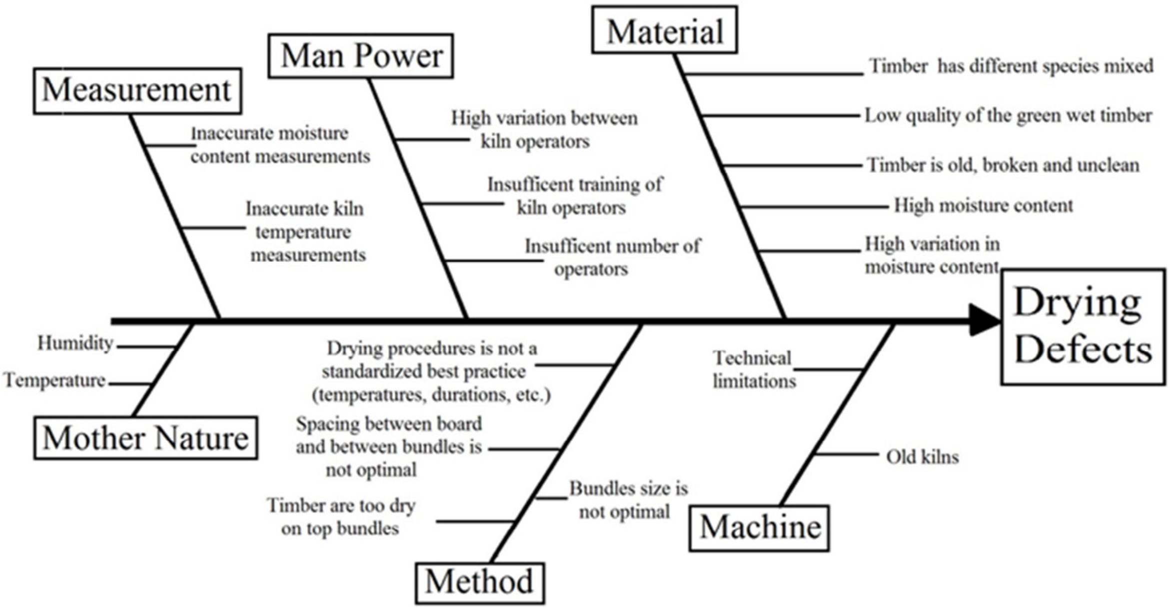


Figure 5.3: Cause and effect diagram

Table 5.3: Summary of possible causes for drying process defects and their weights

Cause and Effect potential causes	weights
Old Kilns	784
Drying procedure	560
Insufficient training of kiln operators	263
High variation between kiln operators	40
Spacing between board and between bundles is not optimal	32
Timber is old, broken and unclean	24
Timber pieces are too dry on top bundles	9
Low quality of the wet timber	2
Inaccurate moisture content measurements	1
Bundles size is not optimal	1

II. Conceptualize solutions. The problem of drying process defects can be considered as a previously well-solved problem. As a follow up from the feasibility study identified from the previous step of FMEA, two solutions for drying defects were identified. The first option is to repair the old kiln and the second is to buy a new more efficient kiln.

Table 5.4: FMEA (Failure Mode and Effect Analysis) for the drying process

Process Step	Key Process input	Potential Failure Mode	Potential failure Effect	Severity	Potential Causes	Occurrence	Current Controls	Detection	RPN	Action Recommendations	Responsibility	Action Taken
Load timber bundles into the kiln	Wet timber	Broken boards	Loss in recovery and grade	3	Operator error	9	Visual inspection	1	27	Loader operator training	Dry end manager	Plan training
Load timber bundles into the kiln	Wet timber	Wrong arrangement of size and spacing	Loss in recovery and grade	5	Operator error and variation between operators	9	Visual inspection	1	45	Loader operator training	Dry end manager	Plan training
Dry the timber	Moisture content	Boards are over-dried	Loss in recovery and grade	9	Kiln instruments failure (old)	9	Moisture detector	1	81	Fix the Kiln or buy a new one	Dry end manager	Study feasibility
Dry the timber	Moisture content	Boards are over-dried	Loss in recovery and grade	9	Drying procedure is not a best practice	9	Moisture detector	1	81	Kiln operator training	Dry end manager	Plan training
Dry the timber	Moisture content	Boards are very wet	Loss in recovery and grade	9	Kiln failure (old)	1	Moisture detector	1	9	Fix the Kiln or buy a new one	Dry end manager	Study feasibility
Unload timber from the kiln	Dry timber	Broken boards	Loss in recovery and grade	3	Operator error	9	Visual inspection	1	27	Loader operator training	Dry end manager	Plan training

Table 5.5: Summary of main potential sources of problems from the knowledge tools

	Key potential causes	**Knowledge tools**		
		FMEA	**Cause and effect diagram**	**Observations**
1	Old Kilns	•	•	•
2	Drying procedure	•	•	•
3	Kiln operator training		•	
4	Loader operator training	•		•

Use prioritization matrix or feasibility study to select the best solution (or use AHP). The first step of the team is to establish the criteria, as in Table 5.6. The second step is to list priorities as voted on by the team based on the data available and the experience of the team members. From the comparison in the table, the second option (buying a new kiln) is a better choice.

Table 5.6: Simple comparison matrix

Available solutions within industry	**Factor 1: Cost $**	**Factor 2: Efficiency**
Fix Current old kiln (contractor A)	175,000	89%
buy a new kiln form (contractor B)	445,000	99%
Priority based on experience and judgment	17%	83%

5.1.4. Design

Improve the chosen concept (buying a new kiln) using FMEA and DOE once implemented. DOE can help in formation of best procedures, understanding the process and investigate which of the input factors are seriously affecting the output and at what levels. Based on the results from the knowledge tools and demonstration, the DOE inputs can be drying procedure (1 or 2), timber bundle size (small or large) and timber arrangement (1 or 2). The output is the percentage of drying defects. A (2^3) factorial design can be selected to study main and interaction effects. Trials are randomized to reduce the effect of noise factors. Then, the effects of factors and interactions are statistically analyzed and the settings of input parameters are determined in order to minimize drying rejections.

5.1.5. Verify

Verify the process control elements (Pilot test) and launch the new design.

6. Conclusions

In this paper, an integrated approach to new product development is proposed by using a Kano-based Six Sigma, QFD which is important to understand the technical requirements, ‚SIPOC which is important to understand the VOC, QLF (which is used to relate the product characteristics to its quality performance, prioritize initiatives and quantify quality loss to society on an economic scale), Theory of Inventive Problem Solving (TRIZ or TIPS) which is used to conceptualize solutions, Analytic Hierarchy Process (AHP) which is used in alternatives' selection, cause and effect diagram and FMEA which are used to brainstorm the potential causes of problems and DOE which is used to optimize the process response. This integrated approach represents a contribution to the existing and new products' innovation. Figure 5.4 shows a proposed high-level framework of the Kano, QFD and Six Sigma to new product innovation and development. Kano model lies in the center of the framework as it forms a basis for a profound understanding customer needs. The DFSS methodology uses Deming's PDCA cycle through the DMADV phases for Cl.

Kano model enhances DFSS and brings a smart approach to understand and prioritize customer requirements. In addition, a generic case study is used for demonstration purposes. This case study gives an example of some of the steps in the proposed methodology to demonstrate how it can be implemented. Additional studies of the practical implementation of the proposed integrated model are required to further verify that model. Also, it would be worthwhile to investigate theoretically and practically the integration of further various tools into it.

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List of Abbreviations

ASQ	American Society for Quality		QLF	Quality Loss Function
ANOVA	Analysis of Variance		QM	Quality Management
AHP	Analytic Hierarchy Process		QMS	Quality Management System
BSC	Balanced Score Card		QS	Quality System
BE	Business Excellence		RPN	Risk Priority Number
CCR	Critical Customer Requirements		SMED	Single Minute Exchange of Dies
CWQC	Company-Wide Quality Control		5S	Sort, Set in order, Shine, Standardize and Sustain
Cl	Continuous Improvement		SIPOC	Supplier-Input-Process-Output-Customer
CEO	Corporate Executive Officer		SPC	Statistical Process control
COPQ	Cost Of Poor Quality		SC	Supply Chain
COQ	Cost Of Quality		SCM	Supply Chain Management
CTQ	Critical to Quality		SKU	Stock Keeping Unit
CRM	Customer Relationship Management		TIPS or TRIZ	Theory of Inventive Problem Solving
DPMO	Defects Per Million Opportunities		Toyota Production System (TPS)	Toyota Production System (TPS)
DMADV	Define, Measure, Analyze, Design and Verify		TPM	Total Productive Maintenance
DMAEV	Define, Measure, Analyze, Enable and Verify		TQ	Total Quality
DMAIC	Define, Measure, Analyze, Improve and Control		TQC	Total Quality Control
DOE	Design Of Experiments		TQM	Total Quality Management
DFSS	Design For Six Sigma		TSS	Traditional Six Sigma
FMEA	Failure Mode and Effect Analysis		USL	Upper Specification Limit
GE	General Electric		VSM	Value Stream Mapping
HOQ	House Of Quality		VOC	Voice Of the Customer
IDOV	Identify, Design, Optimize and Verify		Cpk or Cpm	Process Capability Index
ISO	International Organization for Standardization		Ppk or Ppm	Process Performance Index
KPI	Key Performance Indicator			
LSS	Lean Six Sigma			
LSSL	Lean Six Sigma Light			
LSL	Lower Specification Limit			
N/A	Not Applicable			
PDCA	Plan-Do-Check-Act			
QFD	Quality Function Deployment			
QC	Quality Control			
QI	Quality Improvement			