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**RESEARCH PAPER**

**General Architecture**

# Application of Quality Function Deployment (QFD) to improve product design quality in school furniture

**N. Koleini Mamaghani [1*], E. Barzin [2]**

[1] *Associate Professor, Industrial Design Department, School of Architecture and Environmental Design, Iran University of Science and Technology (IUST), Tehran, Iran*
[2] *Ms Graduated, Industrial Design Department, School of Architecture and Environmental Design, Iran University of Science and Technology (IUST), Tehran, Iran*

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***Abstract***

*Quality Function Deployment (QFD) is a powerful development method with a wide range of applications to translate customers' needs into technical requirements in order to enhance customer satisfaction. The goal of the study was to identify the requirements of the school furniture users in the areas of functionality, material selection, structure, ergonomics and aesthetics. The authors implemented the QFD analytical method to find out whether QFD is an effective method to improve the quality of design outcomes (in this case, high school furniture) or not. To answer this question, the authors extended the QFD analysis to a complex set of customers' requirements in regards to school furniture products. A step-by-step application of QFD, known as House of Quality (HOQ) matrix was for that purpose. The quality-based requirements were considered and then the issues of scheduling were evaluated. The data collection process was carried out by recruiting 160 students from three high schools in Tehran (capital of Iran). Students' requirements were collected and translated into technical requirements using QFD method. Data gathering was carried out through survey, questionnaire distribution and structured interview. Subsequently, the collected data were analysed to find the best solutions for the problems. Obtained results from HOQ matrix evaluation, were used to provide suggestions and solutions to reduce the problems. Results indicated that seat position is the main factor in designing school furniture specified by majority of students. It is highly connected with back injuries, neck and legs pain. QFD method also can help demonstrators to ascertain inter relationship between operational requirements and measures of performance..*

***Keywords:*** *Quality function deployment; School furniture; Voice of customer; Customer satisfying; Methodology.*

## 1. INTRODUCTION

Education, specifically, has a prominent role in economic, political, social and cultural progress of a wide range of developing countries. In this regard, creating a reliable foundation is essential to help education to grow [1-2]. Educational environments, like schools, are needed to be equipped with latest necessary hardware such as school furniture and software, as modern tech tools. The authors chose to focus on designing school furniture as one of the most frequent and immediate items at schools. No doubt, that good furniture facilitates the process of learning [3]. Previous studies in this area, revealed that some specific type of school furniture are problematic causing short-term or chronic injuries in neck, backs and legs [4]. Moreover, other issues such as uneven writing surface, inappropriate size, low quality and poor physical qualities of products, negatively affect the quality of education [5].

The purpose of the present study is to identify the students' requirements regarding functionality, material, structure, ergonomics and aesthetics. Eventually, some suggestions will be provided to design descent, ergonomic, durable and charming furniture that efficiently improves learning process. The thematic structure of the study is as follows: 1) Finding out and explaining the most important problems of school furniture in some selected high schools in Tehran. 2) Describing the methodology of the study which is based on Quality Function Deployment (QFD) method and selected literature review. It should be noted that, the main purpose of the present case study was to apply QFD to develop a method of customer-oriented design. It is also important to emphasize that this study has

* *Corresponding author: koleini@iust.ac.ir*

focused on House of Quality (HOQ), described as the first step of QFD. Finally results of HOQ evaluation will be presented in conclusion.

## 2. PROBLEM STATEMENT

Iranian students spend almost one-third of their daily time at schools. That is about 30 hours weekly. Therefore, comfortable furniture would be essential to their health and the quality of learning [6-7]. In order to gather data from furniture in use, the authors planned to visit different schools. Basic step in QFD method has been considered very well to help to experience the product and the specific environmental parameters where products used. Condition of use and customers' needs and problems were studied, too [8-9]. Based on data collected, some of the reasons for students' exhaustion were identified. Also, the results of previous studies indicated that the most common problems were improper matchup between students' anthropometrics and dimensions of school furniture leading to pain and discomfort [4]. The age range of participants was 14 to 16 years old. The reason to choose it, was the outstanding variations of anthropometric data associated with the age range. However, similar school were used across the studied schools all grades in spite of different anthropometric data. 160 students from three high schools were studied. Students answered a questionnaire which asked about discomforts and dissatisfactions when isung furniture. Most important dissatisfactions were, inappropriate material, dimensions and form. Also several students complained about absence of dedicated place for their tools and bag. Also inferior materials that fall apart quickly, injure body and damage student's clothes. Regarding ergonomics problems, the most important mismatches are between both chairs and tables height with student's body size. The problems were categorized in three different areas. First category was the physical problems arising from the lack of right proportion. Second category were problems connected to students' dissatisfaction which expressed through interview, such as low quality of material, non-attractive form and colour and inadequate surface for writing. The third category was cost-related issues, like poor quality of material and manufacturing leading to the loss of funding (no budget for renewal).

## 3. LITERATURE REVIEW

Designing is a complex problem-orientated process, which must fulfil all the demands and expectation concerning the product [10-11]. The first step in product design is to analyse and translate the need or deficiency into specific qualitative and quantitative customer and design requirements [12]. In order to address all aspects of the design process, a complex methodology was needed. Quality can be defined as meeting customer needs by providing superior value. It focuses on satisfying the customers on products or services. Quality often is hard to explore and sometime measurement of quality is difficult [13]. There are many tools that help researcher to define and measure the quality. One of these methods is QFD. If we consider a line between art and engineering, QFD move on this line and help to combine these to create a successful product [14-15]. Field of QFD application is very broad. This method introduces in Japan as quality system focused on delivering products and services that satisfy customers. Scope and depth of usage QFD was introduced in 1960 by Professor Yuji Akao and subsequently published in 1972 and in 1980 this method was used in Japan industry. According to Perry and Debra (1997) the term QFD is a loose translation from Japanese name for this methodology, "*him shitsu*" (quality), "*kinkou*" (function), "*ten kai*" (deployment) [16]. Traditional QFD has included 16 matrixes that pre computer age was done by hand. In most of USA companies QFD was known equal with 4 matrixes that authors will show that in this paper. HOQ is the name of first matrix that used in QFD method, a process framework to prioritizing consumer's requirement. QFD is a detailed system requirement for implementing the wishes and desires of costumers in the design, manufacturing or service jobs [17]. Generally, QFD is a tool for assuring about both qualities of product and quality of process [18]. To efficiency deliver value to customers, it is necessary to listen to the Voice of Customer (VOC) throughout the product or service development process [19]. The QFD with the creation of a comprehensive process in design background, improve product quality and do this by creating sensitively to the demands of the customers or users [17,20]. In this method the role of experts as translators, is translate the users demand into the technical variables including product specifications, design attributes, and ultimately to the manufacturing process parameters [21-23].

QFD is a product development process that stresses cross-functional integration [8]. Indeed, QFD has been used to translate customers' requirements and needs into technical requirements for achieve customer satisfaction [24]. According to Wolniak (2018) advantages of using QFD are: decreasing the number of design changes, reduced product development cycle time, fewer problem in the start up the project and user satisfaction [25-26]. QFD has been widely adopted in the development of various products [27]. Based on records of activities that done by various organizations, in some cases it was observed that some companies continued in this way for years and then have been achieved remarkable results. Also during this time, reduction in the number of engineering changes cause that product development cycle was reduced by one third. Evaluation of true information could help to designers to make appropriate decisions to better and more efficient design [28]. In other activities the Puritan-Bennett company, designed and manufacturer of respiratory measurement devices, could with using this method introduced a new model of their product to the market that besides having more and better features and prices than their competitors. With this method could take the huge part of product market. This company used 16 types of QFD matrixes in following background: new product design, new manufacturing process, using new technology, manufacture product in new integrated manufacturing,

manufacture product with new equipment and working with new staff [17,29]. Several researchers have been working on approaches for QFD and developed a number of interesting models and applications using QFD as solution tool [2]. Naveiro and de Oliveira (2018) shows with an example that it is possible to integrate QFD and Theory of Inventive Problem Solving (TRIZ), utilizing QFD to identify and quantify engineering parameters and TRIZ inventive principles to achieve solutions [30]. In another study QFD used to evaluate the effectiveness of training sources in Hong Kong City University. They were used QFD and the Analytic Hierarchy Process (AHP) to estimate training courses. They estimated the courses according to students, in spite of times that evaluations have been done by teachers [31]. It should be noted that engineering manager were also asked to prioritize their needs using the AHP. The AHP uses pairwise comparisons that allow for an accurate measure of importance, including a ratio scale distance between values, unlike the more traditional rating scale used in QFD [19]. Another study show that QFD was used for improving social services to disable people and shows that interviewing variables in providing quality services must be identified and managed [32]. Bolt and Mazur (1999) shows another background of QFD usage in tangible product design of animatronic dinosaur to be used in a service operation [33]. Mazur (2008) and also Zhebo et. al. (2018) shows that how the sales and customer satisfactions increase with using QFD in food industry [34-35]. In furniture issue, Knight and Noyes (1999) shows that how student's behaviour is affected from non-standard furniture, and with new design furniture were given more sitting position choice to the student to correction theirs false position of seating [36]. Today, QFD continues to inspire strong interest around the world, generating ever new applications, practitioners and researchers each year [37].

## 4. RESEARCH METHODOLOGY

Much literature has demonstrated both successes and issues with the QFD methodology [27, 38- 39]. According to Jackson and Frigon (1994), QFD uses the following seven management tools: affinity diagram, interrelationship diagram, tree diagram, matrix diagram, process decision program chart, arrow diagram, and matrix data analysis chart [40]. Methodology of the present study based on QFD method is shown in Figure 1. The purpose of using QFD in the current study is summarized in three points. The first one is translation of student's requirements from furniture into the technical requirements in design stage. Finding solutions to reduce furniture problems and defining the most important variable for the final product that increase student's satisfaction are the following points. The data come from many sources, including focus groups, questionnaire surveys, experimental tests of computer's products, and published materials.

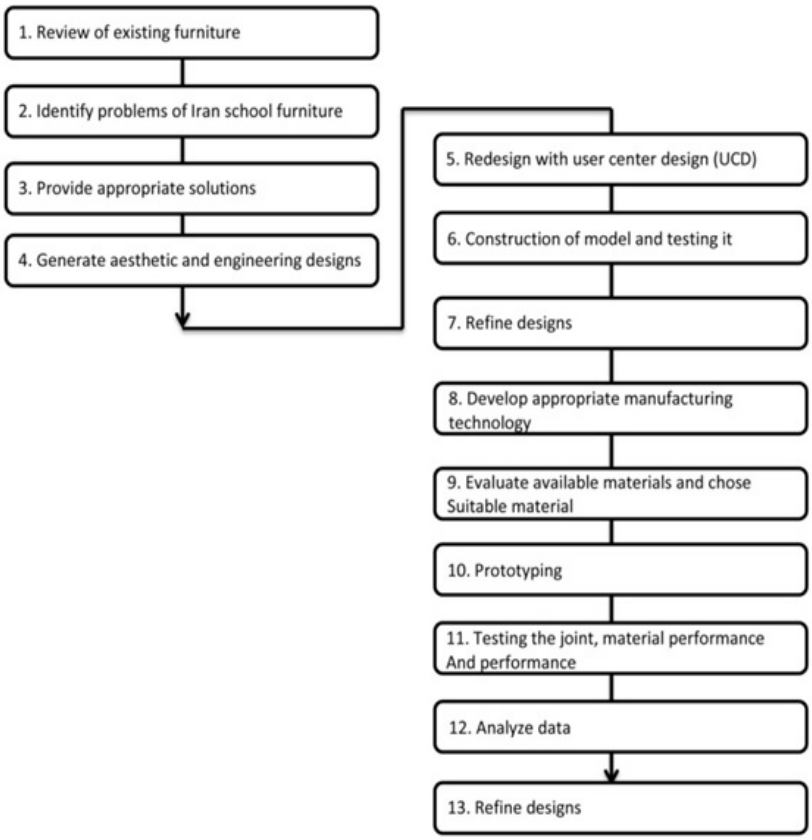



**Fig 1**. Methodology of the present study based on Quality Function Deployment (QFD) method.

Required information was collected by studying on 160 students from three independent high schools located in three areas of Tehran. As shown in Figure 2, QFD often employs four matrixes [8,41-42]. The first phase of QFD is product planning matrix which is normally known as the HOQ. On the other hand, the primary feature of the QFD process is the HOQ, which provides inter-functional product planning mapping to link engineering attributes to customer desires, which are ranked in importance [43-44]. It looks like a real house. The present study focused on the first matrix, HOQ.

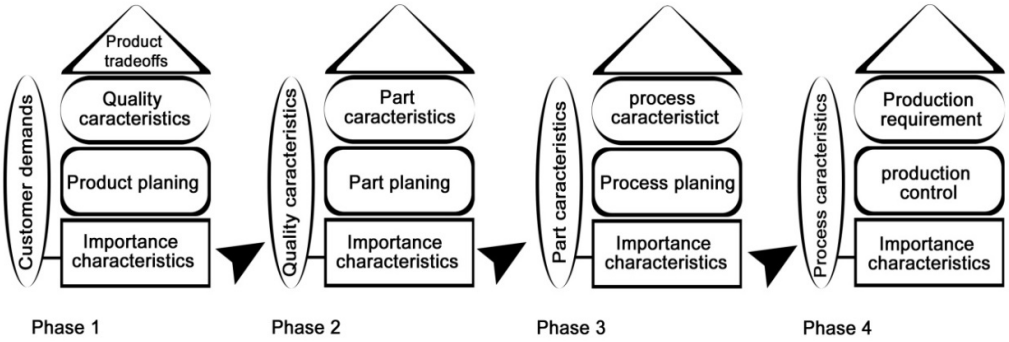



**Fig 2.** The four phase of Quality Function Deployment (QFD) [2, 8]

Collecting the information was started with going to the *Gemba* where the customer interfaces with the service to observe, listen, and record the problems customers experience and the opportunities they wish to seize. *Gemba* is a Japanese word using to describe the information that is achieved from true resources [32]. User's comments and requirements were collected with a questionnaire by opened questions. Then to achieve new requirement from study of environment requirements classification has done with VOC method. In order to obtain and summarize the most important requirement, factor analysis has been used to decrease the number of HOQ variables. Next step is the transferring the student's requirement to the HOQ matrix. The framework of a typical HOQ, mainly includes seven parts, is shown in Figure 3. Step by step of completing the HOQ matrix, has been described in Fig. 3. This particular types of HOQ emphasizes on the correlation matrix between customer requirements and technical parameters. In QFD application, it is essential to define the "*What's*" and "*How's*" according to the nature of the issue. Also it is very frequent that each "*What*" needs a specific "*How*". The key question to be asked is "*What*" the students' expectations would be from the school furniture. Interviews, surveys, organizing groups, *Gemba* visit and content analysis are generally used in order to define the customer needs [2]. To develop the technical requirements as the "*How's*" part of HOQ, a brainstorming was held with the members of the design team which consider the movement of target value for improvement of the layout and feature design. Using the correlation between the customer needs (*What's*) and the technical requirements (*How's*), it is possible to determine strength of relationship and impact on the need (Fig. 3).

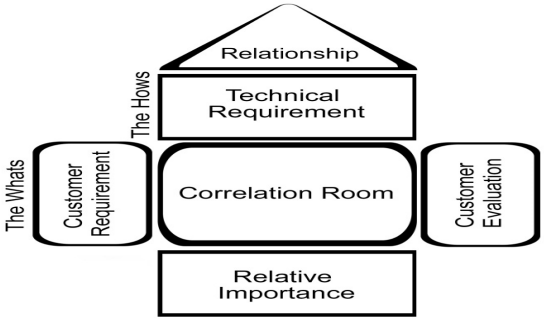



**Fig 3.** The framework of a typical House of Quality (HOQ) matrix [13].

## 5. QFD APPLICATION ON PRODUCT DEVELOPMENT PROCESS

One of the most important purposes of QFD is to search all possible demands from consumers. In this study, student's demands or problems were collected by going to the *Gemba*. *Gemba* include activities such as going to product usage environment, identifying product users and determining the methods to hear the VOC [19], particularly in the context of product usage or service. Context is easily described by the 5W1H (who is using, what is it used for, when is it used, where is it used, why is

it used, and how is it used). Information was collected directly from students without any intermediate. The interviewees were given a questionnaire to fill up with contact information. Students were also asked to describe the school furniture and whether they are satisfied with the current ones. They were also inquired to indicate, if any, the improvements of the current school furniture that could be done. From the personal interviews and questionnaire information, 180 requirements (step 1 of Fig. 4) have been identified. Subsequently, these 180 requirements were increased to 200 with classification and quantification of the VOC (step 2 in Fig. 4).

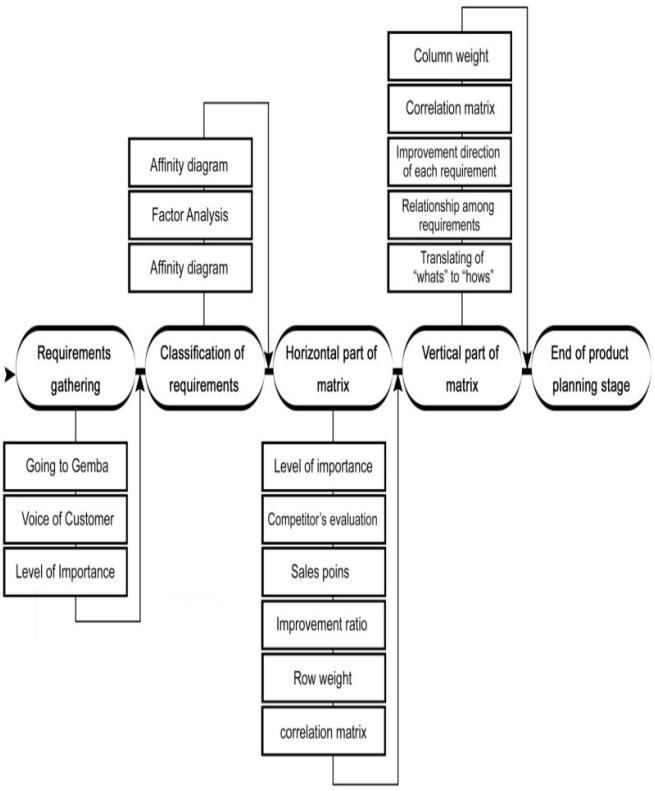
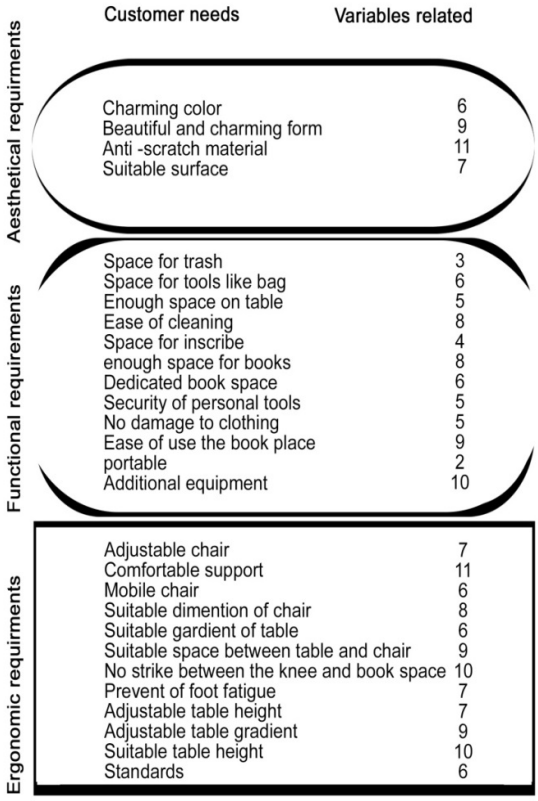



**Fig 4**. The House of Quality (HOQ) methodology in the present study

Next step was creating the harmony between obtained data. Data in this stage should be presented in desirable qualities form. Typically, there are many customer's requirements, but using a technique known as affinity diagramming, the team distils theses many requirements into 20 or 30 most important needs. Affinity diagrams are used to organize and gain insight into a set of qualitative information, such as VOC requirements. Authors also employed affinity diagram to identify the student requirements that were not expressed by them. Usually affinity diagrams are created in four steps: 1) recording each customer statement onto separate cards, 2) sorting cards into groups, 3) selecting or creating a title card, which summarizes the data within each group, and 4) title cards can be sorted into higher-level group. Transferring the 200 requirements to the "*What's*" part of HOQ matrix is very difficult and time-consuming job. Therefore, authors decreased the number of these requirements to the 28 requires using factor analysis (step 2 in Figure 4). In Table 1 shows how the 28 requirements were put into 28 variables. 28 requirements are still difficult to evaluate in HOQ matrix, so the QFD team with help of manufacturer and the people involved in education system, decreased the number of requirements to 13 variables in two groups involved table and chair (Figure 4).

**Table 1**. 28 Original requirements of students.




No doubt, the importance of all requirements is not equal from student's or producer's point of views. So, for determination the level of importance for all requirements, the authors used a rating system (from 1 to 5) with five selections points. Number 1 used to requirements that were not very effective on students satisfying and number 5 for requirement with most importance in their view point (step 3 in Figure 4). Obtained information was transferred into the HOQ matrix. According to the stage three of Figure 4, the number of complains, evaluation of competitors, were considered. This matrix shows comparison of product capabilities in satisfying the customer with other competitor company capabilities. Other information was summarized in the HOQ weight, a computed value relating the importance to customer, row weight and improvement ratio. This information will help us for identifying which customer requirement is most important to correction and spending time and money. In stage 4, authors translated the student's requirements, that called the "*What's*" in this matrix, into the technical requirements that called the "*How's*". In this regards, authors asked manufacturers to how measure these requirements. The positive degree of correlation between student's requirements and technical requirements is denoted with the following sing-scale: strong (9), medium (3), weak (1) and empty box (0). Then matrix like: targets, improvement ratio (relate target with the current performance measure in a specific requirement), sales point (the requirement in which the company has the ability to sell the product) and row weight were completed. Technical requirements were placed at the top of the HOQ, and operational target values associate with these measures (Fig. 5). In this study authors focused on the first matrix for identifying the most important area about product that need to be improved. For building other matrix, inputs come from "*How's*" part of previous matrix that placed on "*What's*" in new matrix and this cycle continues until other matrix.

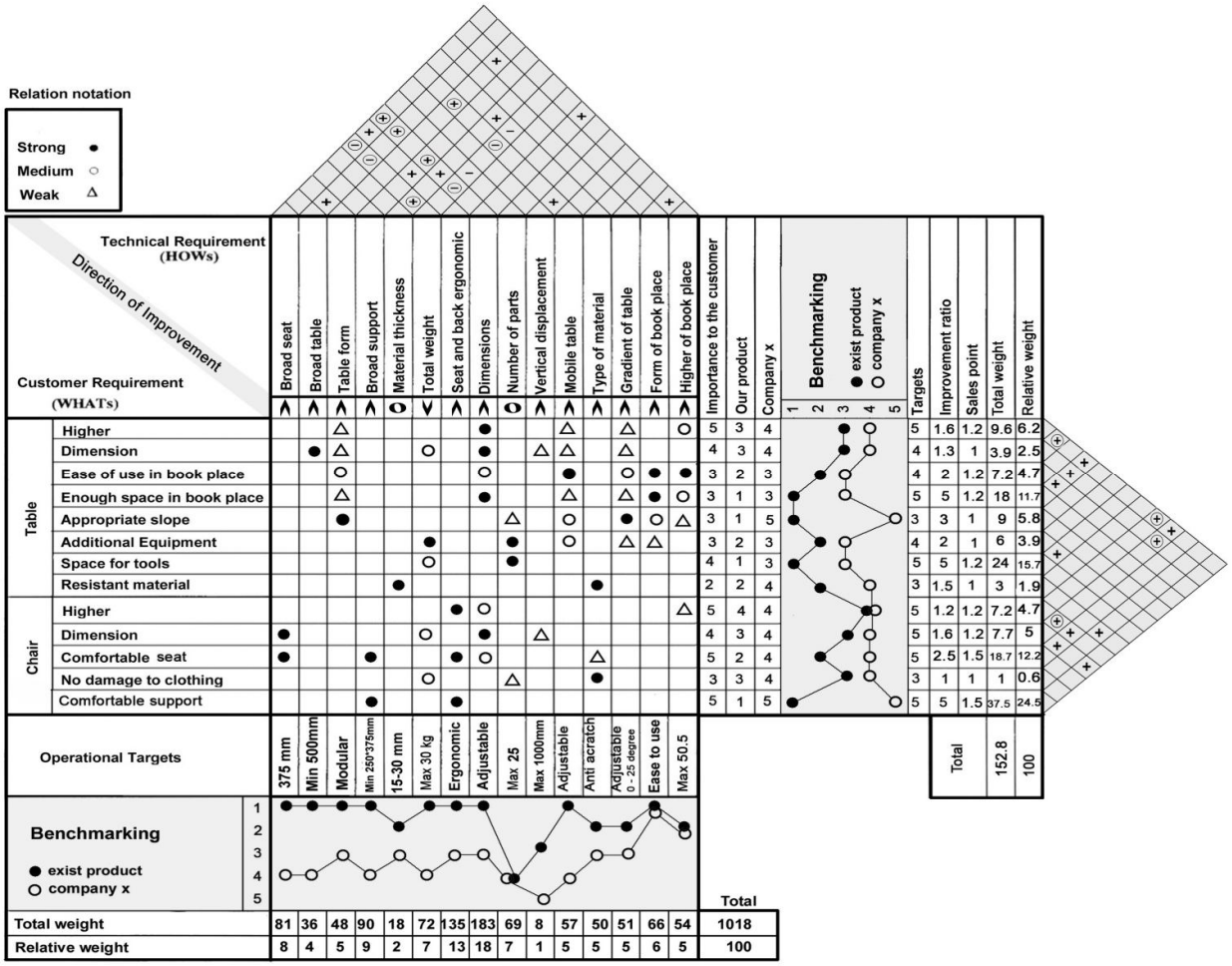



**Fig 5**. House of Quality matrix.

## 6. DISCUSSION

Since traditional QFD may not cover all the urgent deployments, modern QFD (matrix-free) was used to response to the changing the needs of customers [45]. In the present study, QFD matrix (HOQ) helped us to identify student's demands and problems about furniture during school time at three different high schools in Tehran. Using QFD method, the cycle of product design, the risk of product development and the costs can be generally decreased while the quality of the product is increased and the competition of enterprise is enhanced [46-47]. QFD is a valuable and flexible tool for designing. It has provided the tools, methods and structures to perform those activities, particularly at the critical to satisfaction phase. The sequence of parts and steps during the QFD process can be changed according to the strategy adopted by the design team. The correlation matrix is the heart of the QFD process and stores precious information needed for design improvements [48]. The presented study is one of the first report using QFD method undertaken in Iran about school furniture. In the previous studies design of school furniture such as chair and table was not impressible of student required in Tehran's schools. Using QFD, helped us to reach important and accurate information about student's needs and demands. Some of the student's requests seem not necessary at first, but this study showed that some requests such as "*tools place*" are important from viewpoint of students. These requests usually are ignored or unseen from designers. QFD discovered students hidden needs about chair and table that can lead to student's satisfaction and fulfil their demands such as "*no damage to clothes*", "*resistance material*" or "*space for tools*". According to the Figure 5 in "*importance to the customer*" part, our findings showed that "*comfortable seat*", "*height of the table and chair*" and "*comfortable support*", come up with most importance for students. As well "*dimension of table and chair*" and "*space for tools*" are placed in the next stage. As student's bag and clothes will be muddy without special space dedicated space for tools, is one of the requests that student emphasis on it repeatedly. Eventually, other customer need such as "*ease of use and enough space in book place*", "*appropriate slope*",

"*additional equipment*" and "*no damage to clothes*" are in the next level of importance. "Resistance material" avoiding damage during the school time has found as the lowest importance factor.

Quality of furniture that are used in some school in Tehran is low and students have initial needs and request from designer to solve. Our finding indicated that student requests such as ergonomic and dimensional problems are simple and affordable. According to the Figure 5 the "*comfortable support*" requirement, with 24.5 weights, shows the most important requirements that need to superior attention. This comfort will be provided with "*broad support*" of chair and "*seat and back ergonomic*" as technical requirements. Comparing furniture in the present study with other companies' products for this requirement indicated poor quality of our furniture. Weight of this requirements show the importance range of any require to improve. Second requirement representing highest weight is "*space for tools*" with total 15.7 weight. Student's need about space for their tools such as bag, umbrella and etc. is more crucial in their view sight than our expectations. Moreover, requirements such as "*comfortable seat*" and "*enough space in book place*" are important for consideration with 12.2 and 11.7 weights respectively. Another requirement such as "*higher of table*", "*chair dimensions*", "*ease of use*", "*book place*" and "*higher of chair*" are placed on the next rank. Least weighs for "*no damage to clothing*" shows that this requirement is not very necessary to deal with. The comparison between our product and other products, shows that almost in used products is in low quality regarding the student's requirements. This matter shows that existing table and chair need to be improved immediately because low quality of these furniture may cause many serious physical or mental problems for students. So it seems that designer must pay essential attention on school's furniture. Weight of this requirements shows the priorities of them to improve. Finally, the alternative innovative concept of table and chair according to the above results is illustrated in Figure 6.

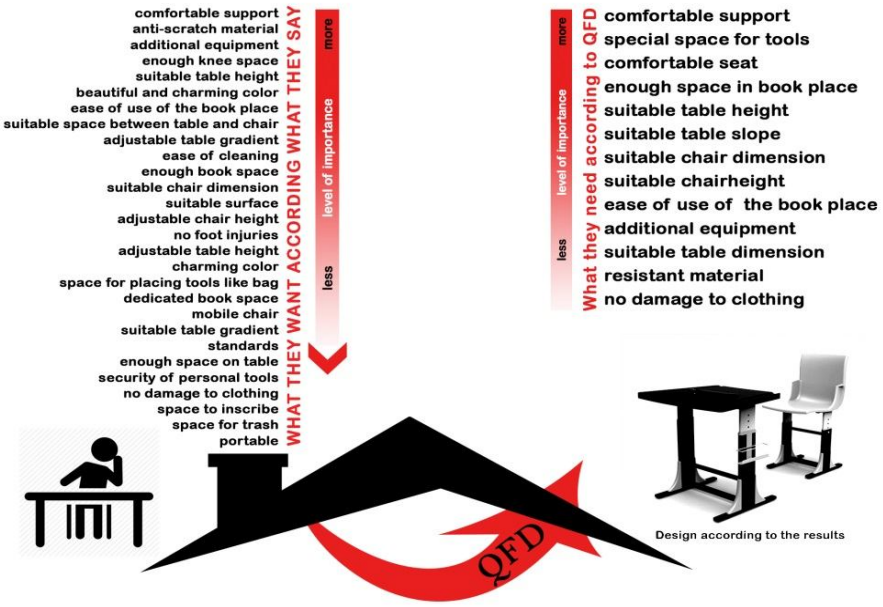



**Fig 6.** The alternative innovative concept of table and chair according to the results.

## 7. CONCLUSION

The QFD method is very useful to analyse the customers' desires with solutions along with a new design to generate high quality and competitive products and processes. The creditability of the QFD method to reach to customer expectations is increasingly growing. This methodological tool is capable of providing a better solution to the problems where all aspects of product design [49-50]. For instance, Yang et. al. (2019) proposes a new hybrid method that adopts the theory of inventive problem solving and the Kansei evaluation in quality function deployment processes to facilitate innovative new product design and evaluation in the early design phase [15]. Artefacts produced in the course of QFD studies contain much data which correspond closely to the data required as input to various popular object oriented methodologies. The QFD enables to know which user's requirements are the most important and which need to be included in the final new product. Understanding the true needs of customers requires work on the part of designers

and planners. In this study, the quality based requirements are considered first, then the issues of scheduling are evaluated.

Our finding revealed that how furniture defects can negatively impact on student satisfaction and exhaustion during learning process. According to obtained data, "*seat comfort*" is the most important factor from students' point of view, causing back, neck and leg pain. Design of table and chair according to the HOQ matrix may solve furniture problems and satisfy student, however more empirical and field research are needed over a longer period of time to produce satisfactory result. Moreover, many other important problems in schools such as teachers' table and classroom board were also identified that require special attention. It should be noted that as QFD just provides a framework deploying the customers' requirements into product design, other approaches must accompany QFD in order to make the method more effective. Giving a theoretical foundation, the analysis of the study has verified that the new design, based on finding, is relevant and effective. Using QFD method, it is possible to determine the most important points in existing furniture that should be corrected and provide technical solution as technical targets in product planning stage. In conclusion, QFD has proved to be an effective means of process development and product deployment. This study presented foundational information about students and their requirements in classroom where future studies could employ this information to move forward. In future work, the authors will consider the conflict and optimization between qualities and schedule, as well as resource limitations to establish a more complete expert system.

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**AUTHOR (S) BIOSKETCHES**

**N. Koleini Mamaghani.,** *Associate Professor, Industrial Design Department, School of Architecture and Environmental Design, Iran University of Science and Technology (IUST), Tehran, Iran*
Email*: koleini@iust.ac.ir*

**E. Barzin .,** *Ms Graduated, Industrial Design Department, School of Architecture and Environmental Design, Iran University of Science and Technology (IUST), Tehran, Iran*
Email: *barzinelham@gmail.com*



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