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# USER REQUIREMENTS CUSTOMIZATION AND ATTRACTIVE QUALITY CREATION FOR DESIGN IMPROVEMENT ATTRIBUTES

***Abstract:*** *The aim of this paper was to customize user requirements and quality creation for design improvement of furniture. The major purpose has been achieved with the use of Quality Function Deployment technique and Kano Model. The study involved 564 students from 3 engineering colleges. Extensive user requirements were identified with the help of Questionnaires. The use of House of Quality, Kano Model and Pareto Diagram helped in prioritizing all important features which are needed in customizing user requirements. The prioritized requirements include ergonomic design, desk adjustability, comfortability, product corners (sharp corners) and latest material. All these factors both got high relative and absolute weight. Therefore, more engineering efforts need to be directed towards these requirements for achieving user customization for design improvement. The developed House of Quality with the help of Kano Model results has proved to be a good tool in customizing user requirements.*

***Keywords:*** *Customization, User Requirements, Quality Function Deployment, Design Improvement, House of Quality*

## 1. Introduction

In the process of improving design of the product or service, user satisfaction is the major aim or target. This is due to that for any industry, organisation or institute customers or users are the key assets (Joshi and Rao, 2013). Customization can be stated as an explicitly way of stating the interests and preferences towards either a service or products from a supplier or producer respectively. In normal human life, the preferences differ from one person to another though sometime it can happen for people to have some interest for the same product or services. Students also like other people have their requirements at various colleges, schools, institutes and/or universities. Even though that student`s interests differs regarding various products which they are supposed to use at colleges or their education centres but still it is not common for many established education centres to involve students in stating their preferable requirements before procuring or designing facilities including classrooms furniture. In one way or other this habit demotivate some student who are not well satisfied with an already supplied furniture which mostly are not customized.

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For example, having completed survey to various colleges in India, it was found that all students have never being involved in the whole process of procuring whatever facilities available at colleges even though some facilities are being procured while students are available at their colleges. According to reference (Khanam et al., 2006) the problem of ignoring customization of user requirements (student requirements) in designing the college furniture and other college facilities in either direct or indirectly way is still a major problem till date to engineering students. Referring to the exhaustive conversations which was done with many engineering students, it was clearly found that there is zero involvement in designing college furniture from the side of students even though the students are the main users of the available college or university furniture. According to reference (Mohanty and Mahaptra, 2013), the authors suggested that the most effective tool that need to be involved in the current situation even for future time as the tool to design any product or service through thoroughly involvement of users or customers is the use of Quality Function Deployment (QFD).

Once again, reference (Mohanty & Mahaptra, 2013) suggests that, in order to apply an integrated approach for modelling design characteristic of a product (office chair) in an office environment then there is a need of having an interaction between the product and customer which varies from customer to customer. This can further satisfy the designer and the user after incorporating both customer requirements and technical considerations. Now it is a time for engineering students to state their needs through the use of Quality Function Deployment and Kano Model. The use of QFD helps in achieving user customization. This become possible whenever the technique of Quality Function Deployment (QFD) can be well used especially in team work. Also QFD can help customization of Design (Gharakhani and Eslami, 2012) in case that whatever scientifically proved and recommended after research can get chance of being implemented and monitored.

## 2. Objective

The main objective for the study was to carry out user customization for design improvement attributes by the use of Quality Function Deployment technique and Kano Model. The users considered for this study were engineering students who are studying in India. This study was carried at three (3) engineering colleges in India with aim of customizing classrooms furniture. In order to collect various user requirements, rating through Likert scale of 1 to 5 range was used. QFD technique was used to customize the requirements which later on were translated into engineering characteristics (technical descriptors) through House of Quality.

## 3. Literature review with QFD`s early history

QFD originated in late 1960s in Japan. QFD was developed in the late 1960s by "Professors Shigeru Mizuno" as emeritus of the Tokyo Institute of Technology and "Yoji Akao" (Chan and Wu, 2002; Besterfield et al., 2011; Gharakhani and Eslami, 2012). When they initiated to develop Quality Function Deployment (QFD), Statistical Quality Control (SPC) which was introduced subsequently to World War II (1945) (Adhaye, 2013) had already taken roots in majority of the manufacturing industries in Japanese. At the same time the quality undertakings were being integrated with the lessons of such distinguished gurus (scholars) including "Dr. Juran, Dr. Kaoru Ishikawa, and Dr. Feigenbaum" which put importance on the making quality control a portion of business management for which in the long run became known as Total Quality Control (TQC) and Total Quality Management (TQM) (Chan and Wu, 2002).
Both Yoji Akao and Professors Mizuno they had a goal of starting a technique regarding

to quality assurance which would try to support in achieving user satisfaction into a service or product before the service or product become serviced or manufactured respectively (Jaiswal, 2012). Formerly this planning tool of quality control approaches were predominantly aiming at trying to fix any problem which might be identified during or after servicing or manufacturing the service or product respectively.

According to reference (Akao, 1997), In 1966,"Kiyotaka Oshiumi" presented the first enormous scale application of Quality Function Deployment (QFD) at "Bridgestone Tire" in Japan whereby they managed to use a process assurance under regard of fishbone diagram which also known as "Ishikawa or Cause and Effects Diagram" to classify each user or customer requirement (effect) as the Voice of Customer (VOC) and then to identify the design auxiliary quality characteristics (Technical Descriptors) and process factors (causes) which were desirable to control and measure it.

In 1972 according to reference (Ayoola Oke, 2013) "Mitsubishi Heavy Industry Limited" applied Quality Function Deployment at its "Kobe Shipyards" to design an oil tanker which ensued to the fishbone (Ishikawa or Cause and Effects Diagram) diagrams grew unwieldy. During the same time, "Katsuyoshi Ishihara" managed to introduce the Value Engineering (VE) principles which were used in describing on how a service or product and its components can work up to the mark (Akao, 1997). He get ahead to expand this in describing business functions as the major aspect which are very much important in assuring quality of the design process itself. Afterwards there was an exercise of unification with these new ideas, whereby QFD ultimately became the extensive quality design system for both business process and product (Akao, 1997). According to rreference (Besterfield et al., 2011), it is very precisely explaining that, "Mitsubishi Heavy Industry Limited had applied QFD for 4 years case study in which the starting cost was reduced by 20%. And in November 1982 they decreased the cost by 38%". Regarding to saving of Mitsubishi was also supported by reference (Tsoukalidis et al., 2009).

Subsequently, QFD was then at the outset well introduced in the United States of America (USA) in 1984 by "Dr. Clausing of Xerox" (Ayoola Oke, 2013). It should be noted that QFD can be applied practically in any service or manufacturing industry. Now, since then QFD became a standard practice by most leading organizations in the world, which also requires it for their suppliers (Gharakhani and Eslami, 2012).

QFD has been and will continue to be among the mostly used planning tool in trying to fulfil customer or users expectations as stated by reference (Ayoola Oke, 2013). QFD in other words, it is a method for introducing quality right from design stage to satisfy the customer and to transform customer requirements into design objectives and key points that will be required to ensure quality at production stage. Any organization or industry which can correctly implements QFD, then definitely they can be able to advance the engineering knowledge, productivity, and quality and reduce costs, product development time, and engineering changes and above other many intangible benefits. According to (Erkarslan and Yilmaz, 2011) QFD was applied and they use 1977 as a base, whereby a 20% decrease in start-up costs was stated in the inauguration of the new van in October 1979, a 38% reduction by November 1982, and a cumulative 61% saving by April 1984".

According to reference (Taifa and Desai, 2015a) QFD was also defined as one of the concurrent engineering technique`s which always aims to collect customer (users) needs, translate them into technical characteristics (technical descriptors) for easy customer satisfaction improvement (Ayoola Oke, 2013), implementation time reduction (Marjudi et al., 2012), quality improvement (Gurjar, 2014) and user and

technology driven approach. QFD also is a technique which promotes team work (Taifa and Desai, 2015b) and provide documentation. QFD is very important techniques in designing or improving product or services due to its ability of translating user`s requirements into technical requirements (Rajenthirakumar and Srinivasan, 2010). This is due to that sometimes the requirements (commonly known as Voice of Customers: VOC) can be difficult in quantifying without translating them into technical characteristics. QFD is the technique with potential to identify user requirements and ability to prioritise the gathered requirements (Punchihewa and Gyi, 2009).

In order to customise user requirements, it is important that the basic characteristics of QFD be well understood. QFD has a lot of characteristics depending where someone wants to apply this concurrent engineering technique. Hereby, there are major four various characteristics under QFD.

1) Quality Function Deployment can be defined as a quality system which need commitment from top management of the organisation or company (Fonseca, 2015). This is due to the way QFD implements the elements of "Systems Thinking" (by viewing the development process as a system) and "Psychology" (understanding of the user needs, what "value" is, and how customers or end users can become interested, choose, and how users can be satisfied, etc.) (Zaim and Şevkli, 2002).
2) Quality Function Deployment helps in making decision of what kind of requirements or needs that should be included but those requirements should come from users themselves.
3) Quality Function Deployment is also considered as the competitive techniques whenever there is need of making proper strategies regarding the product to be designed (Chan and Wu, 2002). It is QFD which also help to change primary requirements into engineering characteristics (technical requirements), then prioritize them and guides on how to optimize such features can bring the greatest competitive advantages for market share as well as wallet share.
4) QFD is the only comprehensive quality system (Shrivastava and Verma, 2014) which aims specifically at satisfying the user throughout the development and business process though user attributes cannot be categorised like the way Kano Model can help to improve more the aspect of prioritizing all attributes (Kuijt-Evers et al., 2009).

In order for QFD methodology to be successful in customising user requirements, there are tools which supports it. The commonly tool for QFD is House of Quality (Pant and Raj, 2005; Joshi and Rao, 2013) which combine all the inputs from various cross functional teams depending on the involved departments for easy communication and users satisfaction achievement (Israr and Gangele, 2014).

## 4. Research Methodology

### 4.1. Sample size

Since the study involved questionnaires in collecting various data, hence the equation defined by Cochran (1963) as it was stated in reference (Homkhiew et al., 2012) was used.

$$n = \frac{P(1-P)Z^2}{e^2} \quad (1)$$

Where "n" is the sample size, "P" is the expected proportion at 30%, "Z" is a normal random variable, and "e" is the margin of error in estimating "P". By using equation 1 above, the sample size calculated and used

for collecting various data was 564. Reference (Taifa and Desai, 2016a) used equation (1) with good success in their research.

### 4.2. Case study

User customization was done with involvement of three engineering colleges from India. 564 users of classroom Furniture were supplied with google questionnaires and other students were supplied with a hard copy questionnaires. All these questionnaires were well filled and returned to authors who analysed very well all the feedback by the use of Minitab 16 and Microsoft Excel 2013. House of Quality (HOQ) was developed whereby in prioritizing the requirements for customization, Pareto Diagram and Kano Model were used also to come up with genuine customization.

### 4.3. House of Quality (HOQ) procedures

References (Zhang et al., 2014) identified the most important planning tool to be used in case there is need of using QFD as the "House of Quality" (HOQ). This House of Quality (HOQ) always interprets the Voice of Customers (Voice of Engineering Students) into design requirements that can meet precisely the targeted values and matches all these requirements with all technical descriptors (engineering characteristics) at an engineering colleges in the way to satisfy all identified student requirements.

References (Liu and Wang, 2010) show that, in general QFD technique which should be done through House of Quality can be categorized into four (4) major inter-linked phases as follows: "product planning, part deployment, process planning, and production planning phases". A general QFD system is well presented in in figure 1.

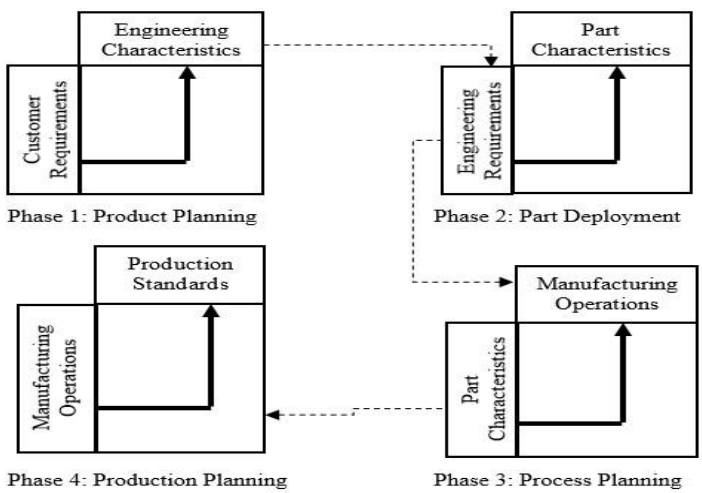



**Figure 1.** General QFD System with its Four Phases Adapted from (Verma et al., 1998; Yegenegi et al., 2011)

Phase 1: Product planning; it is also commonly called "House of Quality". It helps in keeping all records for users (customer) requirements, competitive opportunities, service contract data, product measurements, competing product measures, and the technical ability of the organization to run into every requirement. Phase 1 (one) has been the major crucial phase among the four phases due to its task of accomplishing the whole process of developing QFD (Khangura and Gandhi, 2012; Yegenegi et al., 2011; Verma et al., 1998).

Phase 2: Product Design; requires much

creativity and innovative team ideas. Concepts are created during this phase and documentation of part specifications. Most important parts for satisfying users or customer needs are then being positioned into Phase 3 (three) (Verma et al., 1998; Yegenegi et al., 2011).

Phase 3: Process Planning; this phase helps to document flowchart for all manufacturing processes and process parameters (or target values) (Yegenegi et al., 2011; Jaiswal, 2012).

Phase 4: Process Control; this phase create performance indicators for monitoring maintenance schedules. Also this phase helps training to operators regarding to production process and skills for operation (Yegenegi et al., 2011).

The following are various QFD procedures which were used for this case study. These procedures were collected from various researchers (Taifa and Desai, 2015a; Gurjar, 2014) who used QFD for different studies.

a) Listing all users' requirements which commonly are referred as *(WHATs).*
b) Engineering characteristics (Technical descriptors) list which commonly referred as *(HOWs).*
c) Creating user requirements *(WHATs)* and the engineering characteristics *(HOWs)* relationship
d) Development of interrelationship Matrix between Technical descriptors
e) Carry out competitive assessments
f) Prioritise Users requirements;
g) Developing prioritized engineering characteristics by considering degree of technical difficulty, target value and absolute and relative weights.

**Absolute weight for the $j^{th}$ technical descriptors** is given by $a_j = \sum_{i=1}^{n} R_{ij} C_i$ (Besterfield et al., 2011)

where:

$a_i$: row vector of absolute weights for the technical descriptors (i = 1, 2, 3…., m).
$R_{ij}$: weights assigned to the relationship matrix (i = 1, 2, 3… n, j=1, 2, 3…, m).
$c_i$: column vector of importance to customer for the customer for the customer requirements (i = 1, 2, 3…., n).
m: number of technical descriptors and n = number of customer requirements.

**Relative weight is given by** $b_j = \sum_{i=1}^{n} R_{ij} d_i$ (Besterfield et al., 2011).

$b_i$: row vector of relative weights for the technical descriptors (i = 1, 2, 3…., m).
$d_i$: column vector of absolute weight for the customer requirements (i = 1, 2, 3…., n).

h) To decide an area for concentration with the help of Pareto Diagram by relying on higher absolute and relative rating.

## 5. Results and discussion

### 5.1. User requirements

In order to customise student requirements which were much important for improving the available classrooms furniture, all requirements were collected through the use of hardcopy and Google docs (Online) questionnaires. A 5-point Likert scale was used in the questionnaires "(1: extremely important, 2: very important, 3: important, 4: not important, 5: not very important)". The rating of all student requirements (Table 1) were pre-analysed with the help of Histogram (Figure 2).

Table 1 consist all 29 students requirements' which was plotted in Histogram as shown by Figure 1. Various requirements which were collected with the use of questionnaires (both Hardcopy and Google Docs) were both analysed. Minitab 17 and Microsoft Office Excel 2013 were both used as the key tools for carrying out a thorough analysis.

**Table 1.** A List of Student Requirements (WHATs)

| ID | Students` Requirements |
|---|---|
| **FR1** | Presence of Backrest |
| **FR2** | Presence of Armrest |
| **FR3** | Presence of Footrest |
| **FR4** | Adjustable Backrest |
| **FR5** | Adjustable Armrest |
| **FR6** | Adjustable Footrest |
| **FR7** | Adjustable Height |
| **FR8** | Adjustable Seat |
| **FR9** | Comfortable Seat |
| **FR10** | Bigger Size |
| **FR11** | Stronger and Durable |
| **FR12** | Padded Seat (With Cushion) |
| **FR13** | Separation location for parts |
| **FR14** | Low Price |
| **FR15** | Two Seated People |
| **FR16** | Pen Holder |
| **FR17** | Easy to Move |
| **FR18** | Easy of cleaning |
| **FR19** | Suitable Weight |
| **FR20** | Bag Shelf |
| **FR21** | Individual Lock |
| **FR22** | Tilt Angle of Backrest |
| **FR23** | Smooth Edges |
| **FR24** | Quality of Material |
| **FR25** | Desk is Made from Steel Material |
| **FR26** | Desk is Made from Wood Material |
| **FR27** | Desk is made from Plastic Material |
| **FR28** | Good Aesthetics |
| **FR29** | Long Term Use |

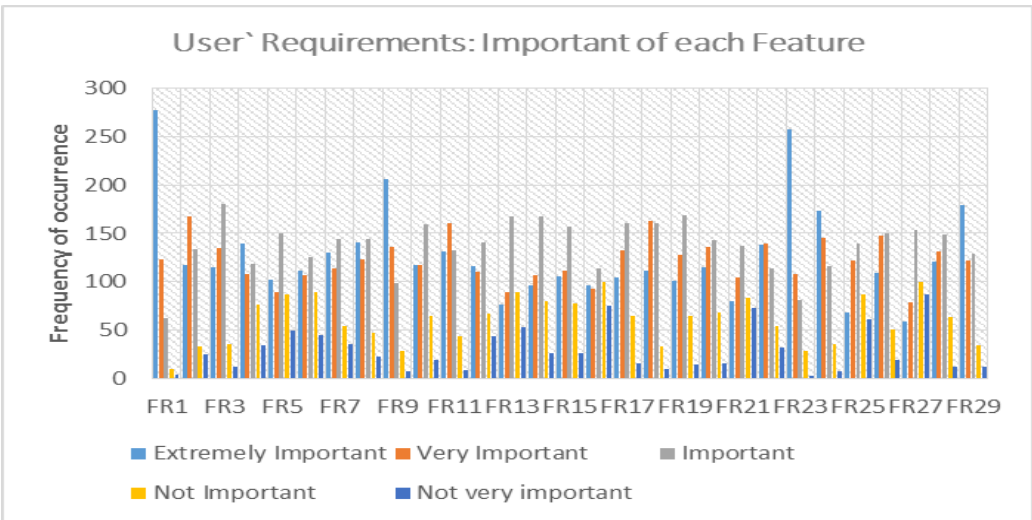



**Figure 2.** User Requirements: Important of each Feature

The mostly stated as the user (customer) requirements include: "Presence of Backrest", "Presence of Armrest", "Presence of Footrest", "Adjustable Seat", "Comfortable Seat", "Easy of cleaning", "Bag Shelf (for keeping books and other stationeries)", "Tilt Angle of Backrest", "Smooth Edges (Safety of clothes and students)", "Quality of Material", "Desk Made from Wood Material", "Good Appearance(Aesthetics)", and "Long Term Use" as shown at Figure 2. These requirements were selected after combining extremely important and very important scores which shows that the selected requirements have the score of above 50%.

### 5.2. House of quality development

In order to develop House of Quality there was a major need of knowing customer requirements (Voice of Customers). For this study the Voice of Customers (VOC) were collected from Students. The VOC can be explained as the term that describes either stated and unstated customer (user) needs or necessities. The VOC were taken through questionnaires which were supplied to engineering students. Other way used for this study were observation of the available furniture as the case study, literature review to get the standards for customization and consultants to experts of product development (Yadav et al., 2013). The clear understanding of the user needs can then be summarized in a product planning matrices or "House of Quality" (Khangura and Gandhi, 2012). HOQ translate user (students) requirements Engineering Characteristics or Technical Descriptors for creating high satisfaction of all the stated needs from customers (users). Habitually, customer expectations are imprecise and wide-ranging in nature therefore it is the task of the Quality Function Deployment team to try by any means to break down all users or customer expectations into more detailed customer requirements. Student (user requirements) are shown in Table 2 and these requirements are the one which were used to make House of Quality. These requirements were all collected via exhaustive well prepared questionnaires. In order to complete HOQ development there was a need of making Relationship between user (student) requirements and engineering characteristics (technical descriptors) are in Table 3. Also Table 4 helped to create interrelationship between engineering characteristics (technical descriptors).

**Table 2.** Students Requirements for developing House of Quality

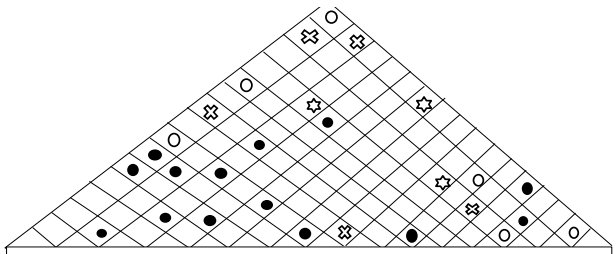
| S/N | Primary Requirements | Secondary Requirements | ID for Requirements |
|---|---|---|---|
| 1 | Comfortability | Presence of Backrest | R1 |
| 2 | | Presence of Armrest | R2 |
| 3 | | Presence of Footrest | R3 |
| 4 | | Adjustable Backrest | R4 |
| 5 | | Adjustable Armrest | R5 |
| 6 | | Adjustable Footrest | R6 |
| 7 | | Adjustable Height | R7 |
| 8 | | Adjustable Seat | R8 |
| 9 | | Comfortable Seat | R9 |
| 10 | | Tilt Angle of Backrest | R10 |
| 11 | | Padded Seat(With Cushion) | R11 |
| 12 | Usability | Bigger Size | R12 |
| 13 | | Two Seated People | R13 |
| 14 | | Suitable Weight | R14 |
| 15 | | Easy to Move | R15 |
| 16 | | Pen Holder | R16 |
| 17 | Maintenance | Quality of Material | R17 |
| 18 | | Easy of cleaning | R18 |
| 19 | | Long Term Use | R19 |
| 20 | | Stronger and Durable | R20 |
| 21 | Others | Separation location for parts | R21 |
| 22 | | Individual Lock | R22 |
| 23 | | Smooth Edges (Safety) | R23 |
| 24 | | Bag Shelf | R24 |
| 25 | | Good Aesthetics | R25 |
| 26 | | Low Price | R26 |

**Table 3.** Relationship between Customer requirements and technical descriptors

| | |
|---|---|
| + (9) ● Strong positive | + (3) ○ Positive |
| —(3) X Negative | —(9) * Strong Negative |

**Table 4.** Correlation matrix which shows Interrelationship between technical descriptors

| | | |
|---|---|---|
| + (9) ● Strong | + (3) ○ Medium | + (1) Δ Weak |




| Requirements | Ergonomic Design (Seat and back) | Adjustability of desk | Operation | Safety | Comfortable seat | Product corners | Weight | Size | Strength | No. of assembly parts | Easy to assembly | Material thickness | Latest material | Durability of material | Standard cost(Economic) | Customer competitive assessment | Importance to Customer | Target Value | Scale-up factor | Sales point | Absolute weight |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R1 | ● | ○ | | | ● | ● | | | Δ | ○ | ○ | ○ | ● | ● | | 3 | 10 | 3 | 1.0 | 2 | 20 |
| R2 | | ○ | | | | | | | | ○ | | ○ | | | | 2 | 7 | 4 | 2.0 | 2 | 28 |
| R3 | | ○ | | | | | | | | ○ | | ○ | | | | 1 | 8 | 4 | 4.0 | 2 | 64 |
| R4 | ● | ● | ○ | | | | | | | | Δ | | | | | 1 | 2 | 2 | 2.0 | 1.5 | 6 |
| R5 | | ● | ○ | | | | | | | | Δ | | | | | 1 | 3 | 2 | 2.0 | 1.5 | 9 |
| R6 | | ● | ○ | | | | | | | | Δ | | | | | 1 | 4 | 1 | 1.0 | 1 | 4 |
| R7 | | ● | ○ | | | | | | | | Δ | | | | | 1 | 8 | 3 | 3.0 | 1 | 24 |
| R8 | ● | ● | ○ | | | | | | | | Δ | | | | | 1 | 5 | 2 | 2.0 | 1 | 10 |
| R9 | ● | ● | | | ● | ○ | | Δ | | | | | | | | 3 | 8 | 5 | 1.7 | 1.5 | 20 |
| R22 | ● | ● | | ● | | | | | | | | | | | | 3 | 9 | 4 | 1.3 | 2 | 24 |
| R12 | ● | ○ | | | ● | | | | | | | | | | | 1 | 3 | 1 | 1.0 | 1.5 | 4.5 |
| R10 | ● | | | | | | ● | ● | | ● | ● | ○ | | | | 4 | 6 | 2 | 0.5 | 1 | 3 |
| R15 | ● | | | | ● | | | ○ | | ● | ● | | | | | 2 | 6 | 2 | 1.0 | 1.5 | 9 |
| R19 | | | Δ | | | | ● | | | ○ | | | | | | 4 | 5 | 2 | 0.5 | 1 | 2.5 |
| R17 | | | ● | | ○ | | ● | ● | | ○ | | ● | | | | 4 | 4 | 2 | 0.5 | 1.5 | 3 |
| R16 | | | | | | | | | | | | | | | | 1 | 5 | 2 | 2.0 | 1.5 | 15 |
| R24 | ● | Δ | | | | | | | ○ | | | ● | ● | ● | | 3 | 7 | 4 | 1.3 | 1 | 9.3 |
| R18 | ○ | | | | | | | | | | | | | | | 4 | 3 | 4 | 1.0 | 1 | 3 |
| R29 | | | | | | | | | ● | | | | ● | | | 4 | 8 | 4 | 1.0 | 1 | 8 |
| R11 | | | | | ○ | | | | ● | | | | ● | ● | | 3 | 7 | 5 | 1.7 | 1.5 | 18 |
| R13 | | | | | | | | | | | | | | | | 1 | 3 | 3 | 3.0 | 1.5 | 14 |
| R21 | | | | | | | | | | ○ | | | | | | 1 | 3 | 3 | 3.0 | 1.5 | 14 |
| R23 | Δ | | | ● | ● | ● | | | | | | | | | | 3 | 10 | 5 | 1.7 | 2 | 33 |
| R20 | | | | | | | | | | ○ | | | | | | 3 | 4 | 2 | 0.7 | 1 | 2.7 |
| R28 | ○ | | | | | | | | | | | | ○ | Δ | | 4 | 7 | 4 | 1.0 | 1 | 7 |
| R14 | | | | | | | | | | | | | | | ● | 5 | 2 | 2 | 0.4 | 1 | 0.8 |
| | **5** | **0** | **5** | **5** | **0** | **5** | **0** | **5** | **5** | **5** | **0** | **5** | **5** | **5** | **0** | Technical Competitive | | | | | |
| | **5** | **10** | **1** | **8** | **3** | **5** | **7** | **8** | **2** | **3** | **4** | **2** | **1** | **1** | **2** | Degree of technical difficulty | | | | | |
| | **5** | **5** | **5** | **5** | **4** | **2** | **5** | **0** | **0** | **2** | **3** | **5** | **5** | **2** | **0** | Target Value | | | | | |
| | **490** | **426** | **107** | **135** | **384** | **204** | **171** | **116** | **166** | **231** | **160** | **192** | **309** | **223** | **18** | Absolute weight | | | | | |
| | **920** | **1077** | **189** | **516** | **843** | **540** | **77** | **101** | **277** | **509** | **221** | **456** | **514** | **428** | **7.2** | Relative weight | | | | | |
| | Prioritized Technical Descriptors | | | | | | | | | | | | | | | | | | | | |

Prioritized Customer requirements

**Figure 3.** Quality Function Deployment: House of Quality for Classroom Furniture

The key information regarding House of Quality in Figure 3.

a) Importance to customer (1: Least important 10: Most important)
b) Target Value (1: Worst and 5: Best)
c) Sales Point (Decide between 1 and 2)
d) Scale up factor (Target value / our product rating)

e) Absolute weight : (Importance to customer) x (Scale factor) x (Sales Point)
f) Degree of Difficulty (1: Least difficult and 10: Most difficult)
g) Customer Competitive Assessment (1: Worst and 5: Best)

Based on the systematic procedure on constructing House of Quality, the final step was to make decision by looking the higher absolute and relative rating so as the technical factors could be identified and these were the areas where engineering efforts were needed for much concentration. The primary distinguish between the two is that, the relative weight include student scale up factor and sales point information.

In order to get clearly the key technical factors for concentration, Pareto diagram was used for further analysis as shown in Figure 4 and 5.

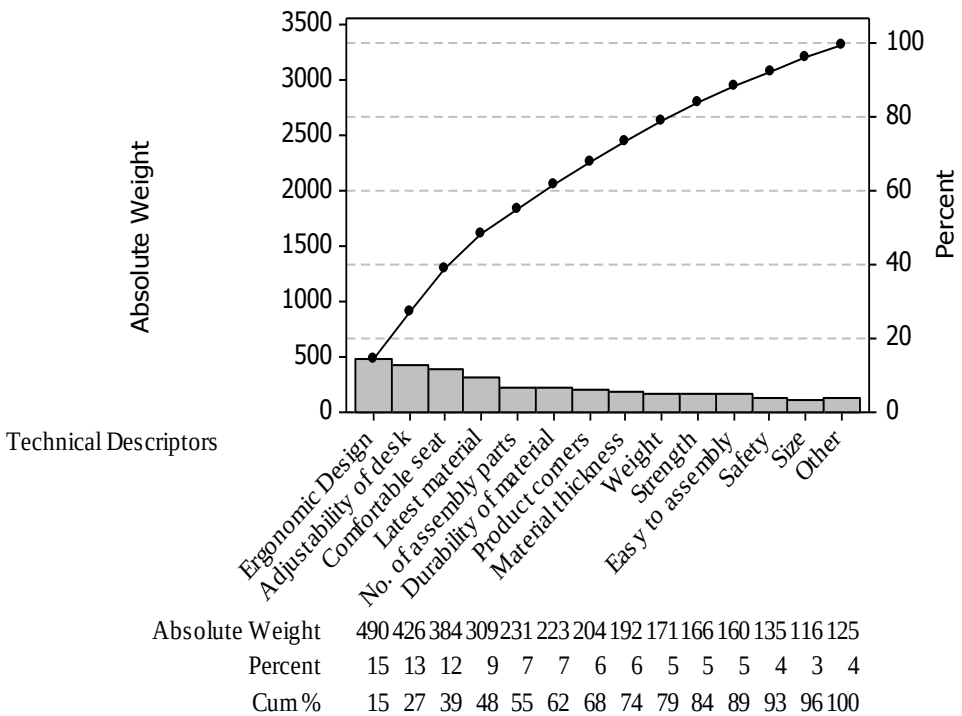



**Figure 4.** Pareto Diagram: Absolute weight and percent

By referring Figure 3, Figure 4 and Figure 5, the factors like "Ergonomic Design (Seat, Table and back)", "Adjustability of desk", "Comfortable seat", "Product corners (sharp corner to be removed)" and "Latest material" were both having high relative weight and absolute weight. Therefore, more engineering efforts should be concentrated on the identified technical characteristics or factors which helps for user customization in designing the furniture of students.

In such studies where one technique be used, reference (Taifa and Desai, 2016b) suggests to integrate with other techniques like Kano Model and Anthropometric measurements. Integration process for such case results to come up with the genuine recommendations and conclusion. It is therefore highly recommended to integrate various techniques so as to solve the intended problem as it was suggested by (Taifa and Desai, 2016b).

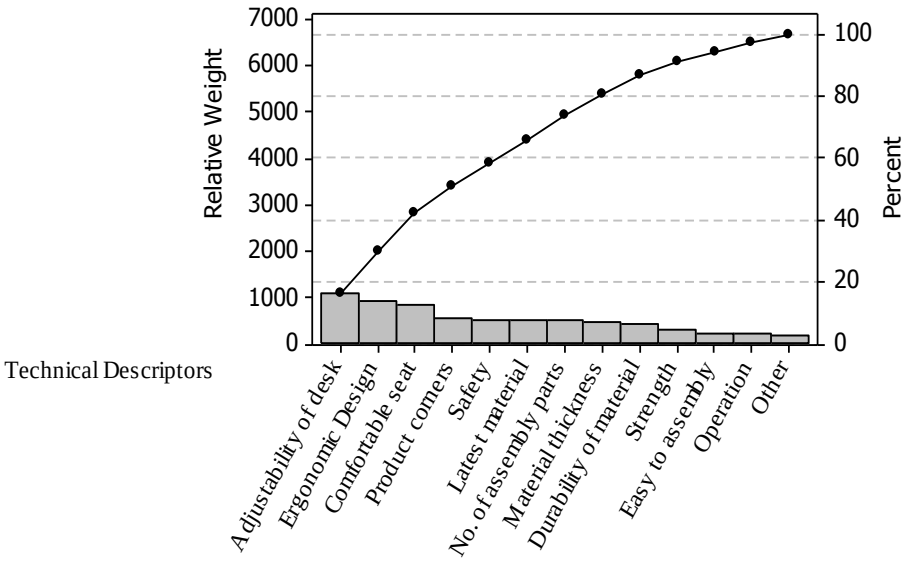



**Figure 5.** Pareto Diagram: Relative weight and percent

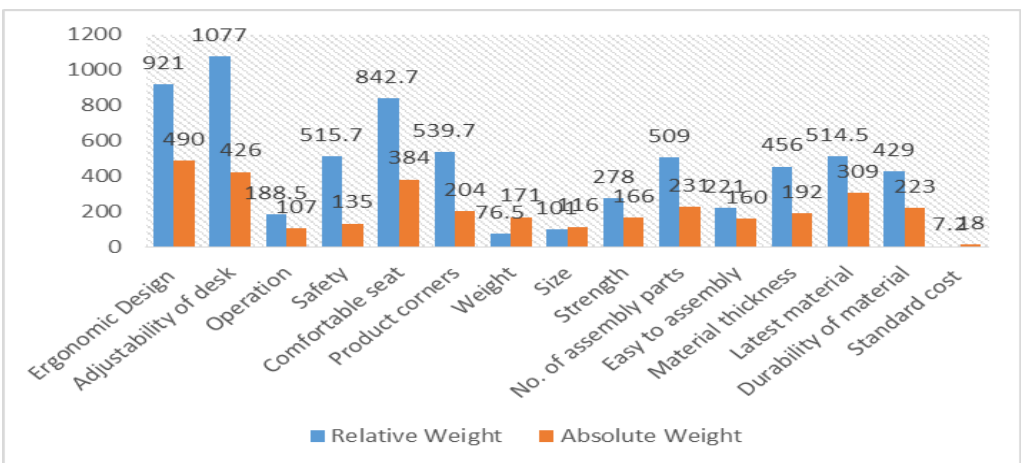



**Figure 6.** Histogram of Relative weight and Absolute Weight

Figure 6 indicate the combined Histogram for relative weight and absolute weight in making decision on the area for concentration. From this Figure 6, the area for concertation are same like those obtained from Figure 4 and Figure 5.

### 5.3. Benefits of QFD

QFD as has various benefits to both user and designer or organisation. Some of the benefits which can be obtained in the long way of implementing QFD include the following as shown in Table 5.

**Table 5**. Benefits of Quality Function Deployment

| S/N | Benefits of QFD |
|---|---|
| 1 | QFD have a great potentiality of saving time and cost in the whole process of carrying out development, shorter design cycle and making any kind changes. Therefore QFD is there to help considerably in decreasing start-up problems, times and costs if it be implemented well. |
| 2 | QFD is considered as the key in satisfying users or customer and mostly help in delighting customers in the same if well implemented. But mostly QFD can delight Customer if it be integrated with Kano Model as the model which categorize quality attributes into very detailed way. |
| 3 | QFD helps in expanding communication within the Organization and boost team works spirit rather than working in a traditional way whereby a designer can come up with a product. In the same way, QFD help involvement at each stage of collecting all user needs, both unstated needs and stated one and brings organised multifunctional teams. |
| 4 | QFD help in making continual upgradation process and hence helps company or industry to reach world class after improving the quality and productivity. If QFD is being applied to a small scale like a college, then there is good possibility if attracting more students since the facilities at the particular colleges are good. This become good way of marketing the particular institution especially for private education institutions. |
| 5 | QFD help in clarifying the customer priority for competitive marketing advantage and market acceptability as the major goal of any business so as profit of the organisation or company can increase. |
| 6 | In the way to apply QFD, VOC be focused proactively early in the design stage. This helps in making straightforward identification of critical items for parameter design and product planning. |

### 5.4. QFD Application

House of Quality as a primary planning tool for QFD has been used to customise user requirements for furniture design improvements. All identified user requirements were correlated with technical descriptors. Using these requirements in designing, would create high satisfaction to users since all requirements were collected from the user themselves. QFD has high potentiality of saving implementation time especially when all user requirements are well documented by the authors or designers. QFD can be applied to encourage the team work among the designers. Then, also QFD is there to help in making interrelationship between user requirements and engineering characteristics before designing. This is one of the major advantages for applying QFD comparing to other techniques like Kano Model. Techniques like Kano Model have the potentiality of prioritizing all user requirements in different attributes but does not make interrelationship between user requirements and engineering characteristics. This comes to conclude that whenever QFD and Kano Model be integrated, it result to great list of user requirements.

## 6. Integration of QFD with Kano Model

Integration in Figure 7 was done with the help of the following guideline.

1) *User Importance, i:* obtained from a survey conducted to students. Each student was asked to rate the importance of each quality in Likert scale (1=Unimportant to 5=Most important).
2) *Kano category:* from Kano Model which was done by reference (Taifa and Desai, 2016b).

3) *The k value* was decided according to extended options by "Chaudha et al. (2011)" in which the value of k is defined as 0, 0.5, 1 and 1.5 for Indifferent (I), Must-be (M), One-dimensional (O) and Attractive (A) respectively.
4) *User satisfaction, u:* the value was the mean calculated for each quality from the user importance survey.
5) *Target expectation* for each quality attribute was defined by the users themselves from the user importance survey.
6) *Adjustment factor:* proposed by "Tontini (2007)" to be used directly in the QFD matrix.

Adjustment factor = max ([SS], [SD])

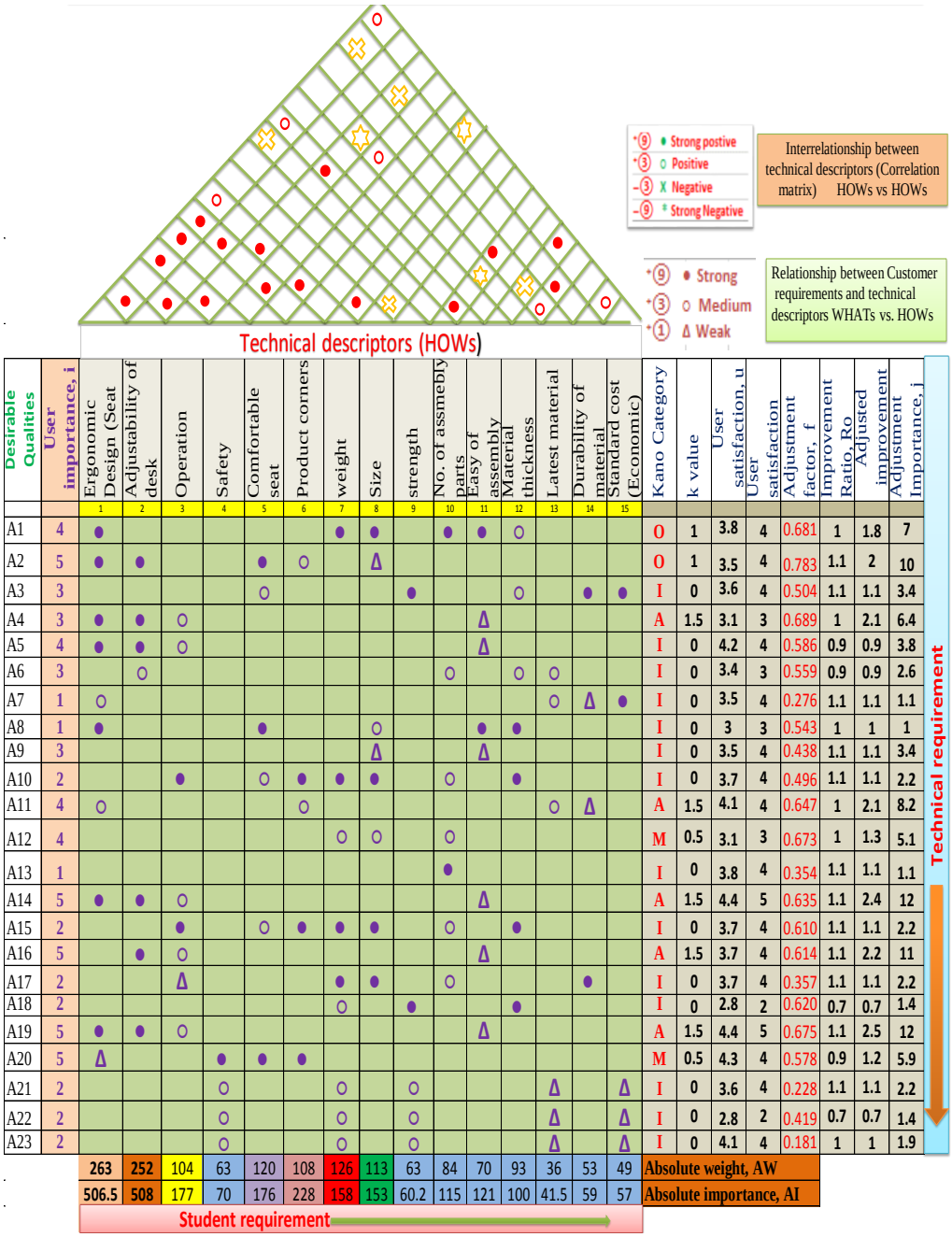
Whereby; SS = Student satisfaction; and CS = Student dissatisfaction

7) *Improvement ratio :* "Tan and Shen (2000)" suggested a calculation to describe the user satisfaction improvement ratio as; Improvement ratio, R0= t / u
Whereby; t = User satisfaction target; u = User importance
8) *An adjusted improvement ratio, R1* was recommended by "Chaudha et al. (2011)" which utilized important parameters from Kano method to be contributed in QFD matrix. R1 = $(1 + f)^{k}$ x R0
Whereby;
f = Adjustment factor; k = Kano Category; R0 = Improvement ratio
9) *Absolute weight (*AW) = Σ i x r
10) *Absolute importance (*AI) = Σ j x r
Whereby;
i = user importance; j = adjustment importance; and r = relationship rating

**Table 6.** Requirements for Integration of Kano Model and QFD

| SN | Desirable Qualities (WHATS) | Key |
|---|---|---|
| **1** | Bigger size of Desk | A1 |
| **2** | Comfortable seat, | A2 |
| **3** | Stronger and durable | A3 |
| **4** | Adjustable backrest | A4 |
| **5** | Adjustable Seat | A5 |
| **6** | Adjustable Footrest | A6 |
| **7** | Low price | A7 |
| **8** | Desk is for two seated people | A8 |
| **9** | Desk is having pen holder | A9 |
| **10** | Easy to move | A10 |
| **11** | Attractiveness (aesthetics) | A11 |
| **12** | Bag shelf | A12 |
| **13** | Individual lock | A13 |
| **14** | Tilt angle for writing surface | A14 |
| **15** | Easy to use | A15 |
| **16** | Adjustable height | A16 |
| **17** | Suitable weight | A17 |
| **18** | Correct thick board | A18 |
| **19** | Tilt angle of backrest | A19 |
| **20** | Smooth edges (safety) | A20 |
| **21** | Desk is made from steel material | A21 |
| **22** | Desk is made from wood material | A22 |
| **23** | Desk is made from plastic material | A23 |

Integration of both QFD and Kano Model were done with the presence of desirable qualities at Table 6. From Figure 7, it was observed that the key area which conclude customisation of user requirements and creation of quality attractiveness include ergonomic design, adjustability of Desk, product corners to be well finished, student desk to be of big size, comfortable seat and weight. In order to customize user requirements there is need of integrating QFD and Kano Model.




| Desirable Qualities | User importance, i | Ergonomic Design (Seat | Adjustability of desk | Operation | Safety | Comfortable seat | Product corners | weight | Size | strength | No. of assmebly parts | Easy of assembly | Material thickness | Latest material | Durability of material | Standard cost (Economic) | Kano Category | k value | User satisfaction, u | User satisfaction | Adjustment factor, f | Improvement Ratio, Ro | Adjusted improvement | Adjustment Importance, j |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | | | | | | | | |
| A1 | 4 | ● | | | | | | ● | ● | | ● | ● | ○ | | | | O | 1 | 3.8 | 4 | 0.681 | 1 | 1.8 | 7 |
| A2 | 5 | ● | ● | | | ● | ○ | | Δ | | | | | | | | O | 1 | 3.5 | 4 | 0.783 | 1.1 | 2 | 10 |
| A3 | 3 | | | | | ○ | | | | ● | | | ○ | | ● | ● | I | 0 | 3.6 | 4 | 0.504 | 1.1 | 1.1 | 3.4 |
| A4 | 3 | ● | ● | ○ | | | | | | | | Δ | | | | | A | 1.5 | 3.1 | 3 | 0.689 | 1 | 2.1 | 6.4 |
| A5 | 4 | ● | ● | ○ | | | | | | | | Δ | | | | | I | 0 | 4.2 | 4 | 0.586 | 0.9 | 0.9 | 3.8 |
| A6 | 3 | | ○ | | | | | | | | ○ | | ○ | ○ | | | I | 0 | 3.4 | 3 | 0.559 | 0.9 | 0.9 | 2.6 |
| A7 | 1 | ○ | | | | | | | | | | | | ○ | Δ | ● | I | 0 | 3.5 | 4 | 0.276 | 1.1 | 1.1 | 1.1 |
| A8 | 1 | ● | | | | ● | | | ○ | | | ● | ● | | | | I | 0 | 3 | 3 | 0.543 | 1 | 1 | 1 |
| A9 | 3 | | | | | | | | Δ | | | Δ | | | | | I | 0 | 3.5 | 4 | 0.438 | 1.1 | 1.1 | 3.4 |
| A10 | 2 | | | ● | | ○ | ● | ● | ● | | ○ | | ● | | | | I | 0 | 3.7 | 4 | 0.496 | 1.1 | 1.1 | 2.2 |
| A11 | 4 | ○ | | | | | ○ | | | | | | | ○ | Δ | | A | 1.5 | 4.1 | 4 | 0.647 | 1 | 2.1 | 8.2 |
| A12 | 4 | | | | | | | ○ | ○ | | ○ | | | | | | M | 0.5 | 3.1 | 3 | 0.673 | 1 | 1.3 | 5.1 |
| A13 | 1 | | | | | | | | | | ● | | | | | | I | 0 | 3.8 | 4 | 0.354 | 1.1 | 1.1 | 1.1 |
| A14 | 5 | ● | ● | ○ | | | | | | | | Δ | | | | | A | 1.5 | 4.4 | 5 | 0.635 | 1.1 | 2.4 | 12 |
| A15 | 2 | | | ● | | ○ | ● | ● | ● | | ○ | | ● | | | | I | 0 | 3.7 | 4 | 0.610 | 1.1 | 1.1 | 2.2 |
| A16 | 5 | | ● | ○ | | | | | | | | Δ | | | | | A | 1.5 | 3.7 | 4 | 0.614 | 1.1 | 2.2 | 11 |
| A17 | 2 | | | Δ | | | | ● | ● | | ○ | | | | ● | | I | 0 | 3.7 | 4 | 0.357 | 1.1 | 1.1 | 2.2 |
| A18 | 2 | | | | | | | ○ | | ● | | | ● | | | | I | 0 | 2.8 | 2 | 0.620 | 0.7 | 0.7 | 1.4 |
| A19 | 5 | ● | ● | ○ | | | | | | | | Δ | | | | | A | 1.5 | 4.4 | 5 | 0.675 | 1.1 | 2.5 | 12 |
| A20 | 5 | Δ | | | ● | ● | ● | | | | | | | | | | M | 0.5 | 4.3 | 4 | 0.578 | 0.9 | 1.2 | 5.9 |
| A21 | 2 | | | | ○ | | | ○ | | ○ | | | | Δ | | Δ | I | 0 | 3.6 | 4 | 0.228 | 1.1 | 1.1 | 2.2 |
| A22 | 2 | | | | ○ | | | ○ | | ○ | | | | Δ | | Δ | I | 0 | 2.8 | 2 | 0.419 | 0.7 | 0.7 | 1.4 |
| A23 | 2 | | | | ○ | | | ○ | | ○ | | | | Δ | | Δ | I | 0 | 4.1 | 4 | 0.181 | 1 | 1 | 1.9 |
| | | 263 | 252 | 104 | 63 | 120 | 108 | 126 | 113 | 63 | 84 | 70 | 93 | 36 | 53 | 49 | Absolute weight, AW | | | | | | | |
| | | 506.5 | 508 | 177 | 70 | 176 | 228 | 158 | 153 | 60.2 | 115 | 121 | 100 | 41.5 | 59 | 57 | Absolute importance, AI | | | | | | | |

**Figure 7.** Integration of Kano Model and QFD

This type of integration has various advantages towards achieving user customization as follows. First, Integration of the two helps to get deeper knowledge and understanding of user requirements and problems regarding to the products or service which are either being produced or served. Second, Integration help the trade-of

within service or product developments especially in the way to manage it effectively. Third, Integration helps to begin with fewer problems in either design new, improve existing or innovate totally new product or service. Fourth, integration of QFD and Kano Model whenever there is high competitive analysis then at such moment it make the whole process much easier whereby it can helps to improve market research. Firth, integration of QFD and Kano Model helps in reduction of development time and planning. Sixth, integration of the two facilitates effective communication within the department (divisions). Lastly, integration of the two helps to build quality in upstream. Therefore, such advantages and other so many advantages can be explored wherever QFD can be integrated with all techniques and tools which are appropriate for customization of user requirements in the whole process of design improvement.

### 6.1. Data validation

All data collected for user requirements (Importance of each user requirement) were validated by calculating Cronbach Alpha with the help of SPSS. According to (Tavakol and Dennick, 2011) "Cronbach Alpha was developed by Lee Cronbach in 1951 to provide a measure of the internal consistency of a test or scale; it is expressed as a number between 0 and 1". The value for Alpha obtained was 0.921. This validation was done to check the internal consistency of the data whereby Cronbach Alpha had to be computed for each category of the collected data. The Cronbach Alpha calculated for the study indicates "High Internal Consistency" which means that the data were all correct to be used for making scientific suggestions and conclusion.

## 7. Results and discussion

Combination of QFD and Kano Model are old and efficient tools for product improvement. They both have great impact towards customization of user requirements and creation of quality attractiveness. Pertaining to this study, there are various crucial requirements which has been identifies in the way to customize user requirements (student requirements). The factors like "Ergonomic Design (Seat, Table and back)", "adjustability of desk", "Comfortable seat", "Product corners (sharp corner to be removed)" and student desk to be of big size, and weight were both having high relative weight and absolute weight. This indicates that in the way to improve the design of the available furniture at engineering colleges, consideration of these factors will create high satisfaction to students since all are attributes were generated after involving them in the whole study. Now, it should to be noted that success of QFD technique always helps manufacturer to understand easily all the attributes which are expected or desired by users. The product which will be manufactured after the application of this customizing technique i.e. QFD and Kano Model, definitely will be of great impact in creating good probability of acceptance to users (customers) since majority of the requirements have been considered after being gathered from the users themselves. QFD as one of the "Concurrent Engineering" techniques and Kano Model need team work rather than traditional way of performing various design aspects. Working as a team work rather in designing product has a great impact in this 21$^{st}$ Century where there is big competition in getting large market share as the way to increase the bottom line as well as wallet share of the organisation or company. Further research can be done regarding customization of user requirements and attractive quality creation by the use of other techniques which are appropriate and which can result to more precisely results than the use of QFD and Kano Model alone. Authors are hereby suggesting having an integration of QFD with other tools like Analytic Hierarchy Process (AHP) and Service

Quality Model (SEVQUAL) so as to come up with excellent list of customer requirements which are in line with the principles of making accurate customization of requirements from users and attractive quality creation for design improvement.

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## References:

Adhaye, A. (2013). Overview of QFD – a Concept and Implementation. *International Journal of Engineering Research & Technology (IJERT), 2*(9), 671-676.

Akao, Y. (1997). QFD: past, present, and future. *International Symposium on QFD '97 – Linköping*, (2), 1-12. Retrieved from http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:QFD:+Past,+Present,+and+Future#0

Ayoola Oke, S. (2013). Manufacturing quality function deployment: Literature review and future trends. *Engineering Journal*, *17*(3), 79-103. http://doi.org/10.4186/ej.2013.17.3.79

Besterfield, D. H., Besterfield-Michna, C., Besterfield, G. H., Besterfield-Sacre, M., Urdhwareshe, H., & Urdhwareshe, R. (2011). Quality Function Deployment (QFD). In *Total Quality Management* (3rd ed., pp. 259-295). Pearson India.

Chan, L., & Wu, M. (2002). Quality function deployment : A literature review. *European Journal of Operational Research*, *143*, 463-497.

Erkarslan, Ö., & Yilmaz, H. (2011). Optimization Of The Product Design Through Quality Function Deployment And Analytical Hierarchy Process: A Case Study Of A Ceramic Washbasin. *Metu Journal of the Faculty of Architecture*, 1-22. http://doi.org/10.4305/METU.JFA.2011.1

Fonseca, L. M. (2015). From Quality Gurus and TQM To ISO 9001:2015: A Review of Several Quality Paths. *International Journal for Quality Research*, *9*(1), 167-180.

Gharakhani, D., & Eslami, J. (2012). Determining Customer Needs Priorities for Improving Service. *International Journal of Economics and Management Sciences*, *1*(6), 21-28.

Gurjar, A. S. (2014). Employing Quality Function Deployment for Integrated Design. *American International Journal of Research in Science, Technology, Engineering & Mathematics*, *7*(3), 201–204.

Homkhiew, C., Ratanawilai, T., & Pochana, K. (2012). Application of a quality function deployment technique to design and develop furniture products. *Songklanakarin Journal of Sciience and Technology*, *34*(6), 663-668.

Israr, M., & Gangele, A. (2014). A Quality Function Deployment Methodology for Product Development. *International Journal of Emerging Trends in Engineering Research*, *2*(11), 317-325.

Jaiswal, E. S. (2012). A Case Study on Quality Function Deployment (QFD). *IOSR Journal of Mechanical and Civil Engineering*, *3*(6), 27-35. http://doi.org/10.9790/1684-0362735

Joshi, C. K., & Rao, S. (2013). Developing an effective internal customer attribute with in Manufacturing by applying Quality Function Deployment (QFD ). *International Journal of Emerging Trends in Engineering and Development*, *5*(3), 5-14.

Khanam, C. N., Reddy, M. V, & Mrunalini, A. (2006). Designing Student's Seating Furniture for Classroom Environment. *Journal of Human Ecology*, *20*(4), 241-248.

Khangura, A. S., & Gandhi, S. K. (2012). Design and Development of the Refrigerator with Quality Function Deployment Concept. *International Journal on Emerging Technologies*, *3*(1), 173-177.

Kuijt-Evers, L. F. M., Morel, K. P. N., Eikelenberg, N. L. W., & Vink, P. (2009). Application of the QFD as a design approach to ensure comfort in using hand tools: Can the design team complete the House of Quality appropriately? *Applied Ergonomics*, *40*(3), 519-526. http://doi.org/10.1016/j.apergo.2008.09.009

Liu, H.-T., & Wang, C.-H. (2010). An advanced quality function deployment model using fuzzy analytic network process. *Applied Mathematical Modelling*, *34*(11), 3333-3351. http://doi.org/10.1016/j.apm.2010.02.024

Marjudi, S., Sulaiman, R., & Amran, M. F. M. (2012). CAD: Designing Computer Aided Design for Malaysia SMEs Food Packaging (PackCAD) using Quality Function Deployment (QFD). *International Journal of Computer Applications*, *41*(16), 16-19. http://doi.org/10.5120/5623-7907

Mohanty, P. P., & Mahaptra, S. S. (2013). Design of office Chair : A Quality Function Deployment Approach. *Advanced Materials Manufacturing & Characterization*, *3*(2), 520-523. http://doi.org/Doi: http://dx.doi.org/10.11127/ijammc.2013.07.10

Pant, R., & Raj, V. (2005). Quality Function Deployment for Incorporating the need of the Customere for Product Development and Design. *International Journal of Engineering Science and Technology (IJEST)*, *5*(04).

Punchihewa, H., & Gyi, D. (2009). Development of a QFD based collaborative design approach to reduce work-related musculoskeletal disorders (MSDs). *DESIGN: Principles & Practices*, *3*(6), 209-223. Retrieved from https://dspace.lboro.ac.uk/dspace/handle/2134/6014

Rajenthirakumar, D., & Srinivasan, P. (2010). Design and Development of Lean Quality Function Deployment Technique. *Manufacturing and Industrial Engineering*, *3*, 60-62.

Shrivastava, P., & Verma, D.S. (2014). Application of Quality Function Deployment To Improve Customer Satisfaction In Hotel Industry. *International Journal of Scientific & Engineering Research*, *5*(6), 957-962.

Taifa, I. W., & Desai, D. A. (2015a). A Review and Gap Analysis on Integration of Quality Function Deployment and Ergonomics Principles for Product Improvement (Classroom Furniture). *Industrial Engineering Journal*, *VIII*(12), 16-25.

Taifa, I. W., & Desai, D. A. (2015b). Quality Function Deployment Integration with Kano Model for Ergonomic Product Improvement (Classroom Furniture)-A Review. *Journal of Multidisciplinary Engineering Science and Technology (JMEST)*, *2*(9), 2484-2491. Retrieved from http://www.jmest.org/wp-content/uploads/JMESTN42351060.pdf

Taifa, I. W., & Desai, D. A. (2016a). Anthropometric measurements for ergonomic design of students' furniture in India. *Engineering Science and Technology, an International Journal*, 1-8. http://doi.org/http://dx.doi.org/10.1016/j.jestch.2016.08.004

Taifa, I. W., & Desai, D. A. (2016b). Student-Defined Quality by Kano Model: A case Study of Engineering Students in India. *International Journal for Quality Research*, *10*(3), 569-582. http://doi.org/10.18421/IJQR10.03-09

Tavakol, M., & Dennick, R. (2011). Making sense of Cronbach's alpha. *International Journal of Medical Education*, *2*, 53-55. http://doi.org/10.5116/ijme.4dfb.8dfd

Tsoukalidis, I., Karasavvoglou, A., Mandilas, A., & Loukas, A. (2009). Application of Quality Function Deployment on an Alternative Transportation System (Paratransit System). *European Research Studies*, *XII*(2), 131-148.

Verma, R., Maher, T., & Pullman, M. (1998). Effective Product and Process Development Using Quality Function Deployment. *Cornell University, School of Hotel Administration*. Retrieved from http://scholarship.sha.cornell.edu/articles/561

Yadav, H. C., Jain, R., Shukla, S., Avikal, S., & Mishra, P. K. (2013). Prioritization of aesthetic attributes of car profile. *International Journal of Industrial Ergonomics*, *43*(4), 296-303. http://doi.org/10.1016/j.ergon.2013.04.008

Yegenegi, K., Arasti, M., & Mousakhani, M. (2011). The integration of QFD Technique and Value Engineering and its Applying in a Healthcare Center. In *Proceedings of the 2011 International Conference on Industrial Engineering and Operations Management Kuala Lumpur, Malaysia, January 22-24* (pp. 650–659).

Zaim, S., & Şevkli, M. (2002). The Methodology of Quality Function Deployment with Crisp and Fuzzy Approaches and an Application in the Turkish Shampoo Industry. *Journal of Economic & Social Research*, *4*(1), 27-53.

Zhang, F., Yang, M., & Liu, W. (2014). Using integrated Quality Function Deployment and theory of innovation problem solving approach for ergonomic product design. *Computers & Industrial Engineering*, *76*, 60-74. http://doi.org/10.1016/j.cie.2014.07.019

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