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برنـامج إدارة التشييـــد

Vocational Educational Facility Design: A Fuzzy QFD Approach

تصميم منشأة تعليمية مهنية باستخدام طريقة FQFD

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بسم الله الرحمن الرحيم

وقل رب زدني علما

صدق الله العظيم

Dedication

This work is dedicated to my parents for their endless support

Jannat Haider Allahham

Acknowledgment

I would like to express my deepest appreciation to my supervisors Dr. Salah Agha and Dr. Samir Shihada for their valuable guidance and encouragement.

Deepest thanks for the teaching staff in the industrial secondary school in Deer Al-Balah for their support and contribution

Abstract

The construction industry has been one of the most important industries for the development of the Palestinian infrastructure and economy. The construction industry faces many challenges that affect it especially during the design phase. Many of these challenges arise from the changes in the economy and technology, user's unsatisfaction and occupation.

The design process is considered as the most important step in any project. In the construction industry, usually the customer requirements are not treated systematically.

Fuzzy Quality Function Deployment (FQFD) has become a widely used tool in the development of products and services. It helps design teams to gather needs of the customer and organize this data.

The main objective of this research is to design an appropriate vocational educational facility using FQFD. The questionnaire is used as a tool to data collection. This research determines a total of 11 customer requirements and 38 design requirements obtained from literature of vocational educational facilities design, FQFD method and professionals. The data is analyzed using Microsoft Office Excel and SPSS.

This study presents the proposed layout for a proper vocational educational facility. Pareto principle was used to find the critical design requirements of the educational carpentry workshop. A model has been developed using LINDO software to identify the main design requirements of the educational carpentry workshop according to many conditions that achieve most customer requirements. The research points out to the need for more standardization of users' needs. More effort should be made to apply a proper vocational educational facilities design in the construction industry.

الخلاصة

تعتبر صناعة التشييد واحدة من أهم الصناعات المؤثرة في تطوير الاقتصاد و البنية التحتية الفلسطينية. صناعة التشييد تواجه العديد من التحديات التي تؤثر خصوصا على مرحلة التصميم، حيث تزداد العديد من هذه التحديات بسبب التغيرات الاقتصادية و التكنولوجية، عدم رضا المستخدم و الاحتلال.

تعتبر عملية التصميم الأولي أهم مرحلة في أي مشروع حيث عادة في صناعة التشييد لا يتم الاهتمام بمتطلبات و احتياجات المستخدمين.

أصبحت FQFD أداة واسعة الاستخدام في عمليات تطوير المنتج و الخدمات، فهي تساعد فرق التصميم في جمع احتياجات و متطلبات المستخدمين و تنظيمها.

يهدف هذا البحث لتصميم منشأة تعليمية مهنية مناسبة باستخدام FQFD.

تم استخدام الاستبيان كأداة لجمع البيانات و قد احتوى على 11 بنداً تم تحديدها من خلال استعراض واسع النطاق للمراجع و الأبحاث و النظريات و النماذج ذات الصلة بتصميم المباني المهنية و طريقة FQFD و استشارة الخبراء في هذا المجال. و قد تم تحليل البيانات باستخدام برنامج Excel و برنامج SPSS.

و قد استخدم مبدأ باريتو لمعرفة متطلبات التصميم المهمة لورشة النجارة التعليمية. و تم أيضاً تطوير نموذج باستخدام برنامج LINDO للحصول على أهم المتطلبات التصميمية في ورشة النجارة التعليمية حسب متغيرات مختلفة.

و يوصي هذا البحث بأهمية فهم متطلبات و احتياجات المستخدمين، فلابد من جهد يبذل في عملية تصميم المنشات التعليمية المهنية في صناعة التشييد.

Abbreviations

AHP	**Analytic Hierarchy Process**
FQFD	**Fuzzy Quality Function Deployment**
GTC	**Gaza Training Center**
HOQ	**House of Quality**
IUG	**Islamic University of Gaza**
QFD	**Quality Function Deployment**
RI	**Relative Importance**
RII	**Relative Importance Index**
SPSS	**Statistical Package for Social Science**
TFN	**Triangular Fuzzy Numbers**
UNRWA	**United Nations Relief and Works Agency**
U.S.A	**United States of America**

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Chapter 1

Introduction

This chapter contains information about the vocational education facility design using FQFD, problem statement and the objectives.

1.1Vocational Education Facility Design using FQFD

FQFD (Fuzzy Quality Function Deployment) is a strategic management tool, which is capable of managing and improving the quality of the product design process by listening to the customer’s voice. It is used in many fields in a number of countries (Sommerville and Craig , 2002).

FQFD will work in construction if teams work together to mass produce buildings or design construction processes. This seems like a concept that could easily be implemented within the industry, but because of customers' specifications and geographical difficulties, construction operatives are not willing to introduce new processes into building designs when there is no benefit for them at the end of the project when the project teams will split.

Good design of facilities has a significant impact on the performance of users. It is the foundation for a successful outcome and the satisfaction of all users (Harastanee, 2003). Wherever, the school is a learning organization which is composed of two dimensions: technology includes facilities and social includes individuals working together to reach common educational goals (Elewa, 2007). The best designed schools encourage students to learn (Tanner, 2000).

The process of school design responds to the real needs of education and community's goals. It requires an appropriate balance between experience, wisdom and professional skills of all participants. So. if the students study and the teachers teach in an ideal environment, fantastic results would occur (Harastanee, 2003).

Vocational education is one of the most important types of the formal education which increases the economic renaissance. It is responsible for the supply of the labor market with professional technical staff. The education sector in Palestine is facing major difficulties in the absence of political stability, but the challenges should be resisted to obtain the satisfaction to all users (Shaheen, 1987).

Adopting FQFD in Palestine is considered a new method where there are no applications of vocational facilities design using FQFD.

1.2 Problem Statement

One of the problems that face the construction sector in Palestine is achieving high satisfaction for users in terms of design (UN, 2002). So, the appropriate design has many benefits especially on the performance of users (Harastanee, 2003).

A lot of students believed that diverse school facilities' functions play an important role in the mental and emotional development of students and encourage them to learn (Baek and Choi, 2002). So, engineers should focus on the designing process. Thus, the educational level of students will improve and the Palestinian economy will grow (Public administration for colleges and vocational education, 2008). Therefore, more new schools need to be built, given the fact that only two vocational schools are existent in Gaza Strip (Esawee, 2008).

1.3 Objectives

- Identify customer requirements in a specified vocational educational facility.
- Identify design requirements that meet the customer requirements.
- Propose a new design by preparing layout based on customers' requirements using FQFD.
- Compare the existing design with the proposed one.

Chapter 2

Literature Review

This chapter contains information about the vocational education and the vocational education facility design in Palestine. Also, it contains an illustration of FQFD method and its relationship to vocational education facility design.

2.1 Background of the Vocational Education

Vocational education is a type of formal education at the secondary level, in the sense that it is educated in the secondary vocational schools. Vocational education includes educational preparation, acquisition of knowledge, skills and capabilities of professional and aimed at graduates in various fields and disciplines, such as the professional industry, trade, agriculture, and others (Shaheen, 1987).

Vocational secondary schools are dealing with vocational education, which is composed of the branches of agricultural, industrial, commercial, hotel and home economics education, where the student join in after completing the tenth grade and successfully meet the requirements of admission. The duration of the study in vocational schools is two years during which the student studies general and specialized education programs. After graduation, students can enter the labor market directly to work in the field of specialization or go to university to complete his studies (Public administration for colleges and vocational education, 2008). The academic schools provide education to its students primarily focusing on information and concepts rather than the vocational schools as it combines education and training. The vocational education programs achieve the following: (i) to prepare a trained manpower at the level of skilled labor in the fields of industry, agriculture and services to meet the needs of society and development, (ii) to prepare students for admission to institutions of higher education, (iii) to join the vocational sector and (iv) to achieve the objectives of society (Shaheen, 1987).

The vocational education facilities in secondary vocational schools are administration, educational activities, sport, prayer, food, bathroom and workshops facilities. All of these facilities are existent in all schools except the workshops, it is available only in the vocational schools (Clark, 2002).

The vocational education system in Palestine has appeared 144 years ago, when the government allowed the Ottoman population and communities in 1856 to establish schools as it deems appropriate in Palestine, so, the Arab-Islamic schools spread across private and foreign missionary schools. In 1860 the "Schneller" school was established for orphan students as the first foreign school focused on vocational training and manual creation of a number of concerns for training such as tailoring, carpentry, blacksmithing, bookbinding, printing, shoe manufacturing, machining and pottery. In 1863, was established to a school in Bethlehem "Alszayan" to achieve the same goals for Schneller school. In the era of the British mandate, the Islamic Orphanage in Jerusalem was established in 1922 under the auspices of the Supreme Islamic Council in Palestine as an industrial school to help orphans in their life by acquiring a specific career at this school. Established the "Kadoorie" Agricultural School in 1930 in Tulkarm, to train students who have completed their Arab village primary school on the way of agriculture Assembly for two-years. In 1933 was established the first vocational school in Haifa (Abu-Lughod, 1997).

The most important role in the development of vocational education of this period was done by the UNRWA, which has established two vocational training centers at the level of secondary education, one in the year 1953 in Kalandia and the other in Gaza in 1954. Additionally, the Ministry of Education of Jordan started to interest in vocational education, creating a number of industrial secondary schools as in Nablus in 1962. Then another one in Jerusalem in 1965 for handcrafts in blacksmithing, carpentry and electricity (Mea'yaree, 1991). The vocational educational system has suffered by the Israeli occupation as a result the 1967 war and is still suffering (Hashwa, 1997).

The Palestinian National Authority established many of the vocational schools in the West Bank and Gaza, including four in the West Bank, and two in the Gaza Strip. Nowadays, there are 78 vocational schools in Palestine, including 15 industrial schools, one of which contains a section containing the hotel and the other domestic economy, two agricultural schools and 61 commercial schools. The vocational education programs in secondary vocational schools include 18 programs which are offered in 21 schools in the West Bank and Gaza Strip (Public administration for colleges and vocational and technical education, 2008).

2.2 Vocational Education Facilities Design

The construction project has a life cycle which contains of design phase, procurement phase, construction phase and implementation phase. Design process is a phase of establishment of a scientific conceptual drawings that meet the customer requirements of use, durability, beauty and economy, and meet the needs of the people's material, psychological and spiritual, individual and collective (Barrie and Paulson, 1992).

The process of designing the vocational education facility requires an appropriate balance of experience, wisdom and professional skills of all participants to be beneficial and fun for everyone (Shaheen, 1987).

Design requirements are defined as means of communication between educators and design professionals. Educators describe the educational program and identify factors which affect learning and teaching, thus providing a data base for the designer to use in creating the building plans (Department of Public Instruction, 2002).

Vocational education facilities especially workshops occupy considerable attention because they have a technical nature. This type of education requires a balanced environment between the theoretical and practical sides. Therefore, the duty of the designer is to create the correct link between these different sides (Shaheen, 1987).

Design requirements vary from facility to another, but there share requirements between them like:

- Orientation

Windows that face the west or the east receive excess heat from the sun and this helps with the heating in cold climates. However, the problem of cooling is more important, so, the majority of the facility should be faced to the north or the south (Shaheen, 1987).

- Spaces

The area of the facility is determined due to its type (Shaheen, 1987).

- Windows

Use of windows in certain partitions will help to provide an open atmosphere and aid the instructor with facility control (Indian technology education, 2000).

- Doors

Any facility should be equipped with doors to allow the access and the exit, to move equipment and supplies and to emergency (Indian technology education, 2000).

- Lighting

Adequate levels of illumination, which may be a combination of artificial and natural light, shall be provided, consistent with efficient energy utilization, for the various visual tasks being performed in each area of the facility. The amount of natural light within each space in the facility will depend on the size and configuration of the windows, skylights, and clerestories of the building design. The availability of windows should be more than 1/6 of the workshop area (Office of Facility Planning, 1998).

- Acoustics

Good voice control prevents the sound from moving to outside. Some educational researchers suggest that it is wise to use a certain amounts of sound absorbent materials in walls, floor, ceiling and door to reduce the vibrations generated by the devices and equipment and to prevent undesirable noise in adjacent areas from transmitting into the space (Office of Facility Planning, 1998).

- Ventilation

Ventilation of a building is affected by the air flow resulting from the prevailing wind path over the natural terrain and existing obstructions of the site. The exposure to air flow will affect the air infiltration through the building shell, during the heating season; however, maximum natural ventilation is desirable during spring and fall seasons (Office of Facility Planning, 1998).

- Ceiling

Ceiling height of the facility shall be properly proportioned to the size of the room (Indian technology education, 2000).

- Furniture

A list of furniture should be contained in each facility by type and quantity is helpful to the designer like:

-Blackboard should have an appropriate height and clear to all students in the room.

-Seats should be comfortable.

-Tables should be suitable for students (Department of Public Instruction, 2002).

- Walls

The lower portion of walls should be free from obstructions to allow for the placement of benches, machines, and cabinets. Light reflecting paint colors should be used with scrubable surfaces around points of wear. Scrubable means a glazed, nonporous surface such as produced by epoxy paint or ceramic tile. Appropriate finishes are always easy in cleaning and maintenance, and resistant to moisture and firing (Indian technology education, 2000).

- Floors

Floors should bear heavy loads, resistant to vibration and easy to clean. Floor covering appropriate to the nature of the room activity is recommended. Carpeting in planning and design area, resilient tile or hardwood floors for general work areas, and surface-treated concrete where grit, oil, or water are present in quantity are good selections (Indian technology education, 2000).

- Safety

Appropriate fire extinguishers and fire protection equipment of sufficient capacity like safety glasses or a face shield, shop apron and gloves shall be provided for the facility (Indian technology education, 2000).

- Sanitary Services

A hand-washing, general use sink and hot water suppliers should be located in the cleanup space in the facility (Indian technology education, 2000).

2.3 Quality Function Deployment

Quality function deployment (QFD), originated in Japan firms to improve the quality. "Deployment" has a much broader meaning than its English translation. In Japan "deployment" refers to an extension of activities. Therefore, "quality function deployment" means that responsibilities for producing a quality item must be assigned to all parts of a corporation (Kogure and Akao, 1983).

2.3.1 QFD Definitions

QFD a planning tool that uses matrices to show the relationship between two or more sets of concepts and facilitates a customer focused product and process design by making explicit the relationship between design characteristics and customer requirements (Hauser and Clausing, 1989).

Akao (1990) defined QFD as a strategic management tool that provides a structured way for service providers to assure quality and customer satisfaction while maintaining a sustainable competitive advantage and focuses on delivering “value” by seeking out both spoken and unspoken customers’ needs, translating them into actionable service features involving all members of the supplier organization.

Also, Chen and Weng (2006) defined QFD as a systematic method for translating the voice of customers into a final product through various product planning, engineering and manufacturing stages in order to achieve higher customer satisfaction.

2.3.2 QFD History

QFD was developed in the late of 1960's and early 1970's in Japan by Professors Yoji Akao, Shigeru Mizuno and other quality experts as they wanted to develop a quality assurance method that considers customer satisfaction of a product before it was manufactured at the time that quality control methods were primarily aimed at fixing a problem during or after manufacturing (Akao, 1997). This technique took more than ten years to reach the U.S.A (Guinta and Praizler, 1993). The history of QFD in U.S.A and Japan is summarized in Table 2.1. Many companies have used QFD in all fields and realized significant benefits, and the tool continues to grow in popularity (Griffin and Hauser, 1992). QFD influence also goes beyond Japan and the U.S.A There is reported QFD applications and studies in many countries (Chan and Wu, 2002).

2.3.3 Functional Fields of QFD

QFD has been introduced to the service sector such as government, banking, healthcare, education and research. Later, QFD's functions had been expanded to wider fields such as design, planning, decision-making and costing. Essentially, there is no definite boundary for QFD's potential fields of applications. Now it is hardly to find an industry to which QFD has not yet been applied (Chan and Wu, 2002).

Chan and Wu (2002) described the references in sectors such as telecommunications, transport, services, electronics and construction as shown in Figure 2.1. However, the proportion of manufacturing to construction documents was 10 to 1 (Chan and Wu, 2002).

2.3.4 QFD Phases

Cohen (1995) named the four phases of QFD as product planning, part deployment, process planning and production planning.

Cristiano et al. (2000) conducted a survey that compare between QFD phases in U.S and Japan companies as shown in Figure 2.2.

Figure 2.3 illustrates the 4-phase model of QFD, which is accomplished by using a series of matrices (Chan and Wu, 2002).

Table 2.1: History of QFD [The Researcher].

Year	Japan	U.S.A
1966	Basic concept	---------------
1972	First application	---------------
1975	QFD introduction to Toyota	---------------
1978	First QFD book	---------------
1981	First service application	---------------
1983	---------------	Basic concept
1984	Application of QFD to software industries	---------------
1986	---------------	First reported case study
1987	First service Deming prize	First QFD book
1988	---------------	QFD's popularity increase
1989	First QFD symposium	First QFD symposium
1993	---------------	QFD institute
1996	Akao's first QFD prize	Akao's first QFD prize

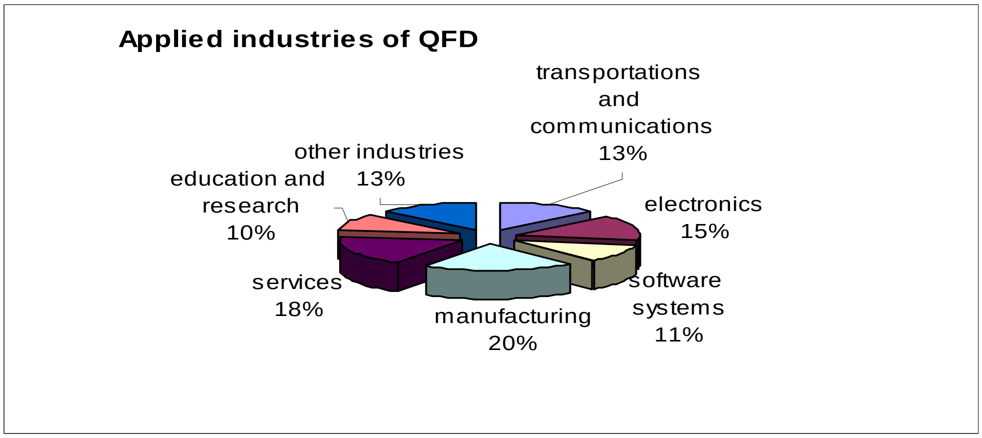

Fig. 2.1: Percentage of Publications in Functional Fields of QFD [Chan and Wu, 2002].

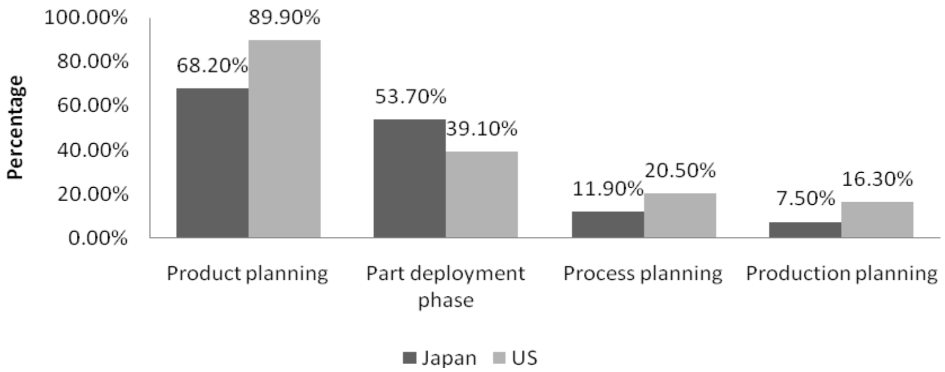

Fig. 2.2: Advanced Phases of QFD Used in Japan and U.S.A [Cristiano et al., 2000].

2.3.4.1 Product Planning

During the product planning phase a matrix called House of Quality (HOQ) is made. It is created by a multidisciplinary team who translate a set of customer requirements that are drawn upon market research and benchmarking data, into engineering targets to be met by a new product or service design (Kivinen, 2008).

2.3.4.2 Part Deployment

This phase is led by the engineering department and translates important technical measures into part characteristics. It requires creativity and innovative team ideas. Product concepts are created during this phase and part specifications are documented. Parts that are considered to be most important to meet customer needs are deployed into the next phase (Kivinen, 2008).

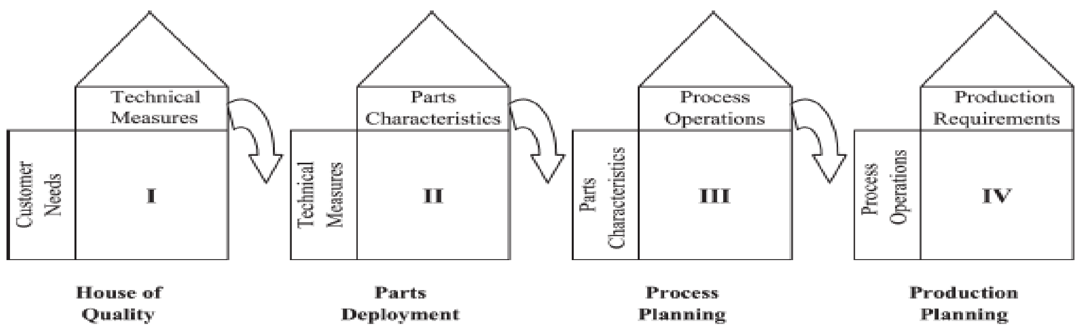

Fig. 2.3: Four-Phase Model of QFD [Chan and Wu, 2002].

2.3.4.3 Process Planning

Process planning is led by manufacturing engineering. In this phase, the important technical measures are translated into parts characteristics. During process planning phase, flowcharts of the manufacturing processes are constructed and process parameters are documented (Kivinen, 2008).

2.3.4.4 Production Planning

Production planning phase is led by quality assurance and manufacturing departments. At this phase, the key process operations are translated into day-to-day production requirements. To monitor the production process, maintenance schedules, and skills training for operators, performance indicators are created (Kivinen, 2008).

2.3.5 Fuzzy Quality Function Deployment

Combining QFD with other techniques gives a credit to the use of QFD as a systematic mechanism that is helpful in increasing the return on investments on quality improvement. Because of the flexibility of QFD, it has been combined with other techniques and tools to develop its abilities. It should be borne in mind that QFD should not be used in isolation, but should be an integral part of the continuous improvement process. Various quantitative methods have been suggested to be used in QFD to improve its reliability and objectiveness, such as fuzzy logic.

The application of fuzzy reasoning techniques provides a systematic tool to deal with qualitative and quantitative data in the construction process (Zeng et al., 2007).

The fuzzy set theory is widely applied to solve real life problems that are subjective, vague and imprecise in nature (Yang et al, 2003).

Fuzzy logic and fuzzy sets were introduced in 1965 by Professor Zadeh. Fuzzy logic uses human linguistics (word or sentences) understanding to express the knowledge of a system. Linguistic variables are characterized by ambiguity and multiplicity of meaning. Specifying good linguistic variables depends on the knowledge of the expert. For example age" is a linguistic variable if its values are "young", "not so young", "old", and "very old". In fuzzy logic theory, a linguistic variable can be a member of more than one group (Zaim and Sevkli, 2002).

Examples of the applications include fuzzy inference-based QFD to determine design targets, fuzzy logic-based extension to QFD, fuzzy logic based simplification of QFD, fuzzy method for prioritizing (HOWS) in QFD, fuzzy multi-criteria methods for QFD, fuzzy QFD framework, fuzzy QFD mechanism for assessing system reliability, and many other applications (Chan and Wu, 2002).

Khoo and Ho (1996) provided a fuzzy QFD framework (which is generally more representative than traditional crisp approach of using simple numbers) to perform QFD analysis using symmetrical triangular fuzzy numbers TFNs. Also, Chan et al. (1999) used TFNs to analyze the voice of the customer. So, it means that the crisp variables are expressed as fuzzy numbers (Wang, 1999).

Chan and Wu (2005) present a systematic and operational approach to HOQ. Firstly, obtaining a comprehensive description of the relevant elements in HOQ. Then proposing a 9-steps HOQ model to unify the HOQ process and a few 9-points scales to unify the measurements in HOQ to avoid arbitrariness and incomparability. The authors address the various voices in the HOQ process and suggest the use of symmetrical triangular fuzzy numbers to reflect the vagueness in people's linguistic assessments. So, a fried Chinese vegetable was an example that involves 10 customer needs, 9 technical measures. Two difficult parts omitted from the model, especially the correlation matrices and possible approaches were also suggested to deal with them in a potentially more complete HOQ model.

2.3.6 FQFD in Construction

There are some of FQFD applications in the construction industry as follows:

Yang et al. (2003) presented a FQFD system for buildable designs based on the mechanisms of conventional QFD methodology and fuzzy set theory. This system provides a quantitative method and advances the conventional QFD methodology for early buildability evaluation in 3 aspects: (i) HOQ is considered to support the integrated evaluations of buildable designs through adapting matrices of conventional HOQ, (ii) triangular fuzzy numbers are used to intuitively represent the linguistic nature of decisions of buildable designs and (iii) fuzzy inference mechanism is established to process the design-relevant HOQ data. An example is presented to illustrate the system, which provides a viable decision-making method for quantitative buildability evaluation at the early design phase.

Zeng et al. (2007) presented a new assessment methodology for construction project risk analysis to deal with risks associated with the construction projects in the complicated situations. The application of fuzzy reasoning techniques provides an effective tool to handle the uncertainties and subjectivities arising in the construction process. An illustrative example on risk analysis of steel erection in a shopping center is used to demonstrate the proposed methodology. Directly risk evaluation is an advantage of the proposed method.

Juan et al. (2009) proposed a hybrid approach combining QFD and fuzzy set theory to establish a housing refurbishment contractor selection model and to support the relation assessment for residents' refurbishment requirements and contractors' specifications. By using the fuzzy set theory, residents can select a satisfactory contractor even when they have indistinct needs and vague preferences. The results reveal that the proposed hybrid FQFD approach can be expected to be successful and has potential for handling multiple criteria decision-making problems.

2.3.6 FQFD Benefits

The benefits of using FQFD are:

● FQFD is a useful tool that can help a company move towards a more proactive product development (Chan and Wu, 2002).

● According to Kamara et al. (2000), FQFD encourages communication in the construction process, an important aspect to ensure project and business success.

● Customer satisfaction by: creates focus on customer requirements, uses competitive information effectively, prioritizes resources, identifies items that can be acted upon and structures resident experience (Fernandez et al., 1994).

● Reduces implementation time to perform quality features throughout product development (Gargione, 1999).

● FQFD delivers value to the final product: this leads to customer satisfaction. FQFD differs from traditional quality systems which aim at minimizing negative quality such as poor service, and broken product. Traditional systems gives you nothing wrong, which is no longer good enough (Hauser and Clausing, 1996; Kamara et al,1999).

● Promotes Teamwork (Griffin and Hauser, 1992).

● Decreases cost (Fortuna,1988).

2.3.7 FQFD Limitations

FQFD is not always easy to implement, particularly in large, complex systems (Harding et al., 2001).

Problems of FQFD can be categorized into three groups as: methodological problems, organizational problems and problems concerning product policy (Govers, 2001).

Martins and Aspinwall (2001) reported that there were problems in companies associated with working in teams, maintaining a commitment to the methodology and an unsuitable organizational.

In summary, critical problems and limitations of using the FQFD method include:

● Customers requirements can change quickly nowadays.

● Time consuming and difficult to manage when FQFD is too large-sized (Gargione, 1999).

● FQFD is a qualitative method, and due to the ambiguity in the voice of the customer, many of the answers are difficult to categorize as demands.

● FQFD is not appropriate for all applications. For example, in the automotive industry there are only a limited number of potential customers; the customer identifies their needs and the supplier acts to satisfy them (Bouchereau and Rowlands, 1999).

● Setting target values in the HOQ is imprecise and strengths between relationships are ill-defined (Bouchereau and Rowlands, 1999).

● It can be difficult to determine the connection between customer demands and technical properties. So some of the organizations do not extend the use of FQFD past the product planning stage.

● FQFD process depends on a series of processes, so a mistake occurred at the early stages might cause inaccuracy of the subsequent stages (Han, 2001).

2.4 FQFD and Vocational Facility Design

There are many studies on FQFD. However, a few studies focused on the vocational facilities design, but to the researcher knowledge there is no application that combines FQFD and vocational facilities design.

Ch 3

Methodology

This chapter includes the methodology used in this research and provides the information about the research design, research strategy, and population. Also, it highlights the questionnaire design, FQFD method and model development.

3.1 Research Strategy

Research strategy can be defined as the way in which the research objectives can be realized. There are two types of research strategies namely quantitative research and qualitative research. Quantitative research is objective in nature and objective measurement of problem, while qualitative research is subject in nature and seeks to gain insights and to understand peoples' perception of the world. In this research qualitative research is selected to gather factual data and to determine the important customer requirements and design requirements in the educational vocational facility (Naoum, 1998).

3.2 Research population

In this research, the population is the customers which includes all 19 students and 2 teachers of carpentry specialization in the industrial secondary school in Dair-Albalah.

3.3 Research Design

The term research design refers to the plan or organization of scientific investigation. Design of a research study involves the development of a plan that will guide the collection and analyses of data (Naoum, 1998).

In this research, interviews were conducted with the professionals in civil, architectural and mechanical engineering and the customers and a structured questionnaire was designed to gather data from the customers to prepare a new design of educational carpentry workshop using FQFD. Figure 3.1 summaries the methodology used in research.

3.3.1 Interviews

For data completion, interviews were conducted to get the customers' requirements, design requirements, target value of the design requirements and the relationship between the customers' requirements and the design requirements in educational carpentry workshop.

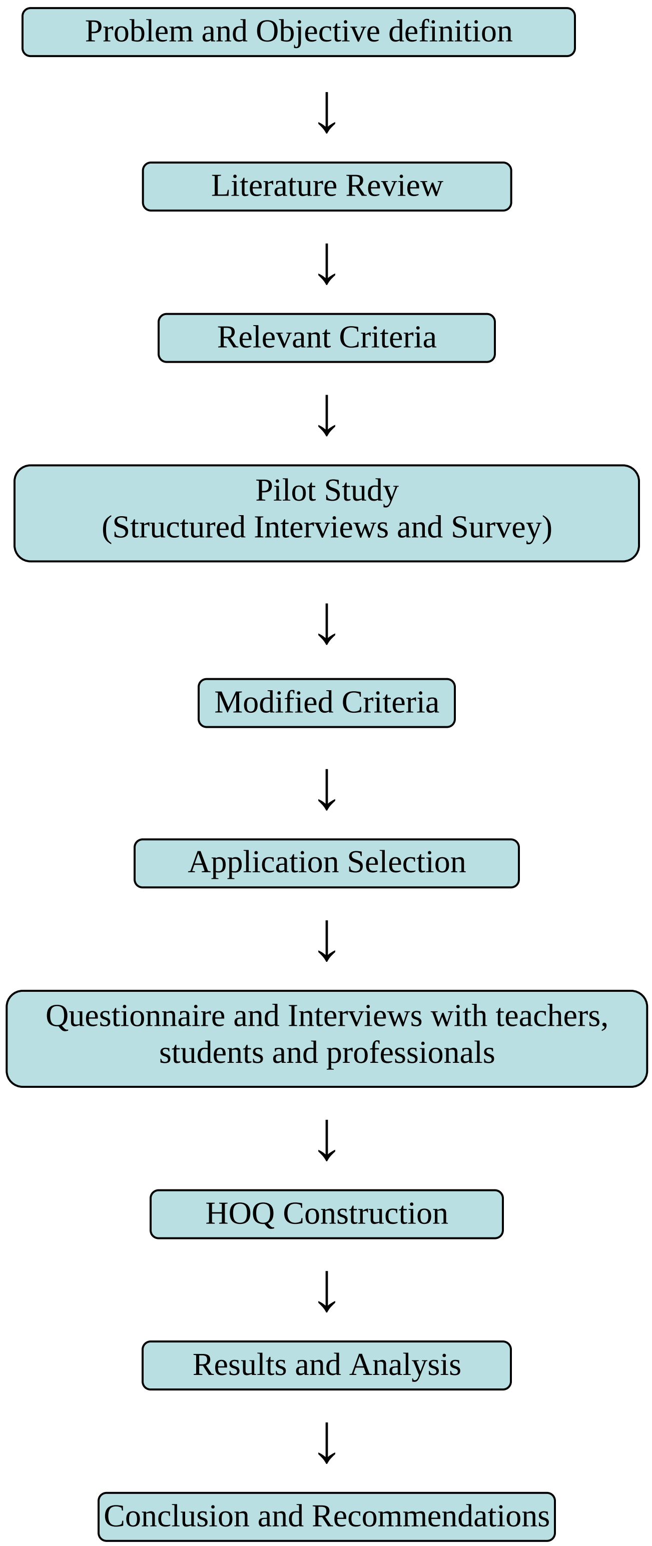

Figure 3.1: The Methodology Used in Research.

3.3.2 Questionnaire Design

A closed-ended questionnaire was used for its advantages such as: it is easy to ask and quick to answer, they require no writing by either respondent or interviewer, and their analysis is straight forward (Naoum, 1998).

Customer requirements in this questionnaire were selected from the literature review, interviews with the professionals in civil, architectural and mechanic engineering and the customers. The customers were asked to rate this requirements on likert scale 1 to 5 where (5"very important", 4 " important", 3 "moderate", 2 "unimportant", 1 "very unimportant"). The composition of the questionnaire is described in details in Arabic language and translated into English language (Appendix B).

3.3.3 Questionnaire Piloting

This section presents the steps used to examine the validity and reliability of the questionnaire.

3.3.3.1 Questionnaire Validity

Testing the questionnaire validity was performed statistically using the criterion-related validity test (Pearson test). The internal consistency of the questionnaire was measured using a scouting sample of sixteen questionnaires. It measured the correlation coefficients between each paragraph in one field and all the filed. Table 3.1 shows the correlation coefficient and p-value for each field paragraph.

Table 3.1: Pearson Coefficient between each Paragraph in Field and Whole Fields.

	Item	Pearson correlation coefficient	P-value	Significance
1	Fresh Air	0.420	0.051	*
2	No Dead Viewing Area	0.365	0.051	*
3	Noiseless	0.599	0.007	**
4	Temperature Controlled Year Round	0.663	0.003	**
5	No Accidents and Incidents	0.404	0.050	*
6	Clearly See the Visual Information	0.609	0.006	**
7	Easy and Quick Access to Tools	0.30	0.012	*
8	Comfortable Seats	0.461	0.036	*
9	Appropriate Space for Practical Applications Like: Enough Area and Equipments.	0.158	0.028	*
10	Appropriate Space for Cleaning Like: Enough Area and Availability of Hot and Cold Water	0.666	0.002	**
11	Appropriate Space for Painting Process Like: Enough Area, Equipments and Furniture	0.83	0.000	**

* Correlation is significant at the 0.05 level.
** Correlation is significant at the 0.01 level.

From Table 3.1, it can be seen that the p-values for each paragraph are less than 0.05 or 0.01, so the correlation coefficients of this field are significant at $\alpha = 0.01$ or $\alpha = 0.05$. So, it can be said that the paragraphs of this field are consistent and valid to measure what they were set for.

3.3.3.1 Questionnaire Reliability

The reliability test was repeated to the same sample used in validity test on two occasions. The scores obtained were compared by computing a reliability coefficient.

Two tests were performed on the sample the half split method and Cronbach's coefficient alpha. The results of these tests were as follows:

i- Half Split Method: The Pearson correlation coefficient between the means of odd questions and even questions of each field of the questionnaire was calculated. Then, it was corrected using Spearman Brown correlation coefficient of correction. The corrected correlation coefficient (consistency coefficient) is computed according to the following equation:

Corrected correlation coefficient = 2r/(r+1)

Where, r the Pearson correlation coefficient which equals 0.9471.

The normal range of corrected correlation coefficient is between 0.0 and + 1.0. The corrected correlation coefficients value equals 0.9728 and the significant (α) equal 0.000 which is less than 0.05 so the corrected correlation coefficients are significant at $\alpha = 0.05$. It can be said that according to the Half Split method that the questionnaire is reliable.

ii- Cronbach's Coefficient Alpha: This method was used to measure the reliability of the questionnaire between each field and the mean of all fields of the questionnaire. The normal range of Cronbach's coefficient alpha value is between 0.0 and + 1.0, and the higher values reflect a higher degree of internal consistency. The Cronbach's coefficient alpha equals 0.6944. Therefore, Cronbach's coefficient result ensures the reliability of the questionnaire.

3.3.4 FQFD Implementation

In FQFD process, the implementation of a number of management tools is systematically coordinated. These tools are the part of FQFD process. FQFD process provides a series of structured steps in which theses tools are utilized effectively to guarantee customers' satisfaction with the end product. The following describe these tools (Hauser and Clausing, 1989).

3.3.4.1 FQFD Team

Effective application of FQFD hinges on forming the proper implementation team and employing the FQFD tools (Sullivan 1986; King 1987; Cohen 1995). In this research, the team consists of the researcher and her supervisors. The first task for the FQFD implementation team is identification of all customers' needs. Then, the team uses a number of FQFD tools to translate the customers' needs to measurable engineering characteristics. Proper deployment of the implementation team encompasses three phases:

i-Conceptualizing the subject issue by focusing on developing a comprehensive definition of the purpose of the study which is design of a carpentry workshop for education by using FQFD.

ii-Collecting the necessary by:

- Selection of the focus groups' participants which consist of the professionals in civil, architectural and mechanic engineering and the customers.
- Conduction of the focus groups' participants to collect accurate data by the interviews and the questionnaire.

iii-Analyzing and reporting the results of the data gathered by using the HOQ to record, prioritize, analyze, and translate the data collected from the focus groups' to measurable design parameters that ensure customer satisfaction.

3.3.4.2 FQFD Tools

Tools such as affinity diagram and the house of quality are used to understand the voice of the customer and to forecast the expected success of the end product. (Bossert, 1991). Theses tools are briefly described below:

3.3.4.2.1 Affinity Diagram

The affinity diagram is a tool used to organize the data collected from the focus groups (Cohen 1988).

The data collected in this research were arranged as a set of unstructured ideas in an overall hierarchical structure. Table 3.2 shows the customer requirements of educational carpentry workshop as an example of affinity diagrams.

Table 3.2: Affinity Diagrams of the Customer Requirements of Carpentry Workshop.

Customer Requirement	Detailed Requirement
Fresh air	Environment
No dead viewing area	
Noiseless	
Temperature controlled year around	
No accidents and incidents	Safety
Clearly see the visual information and take notes	Furniture
Easy and quick access to tools	
Comfortable seats	
Appropriate space for practical application	Size
Appropriate space for cleaning	
Appropriate space for painting process	

3.3.4.2.2 House of Quality (HOQ)

The primary tool of FQFD is the house of quality which is a useful tool for arranging facts (Hauser and Clausing 1989). Figure 3.2 illustrates the elements of the HOQ (Erdogan, 2003). Chan and Wu (2005) reported that a house of quality contains the following six steps:

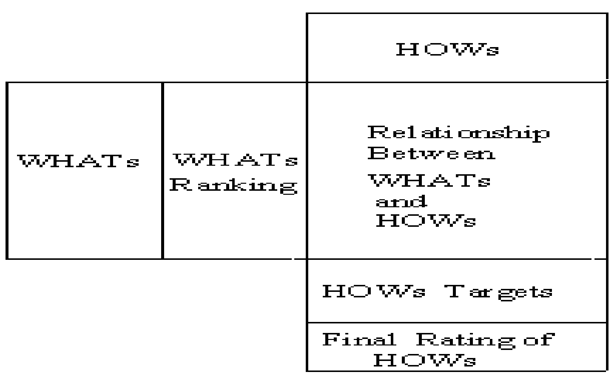

Figure 3.2: HOQ Elements [Erdogan, 2003].

i- Customer Requirements (WHATs)

FQFD starts with the customers (Griffin and Hauser, 1992).

After the collection of all customer requirements, similar requirements are grouped into categories and written into affinity diagram.

ii- Customer Importance Weight

In order to reveal the importance weight of the customer requirements and identify it. Customers are asked to give the importance ratings for each WHAT using five point scales as in Appendix B.

iii- Design Requirements (HOWs)

The design requirements (HOWs) identified by FQFD team from literature review, customer requirements and interviews with the professionals in civil, architectural and mechanical engineering.

iv- Relationship Matrix Between WHATs and HOWs

In this research, (S) is for strong relationship, (M) is for moderate relationship and (W) is for weak relationship.

v- Target Values for HOWs

Target values represent "How Much" for design requirements. At this step, the target value for each design requirement was established from literature review and interviews with customers.

vi- Individual Rating of Design Requirements

Finally, the individual rating of design requirements of educational carpentry workshop were calculated by using the following equation:

$$\text{Individual rating} = \sum_{j}^{n} A_{ij} * X_j$$

Where A_{ij} is a symmetrical triangular fuzzy number (TFN) as illustrated in Table 4.9.

Where X_j is ranges of importance weight.

3.3.5 Model Development

A model has been developed to identify the main design requirements of the educational carpentry workshop to be used as a tool in the designing process of the construction projects in Gaza Strip.

To develop the model, the following steps were used:

1- Determination of the relative weight of design requirements of all design goals using many methods.
2- Calculation of the relative weights of the all determined design goals.

3- Formulating and solving the zero–one goal programming model to identify the main design requirements.

The formula of the model is as follows:

$$Min \quad (W_i\ d_{1n}) + (\sum W_i\ (d_{in} + d_{ip})) + (\sum W_i\ d_{in}) \qquad (1)$$

S.t

$$\sum W_j X_j + d_{1n} - d_{1p} = 1 \qquad (2)$$

$$\sum r_{ij}\ X_j + d_{in} - d_{ip} = 1 \qquad (3)$$

$$\sum W_{ij} + d_{in} - d_{ip} = 1 \qquad (4)$$

$X_j > 0$

j=1,……..,n

where,

w_i: weight of goal i

d_in, d_ip: negative and positive deviation variables of the ith goals

X_j: binary selection variable representation with ith amount of the ith resource used by the jth design requirements

w_{ij}: preference rating of the jth design requirements with respect to the metric i (Karsak et al., 2002).

Chapter 4

Results and Analysis

This chapter presents the results, analysis of data and the proposed design of an educational carpentry workshop that meets customer requirements through the implementation of FQFD and the model development.

4.1 Implementation of FQFD

This section presents the implementation of FQFD through the use of HOQ. The HOQ consists of six steps that are presented in detail in the next section.

Step1: Customer Requirements

After reviewing literature, the design requirements of an educational carpentry workshop were set out. Some of these requirements satisfy one or more of customer requirements. On the other hand, the rest of requirements were based on data collected from the teachers and students using interviews. Table 4.1 shows the final customer requirements for an educational carpentry workshop.

Table 4.1: Customer Requirements for the Educational Carpentry Workshop.

Customer Requirements	**Detailed Customer Requirements**
Environment	Fresh Air
	No Dead Viewing Area
	Noiseless
	Temperature Controlled Year Round
Safety	No Accidents and Incidents
Furniture	Clearly See the Visual Information and Take Notes
	Easy and Quick Access to Tools
	Comfortable Seats
Size	Appropriate Space for Practical Applications Like: Enough Area, Equipments and Furniture
	Appropriate Space for Cleaning Like: Enough Area and Availability of Hot and Cold Water
	Appropriate Space for Painting Process Like: Enough Area, Equipments and Furniture

Step 2: Customer Importance Weights

Educational carpentry workshop teachers and students were asked to specify the importance of their requirements as "very unimportant", "unimportant", "moderately important", "important", and "very important". Where "very unimportant" has 1 as a score, while "very important" has 5 as a score. Then, the total score that each requirement was calculated by multiplying the number of times score was repeated by the score value. After that, this total score was divided by the total number of customers to obtain the relative importance (RI). The relative importance index (RII) was calculated to determine the ranks of the listed customers' requirements using the following expression:

Relative importance index = $\sum w/A$, $(0 \leq index \leq 1)$ (Iyer and Jha, 2005)

where $\sum w$ = the relative importance of each requirements

A = the highest weight (A = 5 in this research)

The relative importance and the relative importance indexes of the customer requirements were obtained using SPSS (Decoursey, 2003). Table 4.2 shows the relative importance and the relative importance indexes of the requirements from the viewpoint of teachers and Table 4.3 shows the relative importance and the relative importance indexes of the requirements from the viewpoint of students.

Table 4.2: Relative Importance and Relative Importance Indexes of Educational Carpentry Workshop Requirements from Teachers' Point of View.

Customer Requirements	RI	RII
No Dead Viewing Area	5	1
Clearly See the Visual Information and Take Notes	5	1
Clearly See the Visual Information and Take Notes	5	1
Fresh Air	5	1
Easy and Quick Access to Tools	5	1
Appropriate Space for Practical Applications Like: Enough Area, Equipments and Furniture	5	1
Appropriate Space for Painting Process Like: Enough Area, Equipments and Furniture	5	1
Comfortable Seats	4	0.8
Appropriate Space for Cleaning Like: Enough Area and Availability of Hot and Cold Water	4	0.8
Temperature Controlled Year Round	4	0.8
Noiseless	3.5	0.7

Table 4.3: Relative Importance and Relative Importance Indexes of Educational Carpentry Workshop Requirements from Students' Point of View.

Customer Requirements	RI	RII
No Dead Viewing Area	4.84	0.968
Clearly See the Visual Information and Take Notes	4.74	0.947
Appropriate Space for Cleaning Like: Enough Area and Availability of Hot and Cold Water	4.74	0.947
Comfortable Seats	4.68	0.937
Fresh Air	4.63	0.926
No Accidents and Incidents	4.63	0.926
Easy and Quick Access to Tools	4.53	0.905
Appropriate Space for Practical Applications Like: Enough Area, Equipments and Furniture	4.53	0.905
Appropriate Space for Painting Process Like: Enough Area, Equipments and Furniture	4.32	0.863
Temperature Controlled Year Round	3.84	0.768
Noiseless	3.63	0.726

It has been noticed that, the RII for both teachers and students were nearly the same as shown in Table 4.2 and 4.3. The customer requirement with highest score was " No Dead Viewing Area" because the customers need intense light in the educational carpentry workshop.

"Noiseless" was the customer requirement with lowest score from students and teachers point of view because they do not care about noise or they be accustomed to it in the carpentry workshop.

Thus, the average of students RII and teachers RII was calculated from:

(students RII + teachers RII) / 2. Then, the importance weight of each customer requirements was determined from the expression:

Importance weight = average (RII / $\sum$ RII) * 100%.

Average RII and importance weight for customer requirements are shown in Table 4.4.

Table 4.12 shows the final relative importance indexes of customer requirements.

Step 3: Design Requirements

Based on literature, each design requirement satisfies at least one of the customer requirements as shown in Table 4.5.

Table 4.4: Average RII and Importance Weight for Customer Requirements of Educational Carpentry Workshop.

Customer Requirements	Average RII	Importance Weight%
No Dead Viewing Area	0.984	9.88
Clearly See the Visual Information and Take Notes	0.974	9.78
Fresh Air	0.963	9.67
No Accidents and Incidents	0.963	9.67
Easy and Quick Access to Tools	0.953	9.57
Appropriate Space for Practical Applications Like: Enough Area, Equipments and Furniture	0.953	9.57
Appropriate Space for Painting Process Like: Enough Area, Equipments and Furniture	0.932	9.36
Appropriate Space for Cleaning Like: Enough Area and Availability of Hot and Cold Water	0.874	8.77
Comfortable Seats	0.869	8.72
Temperature Controlled Year Round	0.784	7.87
Noiseless	0.713	7.16

Table 4.5: Design Requirement for a Carpentry Workshop

<table>
<tr><th>Customer Requirements</th><th>First Level Design Requirement</th><th>Second Level Design Requirement</th><th>Third Level Design Requirement</th><th>Fourth Level Design Requirement</th></tr>
<tr><td>No Dead Viewing Area</td><td rowspan="8">Natural Lighting and Natural Ventilation</td><td>Workshop Orientation</td><td>———</td><td>———</td></tr>
<tr><td>Clearly See the Visual Information and Take Notes</td><td rowspan="2">Roof</td><td>Height</td><td>———</td></tr>
<tr><td>Appropriate Space for Painting Process Like: Enough Area, Equipments and Furniture</td><td>Type</td><td>———</td></tr>
<tr><td>No Accidents and Incidents</td><td rowspan="5">Openings</td><td rowspan="3">Windows</td><td>Type</td></tr>
<tr><td>Temperature Controlled Year Round</td><td>Distance from the floor</td></tr>
<tr><td>Noiseless</td><td>Dimensions</td></tr>
<tr><td>Fresh Air</td><td rowspan="2">Doors</td><td>Entrance and Exit Door Dimensions</td></tr>
<tr><td>Appropriate Space for Practical Applications Like:</td><td>Materials Supply Door Dimensions</td></tr>
</table>

Table 4.5: Continued

Customer Requirements	First Level	Second Level	Third Level	Fourth Level
Enough Area, Equipments and Furniture				Emergency Door Dimensions
Appropriate Space for Painting Process Like: Enough Area, Equipments and Furniture	Artificial Ventilation	Exhaust Fans	Number	—
Fresh Air				
No Dead Viewing Area	Artificial Lighting	Lamps	Type	—
Clearly See the Visual Information and Take Notes				
Appropriate Space for Practical Applications Like: Enough Area, Equipments and Furniture				
Appropriate Space for Painting Process Like: Enough Area, Equipments and Furniture				
Appropriate Space for Cleaning Like: Enough Area and Availability of Hot and Cold Water				
No Dead Viewing Area	Floor	Type	—	—
Noiseless				
Comfortable Seats				
No Accidents and Incidents				
Easy and Quick Access to Tools				
Appropriate Space for Practical Applications Like: Enough Area, Equipments and Furniture				
Appropriate Space for Painting Process Like: Enough Area, Equipments and Furniture				
Comfortable Seats	Furniture	Closets in Equipment Room	Number	—
		Lockers in Cleaning Space	Number	—
No Accidents and Incidents			Number	—

Table 4.5: Continued

Customer Requirements	First Level	Second Level	Third Level	Fourth Level
		Seats in Teaching Space	Type	———
Easy and Quick Access to Tools		Tables in Practical Space	Type	———
Appropriate Space for Practical Applications Like: Enough Area, Equipments and Furniture		Board in Teaching Space	Dimensions	———
			Type	———
Clearly See the Visual Information and Take Notes			Distance from the floor	———
		(LCD+ Computer) in Teaching Space	———	———
No Accidents and Incidents	Safety	Equipments for Safety	Type	———
		Fire Alarm System	———	———
		Fire Extinguishers	Number	———
		First Aid Kit	———	———
No Dead Viewing Area	Walls	Finishing	Type	———
Appropriate Space for Painting Process Like: Enough Area, Equipments and Furniture				
Appropriate Space for Practical Applications Like: Enough Area, Equipments and Furniture				
No Accidents and Incidents		Insulation	———	———
Temperature Controlled Year Round				
Noiseless				
No Accidents and Incidents	Electrical Outlets	Number	———	———
Appropriate Space for Painting Process Like: Enough Area, Equipments and Furniture				
Appropriate Space for Practical Applications Like:				

Table 4.5: Continued

Customer Requirements	First Level	Second Level	Third Level	Fourth Level
Enough Area, Equipments and Furniture				
Appropriate Space for Cleaning Like: Enough Area and Availability of Hot and Cold Water				
No Dead Viewing Area	Spaces	Teachers room	Area	———
Clearly See the Visual Information and Take Notes		Equipment Room	Area	———
Fresh Air		Teaching Space	Area	———
No Accidents and Incidents		Practical Space	Area	———
Easy and Quick Access to Tools		Clean up Room	Area	———
Appropriate Space for Practical Applications Like: Enough Area, Equipments and Furniture			Sanitary Services	Cold Water
Appropriate Space for Painting Process Like: Enough Area, Equipments and Furniture				Hot Water
Appropriate Space for Cleaning Like: Enough Area and Availability of Hot and Cold Water				Sinks
Temperature Controlled Year Round				Showers
		Painting Room	Area	———

It is clear from Table 4.5 that the number of lamps that is fixed in the carpentry workshop depends on their types. Also, carpentry workshop floor should be very strong. Further, tables in carpentry workshop should be furnished with all carpentry requirements. Additionally, type of wall finishing should be appropriate for carpentry workshop. Plus, the number of electrical outlets should be enough in the carpentry workshop. The other carpentry workshop design requirements are illustrated in Table 4.12.

Step 4: Relationship Matrix:

The strength of the relationships between customer requirements and design requirements by using a scale of fuzzy variables: strong, medium, and weak as shown in Table 4.6 (Zaim and Sevkli, 2002).

Table 4.6: Relationships between Customer Requirements and Design Requirements.

Customer Requirement	Design Requirement	Grade
Fresh Air	Workshop Orientation	S
	Roof Height	M
	Roof Type	W
	Windows Type	S
	Windows Distance from the Floor	S
	Windows Dimensions	S
	Entrance and Exit Door Dimensions	S
	Materials Supply Door Dimensions	W
	Emergency Door Dimensions	W
	Number of Exhaust fans	S
	Teaching Space Area	M
	Practical Space Area	M
No Dead Viewing Area	Workshop Orientation	S
	Roof Height	M
	Roof Type	S
	Windows Type	S
	Windows Distance from the Floor	S
	Windows Dimensions	S
	Entrance and Exit Door Dimensions	W
	Materials Supply Door Dimensions	W
	Emergency Door Dimensions	W
	Lamps Type	S
	Floor Type	M
	Walls Finishing Type	S
	Teachers room Area	S
	Equipment Room Area	S
	Teaching Space Area	S
	Practical Space Area	S
	Clean up Room Area	S
	Painting Room Area	S
Noiseless	Roof Height	S
	Roof Type	S
	Windows Type	S
	Windows Distance from the Floor	S
	Windows Dimensions	S

Table 4.6: Continued

Customer Requirement	Design Requirement	Grade
	Entrance and Exit Door Dimensions	S
	Materials Supply Door Dimensions	S
	Emergency Door Dimensions	S
	Floor Type	M
	Walls Finishing Type	S
	Walls Insulation	S
Temperature Controlled Year Round	Workshop Orientation	M
	Roof Height	M
	Roof Type	M
	Windows Type	S
	Windows Distance from the Floor	S
	Windows Dimensions	S
	Entrance and Exit Door Dimensions	W
	Materials Supply Door Dimensions	W
	Emergency Door Dimensions	W
	Walls Finishing Type	S
	Teaching Space Area	M
	Practical Space Area	M
No Accidents and Incidents	Roof Height	S
	Roof Type	S
	Windows Type	M
	Windows Distance from the Floor	M
	Windows Dimensions	M
	Entrance and Exit Door Dimensions	M
	Materials Supply Door Dimensions	M
	Emergency Door Dimensions	S
	Floor Type	S
	Type of Seats	S
	Tables Type	S
	Safety Equipments Types	M
	Fire Alarm System	S
	Fire Extinguishers Number	S
	First Aid Kit	S
	Wall Finishing Type	M
	Electrical Outlets Number	M
	Lockers Number	S
	Practical Space Area	M
Clearly See the Visual Information	Workshop Orientation	S
	Roof Height	M
	Windows Type	M
	Windows Distance from the Floor	S
	Windows Dimensions	M
	Lamps Type	S
	Number of Seats	S
	Seats Type	S

Table 4.6: Continued

Customer Requirement	Design Requirement	Grade
	Board Dimension	S
	Board Type	S
	Board Distance from the Floor	S
	(Computer +LCD)	M
	Teaching Space Area	S
Easy and Quick Access to Tools	Floor Type	S
	Closet Number	S
	Equipment Room Area	S
Comfortable Seats	Floor Type	S
	Number of Seats	S
	Seats Type	S
Appropriate Space for Practical Application	Roof Height	S
	Roof Type	M
	Windows Type	M
	Windows Distance from the floor	M
	Windows Dimensions	M
	Lamps Type	S
	Floor Type	S
	Tables Type	S
	Wall Finishing Type	M
	Electrical Connections Number	S
	Practical Space Area	S
Appropriate Space for Cleaning	Lamps Type	S
	Electrical Outlets Number	S
	Clean-Up Room Area	S
	Cold Water	S
	Hot Water	S
	Sinks Number	S
	Shower Numbers	S
Appropriate Space for Painting Process	Workshop Orientation	S
	Roof Height	M
	Roof Type	M
	Windows Type	S
	Windows Distance from the Floor	S
	Windows Dimensions	S
	Number of Exhaust Fans	S
	Lamps Type	S
	Floor Type	S
	Wall Finishing Type	S
	Electrical Outlets Number	S
	Painting Room Area	S

It is clear from table 4.6, the customer requirement " No Accidents and Incidents " of the educational carpentry workshop is affected by practical space area. When the practical space area is enough for practical application, the accidents and incidents will decrease. So, this relation was assigned a grade "M" to indicate this medium relationship. Also, the customer requirement " No Accidents and Incidents " is affected by the tables' type. Whenever the working tables equipped with all carpentry needs, the accidents and incidents will decrease. Since the working tables type is important for carpentry works, so this relation was assigned a grade "S" to indicate this strong relationship. The grade for the design requirements is illustrated in Table 4.12.

Step 5: Target Values for Design Requirements

Based on results from interviews with experts, teachers and students, the target values of design requirements were determined as shown in Table 4.7.

Table 4.7: Target Values for Educational Carpentry Workshop Design Requirements.

Design Requirements	Target Values
Workshop Orientation	South
Roof Height (m)	5
Roof Type	Trusses
Windows Type	Sliding
Windows Distance from the Floor (m)	1.2
Windows Dimensions (W*H) (m^2)	1.2*2.0
Dimensions of Door for Entrance and Exit (W*H) (m*m)	2*2.5
Dimensions of Door for Materials Supply (W*H) (m^2)	4*2.5
Dimensions of Emergency Door (W*H) (m^2)	1.5*2.5
Number of Exhaust Fans with 2 Horsepower	13
Type of Lamps	Fluorescent
Type of Floor	Concrete with Hardener
Number of Seats	20
Seats Type	Stool
Tables Type	Appropriate Work Tables
Board Dimensions (W*H) (m^2)	2*1.5
Board Type	Whiteboard
Board Distance from the Floor (m)	1.2
Electrical Outlets Number	30
Safety Equipments Types	Safety Glasses or Face Shield, Shop Apron, Cap, Gloves
Fire Alarm System	Available
Fire Extinguishers (Number)	3

Table 4.7: Continued

Design Requirements	Target Values
First Aid Kit	Available
Wall Finishing Type	Acrylic Paint on Plaster
Wall Insulation	Available
Teachers Room Area (m^2)	14
(Computer +LCD)	Available
Equipment Room Area (m^2)	8
Number of Closets with Dimensions (80*60cm^2)	4
Number of Lockers with Dimensions (60*40cm^2)	3
Teaching Space Area (m^2)	30
Practical Space Area (m^2)	150
Clean up Room Area (m^2)	30
Cold Water	Available
Hot Water	Available
Number of Sinks	3
Number of Showers	1
Painting Room Area (m^2)	21

As noticed from Table 4.7, the target value of wall finishing type for the educational carpentry workshop is acrylic paint on plaster. Also, windows dimensions target value in the carpentry workshop is 1.2 m width and 1.6 m height. Other design requirements target values are illustrated in Table 4.12.

Step 6: Individual Rating of Design Requirements

The ranges of importance weight were derived from calculated importance weight and pre-determined uncertainty value and it is considered as an importance weight with moving boundaries. The boundaries of the importance weight of the customer requirements are at 0.5 as a truth value for convenience (Kahraman et al., 2004).

For example the importance weight of the customer requirement "Fresh Air" was calculated and had a score of 9.67 in the traditional QFD approach, but in the FQFD approach the importance weight was calculated in the range of 9.17 to 10.17. Table 4.8 and Table 4.12 shows the ranges of the importance weight for the customer requirements for the educational carpentry workshop.

Then, the individual rating is calculated from the equation:

$$\text{Individual rating} = \sum_{j}^{n} A_{ij} * X_j$$

Where A_{ij} is a symmetrical triangular fuzzy number (TFN) as illustrated in Table 4.9.

Where X_j is ranges of importance weight.

Table 4.8: Rating of Importance Weight for Customer Requirements.

Customer Requirements	Rating	
	From	To
No Dead Viewing Area	9.38	10.38
Clearly See the Visual Information and Take Notes	9.28	10.28
Fresh Air	9.17	10.17
No Accidents and Incidents	9.17	10.17
Easy and Quick Access to Tools	9.07	10.07
Appropriate Space for Practical Applications Like: Enough Area, Equipments and Furniture	9.07	10.07
Appropriate Space for Painting Process Like: Enough Area, Equipments and Furniture	8.86	9.86
Appropriate Space for Cleaning Like: Enough Area and Availability of Hot and Cold Water	8.27	9.27
Comfortable Seats	8.22	9.22
Temperature Controlled Year Round	7.37	8.37
Noiseless	6.66	7.66

Table 4.9: Triangular Fuzzy Number.

Fuzzy Variables	Triangular Fuzzy Number (TFN)
Strong Relation (S)	(0.6-1)
Moderate Relation (M)	(0.3-0.7)
Weak Relation (W)	(0-0.4)

For example, the individual rating for the design requirement "roof type" was calculated as follows:

∑A*X=(0*9.17;0.4*10.17)+(0.6*9.38;1.0*10.38)+(0.6*6.66;1.0*7.66)+(0.3*7.37;0.7*8.37)+(0.6*9.17;1.0*10.17)+(0.3*9.07;0.7*10.07)+(0.3*8.86;0.7*9.86) = (22.7;52.1).

Also, the individual rating for the design requirement "practical space area" was calculated as follows:

∑A*X=(0.3*9.17;0.7*10.17)+(0.6*9.38;1.0*10.38)+(0.3*7.37;0.7*8.37)+(0.3*9.17;0.7*10.17)+(0.6*9.07;1.0*10.07) = (18.78;40.55).

Table 4.10 shows the individual rating for all design requirements in an educational carpentry workshop. Other design requirements individual rating is illustrated in Table 4.12.

Table 4.10: Individual Rating of Design Requirements for Educational Carpentry Workshop.

Design Requirements	Individual Rating	
	From	To
Windows Distance from the Floor	35.90	70.89
Windows Dimensions	33.12	67.80
Windows Type	33.12	67.80
Roof Type	28.16	62.24
Floor Type	31.45	62.02
Roof Height	22.72	52.09
Wall Finishing Type	24.83	50.44
Lamps Type	26.92	49.86
Workshop Orientation	24.23	46.55
Practical Space Area	18.78	40.55
Electrical Outlets Number	18.47	36.32
Teaching Space Area	16.16	33.64
Entrance and Exit Door Dimensions	12.25	32.45
Seats Type	16.00	29.67
Emergency Door Dimensions	9.50	29.40
Materials Supply Door Dimensions	6.75	26.35
Equipment Room Area	11.07	20.45
Tables Type	10.94	20.24
Painting Room Area	10.94	20.24
Exhaust Fans Number	10.82	20.03
Clean up Room Area	10.59	19.65
Number of Seats	105	19.5
Teachers Room Area	5.63	10.38
Board Type	5.57	10.28
Board Distance from Floor	5.57	10.28
Board Dimension	5.57	10.28
Fire Alarm System	5.50	10.17
Fire Extinguishers Number	5.50	10.17
First Aid Kit	5.50	10.17
Lockers Number	5.50	10.17
Closet Number	5.44	10.07
Cold Water	4.96	9.27
Hot Water	4.96	9.27
Number of Sinks	4.96	9.27
Number of Showers	4.96	9.27
Wall Insulation	3.40	7.66
(Computer +LCD)	2.78	7.20
Safety Equipments Types	2.75	7.12

The design requirements are organized in a descending order of priority and the cumulative percentage of design requirements is calculated to use the Pareto principle, which states that 20% of the design requirements achieve 80% of the importance percentage to find the critical design requirements of the educational carpentry workshop. Table 4.11 shows the cumulative percentage of design requirements in descending order.

Table 4.11: The Cumulative Percentage of Design Requirements in Descending Order.

Design Requirements	Cumulative	Cumulative Percentage
Safety Equipments Types	7.12	0.692
(Computer +LCD)	14.32	1.391
Wall Insulation	21.98	2.136
Cold Water	31.25	3.036
Hot Water	40.52	3.937
Number of Sinks	49.79	4.838
Number of Showers	59.06	5.738
Closet Number	69.13	6.717
Fire Alarm System	79.3	7.705
Fire Extinguishers Number	89.47	8.693
First Aid Kit	99.64	9.681
Lockers Number	109.81	10.67
Board Type	120.09	11.67
Board Distance from Floor	130.37	12.67
Board Dimension	140.65	13.67
Teachers Room Area	151.03	14.67
Number of Seats	170.53	16.57
Clean up Room Area	190.18	18.48
Exhaust Fans Number	210.21	20.42
Tables Type	230.45	22.39
Painting Room Area	250.69	24.36
Equipment Room Area	271.14	26.34
Materials Supply Door Dimensions	297.49	28.90
Emergency Door Dimensions	326.89	31.76
Seats Type	356.56	34.64
Entrance and Exit Door Dimensions	389.01	37.80
Teaching Space Area	422.65	41.07
Electrical Outlets Number	458.97	44.59
Practical Space Area	499.52	48.53
Workshop Orientation	546.07	53.06
Lamps Type	595.93	57.90
Wall Finishing Type	646.37	62.80
Roof Height	698.46	67.86

Table 4.11: Continued

Design Requirements	Cumulative	Cumulative Percentage
Floor Type	760.48	73.89
Roof Type	822.72	79.94
Windows Dimensions	890.52	**86.52**
Windows Type	958.32	**93.11**
Windows Distance from the Floor	1029.21	**100**

By knowing the cumulative percentage, the most important design requirements to satisfy customer requirements in the educational carpentry workshop were determined. The most critical design requirements which contributed to the success of the educational carpentry workshop design were: "windows distance from the floor"; "windows dimensions"; "windows type". So, the windows distance from the floor was determined to be the most important design requirements in the educational carpentry workshop design, because it has a maximum percentage and the highest score. The major output of analysis is the HOQ for the educational carpentry workshop shown in Table 4.12.

Table 4.12: HOQ for the Educational Carpentry Workshop.

Requirements	Detailed Requirements	Individual Rating	
		From	To
Environment	Fresh Air	9.17	10.17
	No Dead Viewing Area	9.38	10.38
	Noiseless	6.66	7.66
	Temperature Controlled Year Around	7.37	8.37
Safety	No Accidents and Incidents	9.17	10.17
Furniture	Clearly See the Visual Information	9.28	10.28
	Easy and Quick Access to Tools	9.07	10.07
	Comfortable Seats	8.22	9.22
Size	Appropriate Space for Practical Application	9.07	10.07
	Appropriate Space for Cleaning	8.27	9.27
	Appropriate Space for Painting Process	8.86	9.86
Target Values			
Normalized Individual Rating			To
			From

Table 4.12: Continued

Natural lighting and natural ventilation								
	Roof		Openings					
			Windows			Doors		
Workshop orientation	Type	Height (m)	Dimensions(W*H) (m^2)	Distance from floor(m)	Type	Exit and entrance door dimensions(W*H) (m^2)	Materials supply door dimensions(W*H) (m^2)	Emergency doors dimensions(W*H) (m^2)
S	W	M	S	S	S	S	W	W
S	S	M	S	S	S	W	W	W
	S	S	S	S	S	S	S	S
M	M	M	S	S	S	W	W	W
	S	S	M	M	M	M	M	S
S		M	M	S	M			
	M	S	M	M	M			
S	M	M	S	S	S			
South	Trusses	5	1.2*2.0	1.2	Sliding	2*2.5	4*2.5	1.5*2.5
46.55	52.09	62.24	**67.80**	**70.89**	**67.80**	32.45	26.35	29.40
24.23	22.72	28.16	**33.12**	**35.90**	**33.12**	12.25	6.75	9.50

Table 4.12: Continued

Artificial ventilation	Artificial lighting	Floor type	Furniture								
			Seats in teaching space		(Computer+ LCD) in teaching space	Number of closets in equipment room	Number of lockers in clean up room	Tables type in the practical space	Board in teaching space		
exhaust fans number	Lamps type		Number	Type					Dimension(W*H) (m^2)	Type	Distance from floor(cm)
S											
	S	M									
		M									
		S		S			S	S			
	S		S	S	M				S	S	S
		S				S					
		S	S	S							
	S	S						S			
	S										
S	S	S									
13	Fluorescent	Concrete with hardener	20	Stool	Available	4	3	Work Table Equipped with all carpentry needs	2*1.5	Whiteboard	120
20.03	49.86	62.02	19.5	29.67	7.20	10.07	10.17	20.24	10.28	10.28	10.28
10.818	26.92	31.45	10.5	16.00	2.78	5.44	5.50	10.94	5.57	5.57	5.57

Table 4.12: Continued

Safety				Walls			Spaces									
Safety equipments types	Fire alarm system	Fire extinguishers Number	First aid kit	Finishes type	Insulation	Electrical outlets number	Teachers room	Equipments room	Teaching space	Practical space	Clean up room					Painting room
							Area (m^2)	Area (m^2)	Area (m^2)	Area (m^2)	Area (m^2)	Sanitary services				Area (m^2)
												Cold water	Hot water	Number of sinks	Number of showers	
									M	M						
				S			S	S	S	S	S					S
				S	S											
				S					M	M						
M	S	S	S	M		M				M						
									S							
								S								
				M		S				S						
						S					S	S	S	S	S	
				S		S										S
Safety Glasses or Face Shield, Shop Apron, Cap, Gloves	Available	3	Available	Acrylic Paint on Plaster	Available	30	14	7	30	150	24	Available	Available	3	1	21
7.12	10.17	10.17	10.17	50.44	7.66	36.32	10.38	20.45	33.64	40.55	19.65	9.27	9.27	9.27	9.27	20.24
2.75	5.50	5.50	5.50	24.83	3.40	18.47	5.63	11.07	16.16	18.78	10.59	4.96	4.96	4.96	4.96	10.94

4.2 Educational Carpentry Workshop Design

After obtaining the final results of the main educational carpentry workshop design requirements, it was possible to prioritize and implement the proposed layout and proposed features in the specifications and design of the educational carpentry workshop. The three critical design requirements will be considered in the educational carpentry workshop design, because they will achieve the most customer requirements and will adjust many existing design problems. Figure 4.1 shows the proposed layouts of the educational carpentry workshop after using FQFD.

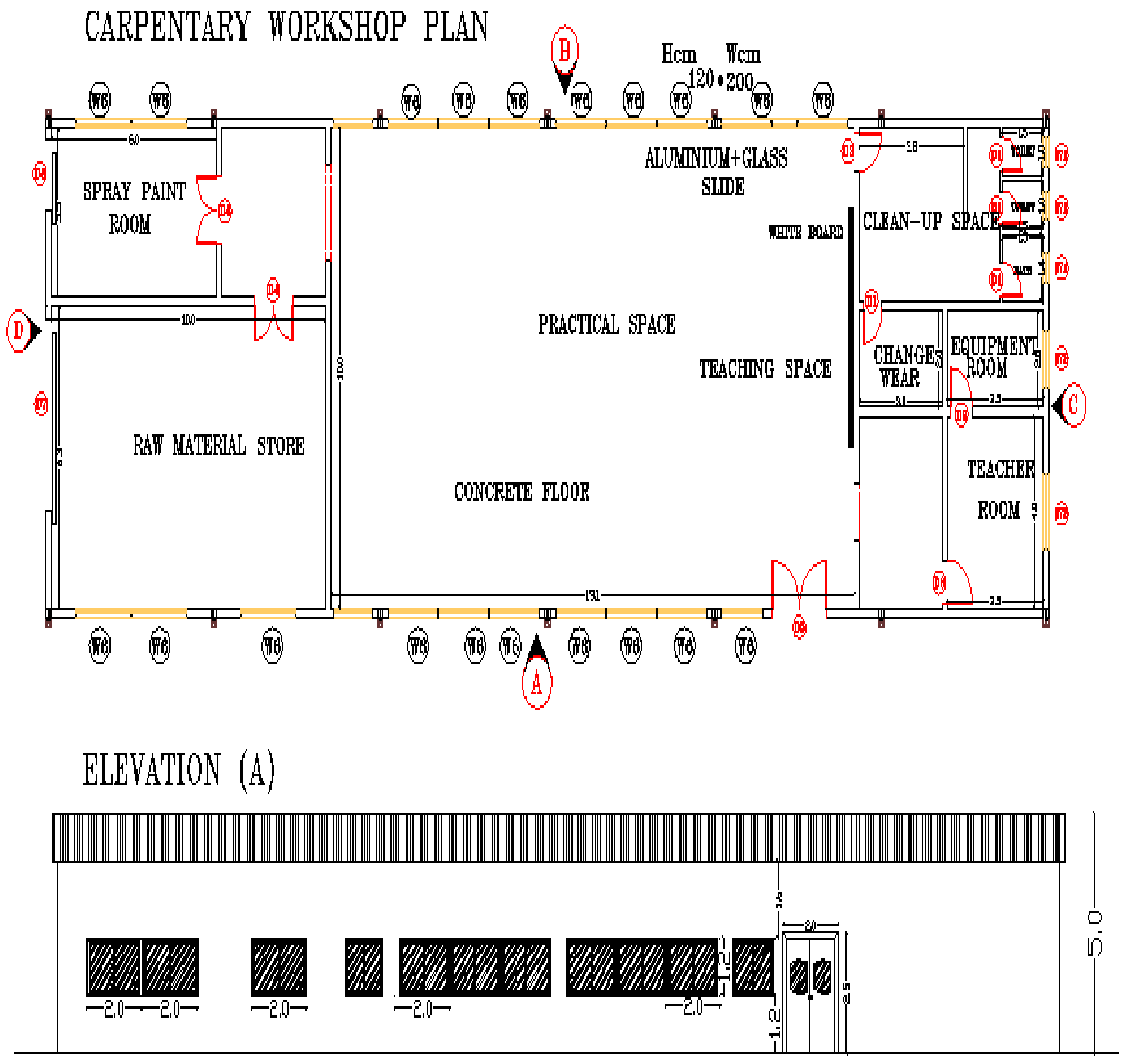

Figure 4.1: The Proposed Educational Carpentry Workshop Design Layout.

4.3 Comparison between Existing and Proposed Educational Carpentry Workshop Design

To compare the results of this research, the existing design of educational carpentry workshop in the industrial secondary school at Dair Al-Balah is studied. The existing design of this school was identified through field visits by the researcher. There are many problems in the existing design of educational carpentry workshop like:

1- Lack of tables, seats and tools as in Figure 4.2.

Fig. 4.2: Problem (1) in Existing Design.

2- Type of door for materials supply is hinged as in Figure 4.3.

Fig. 4.3: Problem (2) in Existing Design.

3- There are no windows and no exhaust fans in the painting room as in Figure 4.4.

Fig. 4.4: Problem (3) in Existing Design.

4- Windows are very high and their type is hinged as in Figure 4.5.

Fig. 4.5: Problem (4) in Existing Design.

5- No lockers for clothing as in Figure 4.6.

Fig. 4.6: Problem (5) in Existing Design.

6- Teacher room is small as in Figure 4.7.

Fig. 4.7: Problem (6) in Existing Design.

7- Few electrical outlets in the practical space as in Figure 4.8.

Fig. 4.8: Problem (7) in Existing Design.

8- Dimensions of the board are small and theoretical area is small as in Figure 4.9.

Fig. 4.9: Problem (8) in Existing Design.

9- No fire alarm system and absence of adequate safety equipments.

According to the results, it was necessary in the proposed design to increase or decrease some of the areas or shapes of compartments and to eliminate or add new elements comparing with the existing layouts. For example, the windows are very high as a problem in the existing layout. This problem is solved from the results that the windows distance from the floor is very important in the design process.

A general view of the existing layout is shown in Figure 4.10. Table 4.13 shows the differences between the educational carpentry workshop before and after using FQFD.

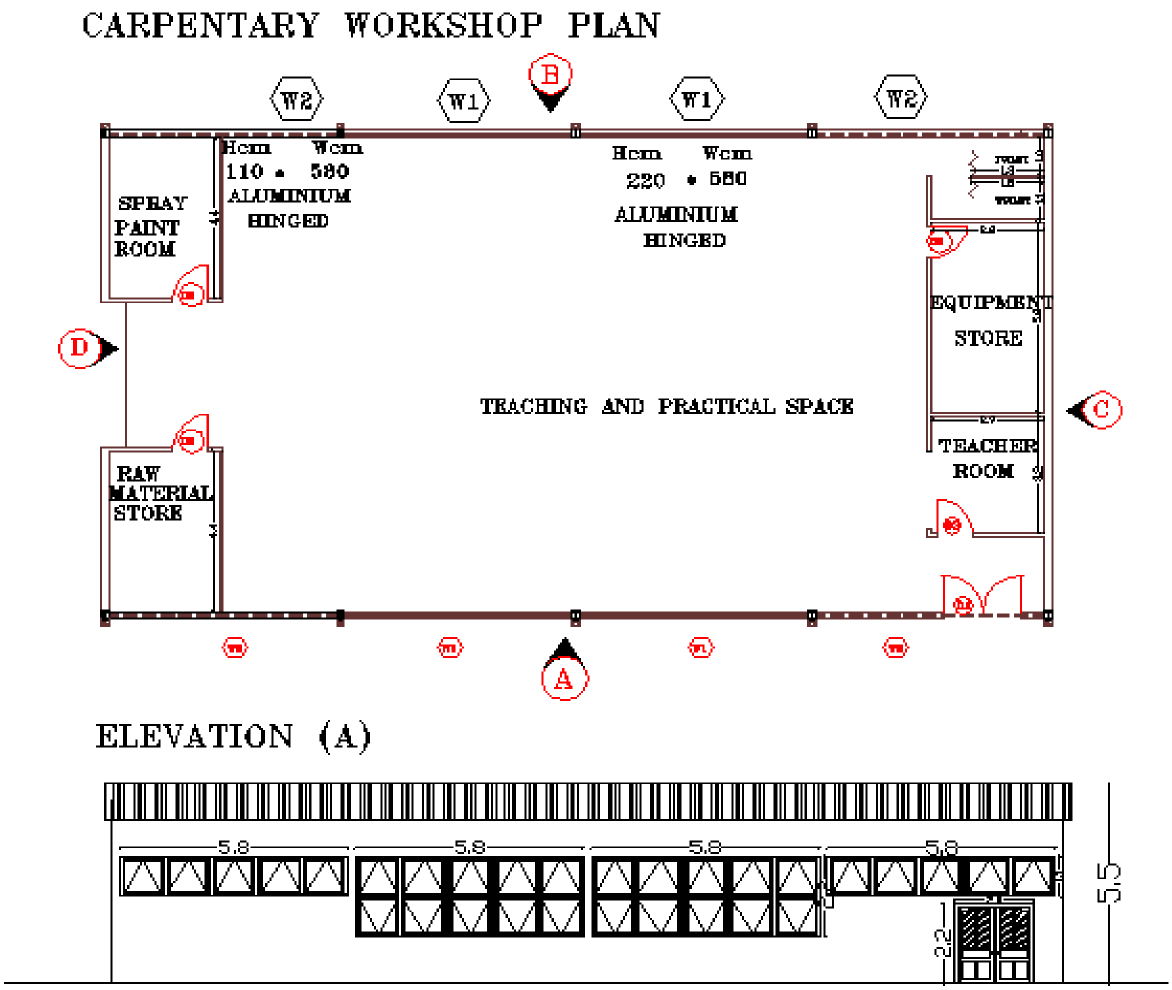

Figure 4.10: The Existing Educational Carpentry Workshop Design Layout.

Table 4.13: Differences Between Educational Carpentry Workshop Before and After Using FQFD.

Design Requirements	After using FQFD	Before using FQFD
Workshop Orientation	South	South
Roof Height (m)	5	5.5
Roof Type	Trusses	Trusses
Windows Type	Sliding	Hinged
Windows Distance from the floor (m)	1.2	2.4
Windows Dimensions (W*H) (m^2)	2.0*1.2	5.8*2.2 5.8*1.1
Dimensions of Door for Entrance and Exit (W*H) (m*m)	2.0*2.5	2.0*2.2
Dimensions of Door for Materials Transport (W*H) (m^2)	4.0*2.5	4.0*4.0

Table 4.13: Continued

Design Requirements	After using FQFD	Before using FQFD
Dimensions of Emergency Door (W*H) (m^2)	1.5*2.5	No Emergency Door
Number of Exhaust fans with 2 horsepower	13	No Exhaust fans
Type of Lamps	Fluorescent	Fluorescent
Type of Floor	Concrete with Hardener	Concrete with Hardener
Number of Seats	20	15
Seats Type	Stool	Stool
Tables Type	Appropriate Work Tables	Inappropriate Tables
Board Dimensions (W*H) (m^2)	2.0*1.5	2.0*1.5
Board Type	Whiteboard	Blackboard
Board Distance from the floor (cm)	120	80
Electrical Outlets Number	30	9
Safety Equipments Types	Safety Glasses or Face Shield, Shop Apron, Cap, Gloves	unavailable
Fire Alarm System	Available	unavailable
Fire Extinguishers (number)	3	1
First Aid Kit	Available	unavailable
Wall Finishing Type	Acrylic Paint on Plaster	Acrylic Paint on Plaster
Wall Isolation	Available	unavailable
Teachers Room Area (m^2)	14	9
(Computer +LCD) Type	Available	unavailable
Equipment Room Area (m^2)	8	14
Number of Closets with dimensions (80*60) (cm^2)	4	3
Number of Lockers with dimensions (60*40) (cm^2)	3	No Lockers
Teaching Space Area (m^2)	30	20
Practical Space Area (m^2)	150	180
Clean up Room Area (m^2)	30	10
Cold Water	Available	Available
Hot Water	Available	unavailable
Number of Sinks	3	1
Number of Showers	1	No Hand-Washing
Painting Room Area (m^2)	21	14

As noticed from Table 4.13, the windows type was changed from hinged to sliding, because sliding windows are easy in cleaning and opening and they facilitate the air fresh and the visibility passing through the carpentry workshop. Roof height was decreased from 5.5m to 5m for many reasons like: the windows height from the floor was decreased from 2.4m to 1.2m for clear visibility and the doors height was decreased. Also, emergency door, safety equipments, fire alarm system, lockers and fire extinguishers for safety and exhaust fans for fresh air was added in the proposed layout. Lamps type, board dimensions and floor type did not change in both proposed and existing layouts. But table type in the existing layout were not equipped with all carpentry needs and the seats were not enough for all students, so, after using FQFD the tables type are equipped with all carpentry needs and the seats are enough for all students for easy and quick practical applications. The board type was changed to be a white board for clear vision of visual information. Electrical outlets numbers was increased from 9 to 30 for easy and quick practical applications in the carpentry workshop. Wall insulation was used after using FQFD to prevent the noise passing from and to the carpentry workshop.

4.4 Model Development

A zero–one goal programming is a decision tool since it can handle multiple objectives and seeks to minimize the total deviation from the desired goals. This property of zero–one goal programming enables us to incorporate multiple goals including FQFD, cost budget and maintainability into the product design process. The weighted goal programming model considers all the goals simultaneously by forming an achievement function that minimizes the total weighted deviation from all the goals stated in the model.

A model has been developed to identify the main design requirements of the educational carpentry workshop according to many conditions that achieve most customer requirements. To develop the model, the following steps have been used:

Step (1): Determine the relative weight of educational carpentry workshop design requirements using FQFD as in Table 4.14.

Table 4.14: Relative Weight of Educational Carpentry Workshop Design Requirements Using FQFD.

Variables	Design Requirements	Relative Weight
X1	Workshop Orientation	0.0452
X2	Roof Height (m)	0.0506
X3	Roof Type	0.0605
X4	Windows Type	0.0659
X5	Windows Distance from the Floor (m)	0.0689
X6	Windows Dimensions (W*H) (m^2)	0.0659
X7	Dimensions of Door for Entrance and Exit (W*H) (m^2)	0.0315
X8	Dimensions of Door for Materials Supply (W*H) (m^2)	0.0256
X9	Dimensions of Emergency Door (W*H) (m^2)	0.0286
X10	Number of Exhaust Fans with 2 Horsepower	0.0195
X11	Type of Lamps	0.0484
X12	Type of Floor	0.0603
X13	Number of Seats	0.0189
X14	Seats Type	0.0288
X15	Tables Type	0.0070
X16	Board Dimensions (W*H) (m^2)	0.0098
X17	Board Type	0.0099
X18	Board Distance from the Floor	0.0197
X19	Electrical Outlets Number	0.0100
X20	Safety Equipments Types	0.0100
X21	Fire Alarm System	0.0100
X22	Fire Extinguishers (Number)	0.0069
X23	First Aid Kit	0.0099
X24	Wall Finishing Type	0.0099
X25	Wall Insulation	0.0099
X26	Teachers Room Area (m^2)	0.0490
X27	(Computer +LCD)	0.0074
X28	Equipment Room Area (m^2)	0.0353
X29	Number of Closets with Dimensions ($80*60cm^2$)	0.0101
X30	Number of Lockers with Dimensions ($60*40cm^2$)	0.0199
X31	Teaching Space Area (m^2)	0.0327
X32	Practical Space Area (m^2)	0.0394

Table 4.14: Continued

Variables	Design Requirements	Relative Weight
X33	Clean up Room Area (m^2)	0.0191
X34	Cold Water	0.0090
X35	Hot Water	0.0090
X36	Number of Sinks	0.0090
X37	Number of Showers	0.0090
X38	Painting Room Area (m^2)	0.0197

Step (2): Determine the relative weight of educational carpentry workshop design requirements with respect to additional design goals like cost and maintainability using AHP method that is shown in Appendix C. The analytic hierarchy process (AHP) method is a well-known technique that decomposes a problem into several levels in such a way that they form a hierarchy. Each element in the hierarchy is supposed to be independent, and a relative ratio scale of measurement is derived from pair wise comparisons of the elements in a level of the hierarchy with respect to an element of the preceding level. In AHP, the relative importance values are determined using pair wise comparisons with a scale of 1–9, where a score of 1 indicates equal importance between the two elements and 9 represents the extreme importance of one element compared to the other one. Table 4.15 shows the relative weight of cost goal and Table 4.16 shows the relative weight of the maintainability goal.

Table 4.15: Relative Weight of educational carpentry workshop Design Requirements for Cost Goal.

Design Requirements	Relative Weight
Workshop Orientation	0.0022
Roof Height (m)	0.0520
Roof Type	0.0573
Windows Type	0.0338
Windows Distance from the Floor (m)	0.0262
Windows Dimensions (W*H) (m^2)	0.0291
Dimensions of Door for Entrance and Exit (W*H) (m^2)	0.0317
Dimensions of Door for Materials Supply (W*H) (m^2)	0.0321
Dimensions of Emergency Door (W*H) (m^2)	0.0327
Number of Exhaust Fans with 2 Horsepower	0.0486
Type of Lamps	0.0066
Type of Floor	0.0469
Number of Seats	0.0119
Seats Type	0.0129

Table 4.15: Continued

Design Requirements	Relative Weight
Tables Type	0.0186
Board Dimensions (W*H) (m^2)	0.0033
Board Type	0.0037
Board Distance from the Floor (m)	0.0060
Electrical Outlets Number	0.0337
Safety Equipments Types	0.0145
Fire Alarm System	0.0475
Fire Extinguishers (Number)	0.0399
First Aid Kit	0.0025
Wall Finishing Type	0.0321
Wall Insulation	0.0315
Teachers Room Area (m^2)	0.0409
(Computer +LCD)	0.0388
Equipment Room Area (m^2)	0.0409
Number of Closets with Dimensions (80*60cm^2)	0.0143
Number of Lockers with Dimensions (60*40cm^2)	0.0150
Teaching Space Area (m^2)	0.0409
Practical Space Area (m^2)	0.0409
Clean up Room Area ($m^{2)}$	0.0401
Cold Water	0.0051
Hot Water	0.0074
Number of Sinks	0.0085
Number of Showers	0.0085
Painting Room Area (m^2)	0.0413

Table 4.16: Relative Weight of educational carpentry workshop Design Requirements for maintainability Goal.

Design Requirements	Relative Weight
Workshop Orientation	0.0014
Roof Height (m)	0.0030
Roof Type	0.0040
Windows Type	0.0320
Windows Distance from the Floor (m)	0.0069
Windows Dimensions (W*H) (m^2)	0.0070
Dimensions of Door for Entrance and Exit (W*H) (m^2)	0.0055
Dimensions of Door for Materials Supply (W*H) (m^2)	0.0055
Dimensions of Emergency Door (W*H) (m^2)	0.0055
Number of Exhaust Fans with 2 Horsepower	0.0163
Type of Lamps	0.0512
Type of Floor	0.0126

Table 4.16: Continued

Design Requirements	**Relative Weight**
Number of Seats	0.0472
Seats Type	0.0458
Tables Type	0.0426
Board Dimensions (W*H) (m^2)	0.0514
Board Type	0.0521
Board Distance from the Floor (m)	0.0507
Electrical Outlets Number	0.0298
Safety Equipments Types	0.0453
Fire Alarm System	0.0116
Fire Extinguishers (Number)	0.0266
First Aid Kit	0.0514
Wall Finishing Type	0.0221
Wall Insulation	0.0221
Teachers Room Area (m^2)	0.0096
(Computer +LCD)	0.0294
Equipment Room Area (m^2)	0.0096
Number of Closets with Dimensions (80*60cm^2)	0.0444
Number of Lockers with Dimensions (60*40cm^2)	0.0444
Teaching Space Area (m^2)	0.0096
Practical Space Area (m^2)	0.0096
Clean up Room Area (m^2)	0.0096
Cold Water	0.0468
Hot Water	0.0453
Number of Sinks	0.0412
Number of Showers	0.0412
Painting Room Area (m^2)	0.0096

Step (3): Calculate the relative weight of all determined goals considered in the design of the educational carpentry workshop using AHP method that is shown in Appendix C. Table 4.17 shows the relative weight of all goals.

Table 4.17: Relative Weight of for All Determined Design Goals.

Goals	**Relative Weight**
FQFD	0.2249
Cost	0.6961
Maintainability	0.0790

Step (4): Formulate and solve the zero–one goal programming model to identify the educational carpentry workshop design requirements to be considered in the designing process. The general form of the ZOGP model employed in the decision framework is as follows:

MIN 0.2249d1n+0.6961d2p +0.0790d3n

subject to

0.0452x1+0.0506x2+0.0605x3+0.0659x4+0.0689x5+0.0659x6+0.0315x7+0.0256x8+0.0286x9+
0.0195x10+0.0484x11+0.0603x12+0.0189x13+0.0288x14+0.0070x15+0.0098x16+0.0098x17+0
.0197x18+0.0099x19+0.0099x20+0.0099x21+0.0069x22+0.0099x23+0.0099x24+0.0099x25+0.
0490x26+0.0074x27+0.0353x28+0.0100x29+0.0199x30+0.0327x31+0.0394x32+0.0191x33+0.0
090x34+0.0090x35+ 0.0090x36+0.0090x37+0.0197x38+d1n-d1p=1 (FQFD)

0.0022x1+0.0520x2+0.0573x3+0.0338x4+0.0262x5+0.0291x6+0.0317x7+0.0321x8+0.0327x9+
0.0500x10+0.0066x11+0.0469x12+0.0119x13+0.0129x14+0.0186x15+0.0034x16+0.0037x17+0
.0060x18+0.0337x19+0.0145x20+0.0475x21+0.0399x22+0.0025x23+0.0321x24+0.0320x25+0.
0409x26+0.0388x27+0.0409x28+0.0143x29+0.0150x30+0.0409x31+0.0409x32+0.0401x33+0.0
051x34+0.0074x35+0.0085x36+ 0.0085x37+0.0414x38+d2n-d2p=1 (Cost)

0.0014x1+0.0030x2+0.0040x3+0.0320x4+0.0069x5+0.0070x6+0.0055x7+0.0055x8+0.0055x9+
0.0163x10+0.0512x11+0.0126x12+0.0472x13+0.0458x14+0.0426x15+0.0514x16+0.0521x17+0
.0507x18+0.0298x19+0.0450x20+0.01157x21+0.0266x22+0.0514x23+0.02208x24+0.0221x25+
0.0096x26+0.0294x27+0.0096x28+0.0445x29+0.0445x30+0.0096x31+0.0096x32+0.0096x33+0
.0468x34+0.0450x35+0.0412x36+0.0412x37+0.0096x38+d3n-d3p=1 (Maintainability)

End

In order to create a practical model that identifies the main educational carpentry workshop design requirements according to different conditions, the zero–one goal programming model was developed. The model was developed based on the relative weight for the educational carpentry workshop design requirements for many goals, and then identifies the main of them according many conditions. The model is solved using LINDO software yielding. The results are shown in Table 4.18 and Table 4.19.

Table 4.18: Results of Zero–One Goal Programming.

Ratio	Objective Function for cost
0.2	0.1488
0.4	0.0932
0.6	0.0504
0.8	0.0202
1.0	0.0000

Table 4.19: Zero–One Goal Programming Solutions of Educational Carpentry Workshop Design Requirements.

Cost Ratio	Variables Selected
0.2	Except X2,X3,X7,X8,X9,X10,X12,X15,X19,X21,X22,X24, X25,X26,X27,X28,X29,X31,X32,X33,X38
0.4	Except X2,X7,X8,X9,X10,X15,X19,X21,X22,X24,X25,X27, X28,X31,X33,X38
0.6	Except X8,X10,X15,X19,X21,X22,X24,X25,X27,X33,X38
0.8	Except X21,X22,X24,X27,X38
1.0	All variables

As shown in Table 4.19, when the right hand of the cost goal equal 1 in the model, all variables (design requirements) can be satisfied in the design process to achieve the most customer requirements. But, when the right hand of the cost goal less than 1 (the percentage of this goal is enough for all design requirements), some of design requirements are satisfied in the design process to achieve the most customer requirements. As in Table 4.18, the objective function is lowest when the ratio equal 1 of the right hand of the model for cost goal that means, when the cost is ideal and real, the deviation is minimum. Figure 4.11 shows the objective function for every ratio of the right hand of the cost goal in the model. So, this model describes the design method, which may be used to assess the designers to strengthen the design process and to be easily extended for real-world applications. So, the results of this chapter clearly indicate that all educational carpentry workshop design requirements are satisfied in the designing process when the cost goal is ideal.

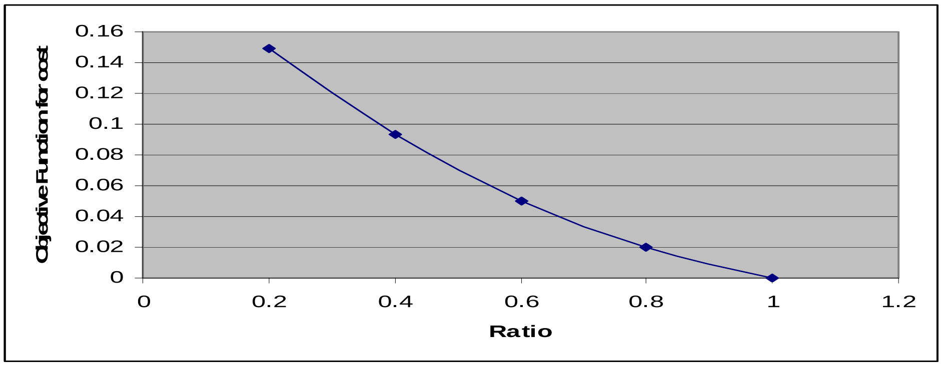

Figure 4.11: Results of Zero–One Goal Programming.

Ch 5

Conclusions and Recommendations

This chapter includes the conclusions and the practical recommendations that help in the development of educational carpentry workshop design.

5.1 Conclusions

The main objective of this research was to design an appropriate educational carpentry workshop using FQFD.

FQFD is a valuable and very flexible tool for design. The practical applications of FQFD mentioned illustrate that it can be utilized in different ways and can be adapted to solve a great number of design problems.

FQFD supports the customer requirements in the educational carpentry workshop (WHATs) and the design requirements (HOWs).

Customer voice was evoked through interviews and from literature reviews that would affect on educational carpentry workshop conceptual design.

A set of design requirements were proposed to satisfy the needs and their relationship with each of customer requirements agreed. Design requirements were ranked through FQFD method to guide the design of educational carpentry workshop. The three most important design requirements of educational carpentry workshop were: windows dimensions, windows type and windows distance from the floor.

At the completion of this research a proposed layout for educational carpentry workshop were presented and a model was developed.

From the comparison between the case study and the results of the research, FQFD has made a successful experiment with more objectivity.

A model has been developed using LINDO software to identify the main design requirements of the educational carpentry workshop according to many conditions that achieve most customer requirements.

5.2 Recommendations

- Future studies can be pursued on developing a computerized intelligent decision support system for group decision making environment.

- Future studies and much better research are needed to demonstrate its usefulness in the detail design, procurement and construction phases as well.

- FQFD can be employed in any stage of the project.
- The FQFD process appears suitable for fast-track design/build contracts.

- The workshops' planning, design characteristics, and each property's relationship to the creation of the school plant should be among chief evaluation considerations.

References

Abu-Lughod, E., (1997), Palestinian education, International Conference for Palestinians Studies, Berzait University, Berzait, Palestine.

Akao, Y., (1997), QFD: Past, Present, and Future, Proceedings of the International Symposium on QFD, Linkping.

Akao, Y., (1990), Quality function deployment: Integrating customer requirements into product design. Journal of Productivity Press, Cambridge, MA.

Baek, S. and Choi, H., (2002), The relationship between students' perceptions of classroom environment and their academic achievement in Korea, Asian Pacific Education Review, Vol. 3, No. 1, pp. 125-135.

Barrie, D. and Paulson, B., (1992), Professional construction management, McGraw-Hill, 3rd ed., New York.

Bossert, J.L., (1991), Quality Function Deployment: A practitioner's approach, Journal of Quality Press, Vol. 3, No. 2, pp. 5-6.

Bouchereau, V. and Rowlands, H., (1999), Analytical approaches to QFD, Journal of Manufacturing Engineer, Vol. 78, No. 6, pp. 249-254.

Chan, L.K., Kao, H.P., Ng, A. and Wu, M.L., (1999), Rating the importance of customer needs in quality function deployment by fuzzy and entropy methods, International Journal of Production and Research, Vol. 37, No. 11, pp. 2499–2518.

Chan L. K., Wu M. L., (2002), Quality function deployment: A literature review, European Journal of Operational Research, Vol. 143, No. 3, pp. 463–497.

Chan L. K., Wu M. L., (2005), A systematic approach to quality function deployment with a full illustrative example, The International Journal of Management and Science, Vol. 33, pp. 119–139.

Chen, L. H., Weng, M. C., (2006), An evaluation approach to engineering design in QFD processes using fuzzy goal programming models, European Journal of Operational Research, Vol. 172, pp. 230–248.

Cohen, L., (1988), Quality function deployment: An application perspective from Digital Equipment Corporation, Nat. Prod. Rev., Vol. 7, No. 3, pp. 197–208.

Clark, H., (2002), Building education: The role of the physical environment in enhancing teaching and research, Institute of Education, London.

Cohen, L., (1995), Quality function deployment: How to make QFD work for You, Addison-Wesley: Reading, MA.

Cristiano, J.J., Liker, J.K., and White, Ch.C., (2000), Customer-driven product development through quality function deployment in the U.S. and Japan, Journal of Production Innovation Management, Vol. 17, No. 4, pp. 286-308.

Decoursey, W.J., (2003), Statistics and probability for engineering applications, Hand Book, Elsevier Science, U.S.A.

Department of Public Instruction, (2002), The development of educational specifications, Public Schools of North Carolina.
http://www.schoolclearinghouse.org. extracted on 4/4/2010.

Elewa, B., (2007), The problems which the agricultural education are faced in Palestine, MA, IUG, Gaza, Palestine.

Erdogan, B., (2003), The extent of information visualization in Turkish construction industry, A QFD approach, MA, The Middle East Technical University.

Esawee, O., (2008), Proposed solutions for low cost housing projects in the Gaza Strip, The Journal of Islamic University, Vol.16, No. 1, pp 131-154.

Fernandez, J.E., Chamberlin, J.L., Kramer, E.G., Broomall, J.H., Rori, H.A. and Begley, R.L., (1994), Making the neon fun to drive, Proceedings of The Sixth Symposium on Quality Function Deployment, Novi, Michigan, June 13-14, pp. 483-508.

Fortuna, R.M., (1988), Beyond quality: Taking SPC upstream, Quality Progress, June, pp. 23-28.

Gargione, L. A., (1999), Using quality function deployment (QFD) in the design phase of an apartment construction project, University of California, Berkeley, CA, USA.

Govers, C.P.M., (2001), QFD not just a tool but a way of quality management, International Journal of Production and Economics, Vol. 69, pp. 151-159.

Griffin, A., Hauser, J.R., (1992), Patterns of communications among marketing, engineering and manufacturing, Journal of Management and Science, Vol. 38, No. 3, pp. 360–373.

Guinta, L.R. and Praizler, N.C., (1993), The QFD Book, The team approaches to solving problems and satisfying customers through quality function deployment, American Management Association, New York.

Han, B. et al. (2001), A conceptual QFD planning model, International Journal of Quality & Reliability Management, Vol. 18, No. 8, pp.796–812.

Harastanee, R., (2003), Architectural design elements, Hand book, Dar-Alayam, Syria.

Harding, J.A., Popplewell, K., Fung, R.Y.K., and Omar, A.R., (2001), An intelligent information framework relating customer requirements and product characteristics, Journal of Computers in Industry, Vol. 44, pp. 51-65.

Hashwa, M., (1997), Vocational training between present and future situations, Professional Staff in Vocational Training Center, Ramalla, Palestine.

Hauser, J., & Clausing, D., (1989), The house of quality, Harvard Business Review, Vol. 66, No. 3, pp. 63-73.

Hauser, J.R. and Clausing, D., (1996), The house of quality, IEEE Engineering Management Review, Vol. 24, No. 1, pp. 24-32.

Indian Technology Education Committee, (2000), Facility planning guide, Indian Engineering Publication.

Iyer, K.C. and Jha, K.N., (2005), Factors affecting cost performance, International Journal of Project Management, Vol. 23, No. 4, pp. 283-295.

Juan, Y., Perng, Y., Castro, D. and Lu, K., (2009), Housing refurbishment contractors selection based on a hybrid FQFD approach, Journal of Automation in Construction, Vol. 18, No. 4, pp. 139-144.

Kahraman, C., Cebec, U. and Ruan, D., (2004), Multi-attribute comparison of catering service companies using fuzzy AHP, International Journal of Production and Economics, Vol. 87, No. 4, pp. 171-184.

Kamara JM, Anumba CJ, Evbuomwan FO., (1999), Client requirements processing in construction: a new approach using QFD, Journal of Architectural Engineering, Vol. 5, No. 1, pp. 8-15.

Kamara, J.M. , Anumba, C.J. and Evbuomwan, N.F.O., (2000), Establishing and processing client requirements, Journal of Architectural Engineering, Vol. 7, No. 1, pp. 15-28.

Karsak, E., Sozer, S. and Alptekin, S., (2002), Product planning in quality function deployment using a combined analytic network process and goal programming approach, Journal of Computers & Industrial Engineering, Vol. 44, No, 2, pp. 171-190.

Khoo, L.P., Ho, N.C., (1996), Framework of a fuzzy QFD system, International Journal of Production Research, Vol. 34, No, 2, pp. 299-311.

King, B., (1987), Better designs in half the time: Implementing quality function deployment in America, GOAL/QPC: Methuen, MA.

Kivinen, T., (2008), Applying QFD to improve the requirements and project management in small-scale project, MA, University of Tampere.

Kogure, M., Akao, Y., (1983), Quality function deployment and CWQC in Japan, Journal of Quality and Progress, Vol. 16, No. 10, pp. 25–29.

Martins, A. and Aspinwall, E.M.., (2001), Quality function deployment: An empirical study in the UK, Journal of Total Quality Management , Vol. 12, No. 5, pp. 575–588.

Mea'yaree, M., (1991), The vocational education in occupied terrain, Palestinians Society Studies Center , Berzait University, Berzait, Palestine.

Naoum S., (1998), Dissertation research and writing for construction student, Read Educational and Professional Publishing Ltd.

Office of Facility Planning, (1998), Manual of planning standards for school buildings, University of The State of New York.

Public Administration for Colleges and Vocational Education, (2008), Ministry of High Education publications, Ramalla, Palestine. (http://www.moe.gov.ps) accessed on January 2010.

Shaheen, B., (1987), Educational Building and its adequacy to high education, Arabic Center for High Education Researches, Demashq, Syria.

Sommerville, J. and Craig, N., (2002), The application of QFD in the IT construction industries, Paper Presented at the Proceedings of RICS Foundation Construction and Building Research Conference, Newton, 5-6 September.

Sullivan, L.P., (1986), Quality function deployment, Journal of Quality and Progress, Vol. 19, No. 6, pp. 39–50.

Tanner, C. K., (2000), The influence of school architecture on academic achievement, Journal of Educational Administration, Vol. 38, No. 4, pp. 309-330.

UN, (2002), New economic figures for West Bank and Gaza Strip show rapid deterioration leading to human catastrophe, UN Information Center, Palestine.

Wang, J., (1999), Fuzzy outranking approach to prioritize design requirements in QFD , International Journal of Production and Research, Vol. 37, No. 4, pp. 899-916.

Yang YQ, Wang SQ, Dulaimi M and Low SP., (2003), A fuzzy quality function deployment system for buildable design decision-makings, Journal of Automation in Construction, Vol. 12, No. 4, pp. 381–393.

Zaim, S. and Sevkli, M., (2002), The methodology of quality function deployment with crisp and fuzzy approaches and an application in the Turkish shampoo industry, Journal of Economic and Social Research, Vol. 4, No. 1, pp. 27-53.

Zeng, J., An, M. and Smith, N., (2007), Application of a fuzzy based decision making methodology to con assessment, International Journal of Project Management, Vol. 25, No. 10, pp. 589-600.

Interviews

- Eng. Abed-Alsalam Zakoot- Al-Resala Office- Khanyounis
- Eng. Bassam Daboor- Ministry of Work- Gaza
- Eng. Esmaeal Abu-Sokhela- Engineering Office- IUG
- Eng. Fawzee Alfara- GTC
- Eng. Hazem Helles- Engineering Vocational Department-Community College of Applied Science & Technology-Gaza
- Eng. Huda Attalla- Engineering Department- UNRWA
- Dr. Mustafa Alfara- Architecture Department- IUG
- Eng. Saed Altartoori- Engineering Office- Khanyounis
- Eng. Yehya Alastal- Engineering Department- UNRWA
- The administrator and carpentry teachers and students of secondary industrial school in Dair-Albalah

List of Appendixes

Appendix (A)

Permissions

بسم الله الرحمن الرحيم

الجامعة الإسلامية – غزة

Islamic University – Gaza

Faculty of Engineering — عمادة كلية الهندسة

الرقم : ج س ع/67/ — Ref. :

التاريخ : 2009/06/01 — Date :

الأخ الفاضل/ قسم الهندسة في وزارة التربية والتعليم حفظه الله

السلام عليكم ورحمة الله وبركاته،

الموضوع/ مساعدة طالب ماجستير

تهديكم كلية الهندسة بالجامعة الإسلامية–غزة أطيب تحياتها، وترجو التكرم بمساعدة الطالبة/ **جنات اللحام**، حيث أنه من طالبات برنامج الماجستير في قسم الهندسة المدنية بكلية الهندسة، حيث أنها تقوم بعمل رسالة ماجستير بعنوان:

"Using QFD in Vocational building "

ونرجو من سيادتكم تزويدها بالمعلومات والبيانات التي تفيدها في بحثها.

وذلك ترسيخاً لمبدأ التعاون والتكامل بين الجامعة والمؤسسات الوطنية والمحلية، ونظراً للفائدة المرجوة التي ستتحقق للطالب.

وتفضلوا بقبول فائق الاحترام والتقدير،،،

رئيس قسم الهندسة المدنية

ع –

د. عصام المصري

P.O. Box 108 - Rimal - Gaza - Palestine - Tel. (+972) 8 2860700 Ex. 2800 Fax (+972) 8 2863552

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بسم الله الرحمن الرحيم

الجامعة الإسلامية – غزة

Islamic University – Gaza

Faculty of Engineering عمادة كلية الهندسة

Ref. : الرقم : ج س غ/67/

Date : 2009/06/01 التاريخ :

الأخ الفاضل/ مدير المدرسة الصناعية - دير البلح حفظه الله

السلام عليكم ورحمة الله وبركاته،

الموضوع/ مساعدة طالب ماجستير

تهديكم كلية الهندسة بالجامعة الإسلامية-غزة أطيب تحياتها، ونرجو التكرم بمساعدة الطالبة/ جنات اللحام، حيث أنه من طالبات برنامج الماجستير في قسم الهندسة المدنية بكلية الهندسة، حيث أنها تقوم بعمل رسالة ماجستير بعنوان:

"Using QFD in Vocational building "

ونرجو من سيادتكم تزويدها بالمعلومات والبيانات التي تفيدها في بحثها.

وذلك ترسيخاً لمبدأ التعاون والتكامل بين الجامعة والمؤسسات الوطنية والمحلية، ونظراً للفائدة المرجوة التي ستتحقق للطالب.

وتفضلوا بقبول فائق الاحترام والتقدير،،،

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Appendix (B)

English and Arabic Students Questionnaires

الجامعة الإسلامية-غزة
عمادة الدراسات العليا
كلية الهندسة
قسم الهندسة المدنية
برنامج إدارة التشييد

السلام عليكم و رحمة الله و بركاته،

استبيان خاص بمتطلبات الطلاب لتحقيق رضاهم أثناء استخدام ورشة النجارة في المدرسة الصناعية الثانوية في دير البلح

تهدف هذه الاستبانة لتحسين التصميم الداخلي لورش النجارة في المدارس الصناعية باستخدام طريقة (FQFD) لتلائم المستخدمين كالطلاب و المدرسين عن طريق التعرف على مدى أهمية المتطلبات التصميمية (الداخلية) للورش.

فالمطلوب منك أخي قراءة العبارات جميعها بدقة ثم اختيار إجابة واحدة بوضع إشارة (X) داخل أحد الأعمدة الخمسة.

إجاباتكم ستكون سرية للغاية، لذا يرجى التكرم بتعبئة الاستبانة بأمانة و دقة و موضوعية.

شاكرة لكم حسن التعاون

الباحثة/ م. جنات حيدر اللحام

التاريخ: 2010/3/2

	متطلبات الطلاب في الورش التعليمية الصناعية لتحقيق رضاهم في استخدامها	درجة الأهمية				
		مهمة بشكل كبير	مهمة	متوسطة الأهمية	غير مهمة	غير مهمة بشكل كبير
1	الحصول على هواء نقي داخل الورشة					
2	الحصول على رؤية واضحة داخل الورشة					
3	عدم الانزعاج من الضجيج أثناء التطبيق العملي داخل الورشة					
4	عدم الشعور بحرارة أو برودة زائدة داخل الورشة					
5	عدم التعرض لحوادث داخل الورشة					
6	وصول المعلومات المرئية للطالب بطريقة سريعة و واضحة عند الشرح النظري داخل الورشة					
7	الحصول على أدوات العمل بسرعة و سهولة عند التطبيق العملي داخل الورشة					
8	الشعور بالراحة عند استخدام الكراسي داخل الورشة					
9	سهولة التطبيق العملي و بدون معوقات و سهولة الحركة في الفراغ العملي داخل الورشة					
10	التخلص من الاتساخ بعد العمل داخل الورشة					
11	تطبيق عملية الدهان بصورة جيدة داخل الورشة					

The Islamic University of Gaza
Higher Education Deanship
Faculty of Engineering
Civil Engineering Department
Construction Management Program

A questionnaire for carpentry workshop students' requirements in Dair-Albalah school

The objective of this questionnaire is to improve the design of carpentry workshops by using FQFD method.

This questionnaire is required to be filled with exact relevant facts as much as possible.

All data included in this questionnaire will be used only for academic research and will be continue confidential.

Thank you a lot.

Please put (X) on the degree of importance of your requirements in carpentry workshop:

Detailed requirement	Very important	Important	Moderate	Unimportant	Very unimportant
Fresh air					
No dead viewing area					
Noiseless					
Temperature controlled year round					
No accidents and incidents					
Clearly see the visual information and take notes					
Easy and quick access to tools					
Comfortable seats					
Appropriate space for practical application					
Appropriate space for cleaning					
Appropriate space for painting process					

Appendix (C)

AHP Method

AHP was used to calculate the importance ratings of 38 design requirements as shown in the following tables:

Score	**Interpretation**
1	Objective i and j are of equal importance
2	Objective i is weakly more important than objective j
3	Objective i is strongly more important than objective j
4	Objective i is very strongly more important than objective j
5	Objective i is absolutely more important than objective j

Design Requirements	Workshop orientation	Roof Height	Roof Type	Windows Type	Windows Type	Windows Dimensions	Dimensions of Door for Entrance and	Dimensions of Door for Materials	Dimensions of Emergency Door	Number of Exhaust Fans with 2	Type of Lamps	Type of Floor
Workshop Orientation												
Roof Height												
Roof Type												
Windows Type												
Windows Distance from the floor												
Windows Dimensions												
Dimensions of Door for Entrance and Exit												
Dimensions of Door for Materials Supply												
Dimensions of Emergency Door												
Number of Exhaust Fans with 2 horsepower												
Type of Lamps												
Type of Floor												
Number of Seats												
Seats Type												
Tables Type												
Board Dimensions												
Board Type												
Board Distance from the floor												

Design Requirements	Number of Seats	Seats Type	Tables Type	Board Dimensions	Board Type	Board Distance from the floor	Electrical Outlets Number	Safety Equipments Types	Fire Alarm System	Fire Extinguishers (Number)	First Aid Kit	Wall Finishing Type
Workshop Orientation												
Roof Height												
Roof Type												
Windows Type												
Windows Distance from the floor												
Windows Dimensions												
Dimensions of Door for Entrance and Exit												
Dimensions of Door for Materials Supply												
Dimensions of Emergency Door												
Number of Exhaust Fans with 2 horsepower												
Type of Lamps												
Type of Floor												
Number of Seats												
Seats Type												
Tables Type												
Board Dimensions												
Board Type												
Board Distance from the floor												

Design Requirements	Wall Isolation	Teachers Room Area (m2)	Computer +LCD	Equipment Room Area (m2)	Number of Closets	Number of Lockers	Teaching Space Area (m2)	Practical Space Area (m2)	Clean up Room Area (m2)	Cold Water	Hot Water	Number of Sinks	Number of Showers	Painting Room Area (m2)
Workshop Orientation														
Roof Height														
Roof Type														
Windows Type														
Windows Distance from the floor														
Windows Dimensions														
Dimensions of Door for Entrance and Exit														
Dimensions of Door for Materials Supply														
Dimensions of Emergency Door														
Exhaust Fans Number														
Type of Lamps														
Type of Floor														
Number of Seats														
Seats Type														
Tables Type														
Board Dimensions														
Board Type														
Board Distance from the floor														

Design Requirements	Workshop orientation	Roof Height	Roof Type	Windows Type	Windows Type	Windows Dimensions	Dimensions of Door for Entrance and	Dimensions of Door for Materials	Dimensions of Emergency Door	Number of Exhaust Fans with 2	Type of Lamps	Type of Floor
Electrical Outlets Number												
Safety Equipments Types												
Fire Alarm System												
Fire Extinguishers												
First Aid Kit												
Wall Finishing Type												
Wall Isolation												
Teachers Room Area												
(Computer +LCD)												
Equipment Room Area												
Number of Closets												
Number of Lockers												
Teaching Space Area												
Practical Space Area												
Clean up Room Area												
Cold Water												
Hot Water												
Number of Sinks												
Showers Number												
Painting Room Area												

Design Requirements	Number of Seats	Seats Type	Tables Type	Board Dimensions	Board Type	Board Distance from the floor	Electrical Outlets Number	Safety Equipments Types	Fire Alarm System	Fire Extinguishers (Number)	First Aid Kit	Wall Finishing Type
Electrical Outlets Number												
Safety Equipments Types												
Fire Alarm System												
Fire Extinguishers												
First Aid Kit												
Wall Finishing Type												
Wall Isolation												
Teachers Room Area												
(Computer +LCD)												
Equipment Room Area												
Number of Closets												
Number of Lockers												
Teaching Space Area												
Practical Space Area												
Clean up Room Area												
Cold Water												
Hot Water												
Number of Sinks												
Showers Number												
Painting Room Area												

Design Requirements	Wall Isolation	Teachers Room Area (m2)	Computer +LCD	Equipment Room Area (m2)	Number of Closets	Number of Lockers	Teaching Space Area (m2)	Practical Space Area (m2)	Clean up Room Area (m2)	Cold Water	Hot Water	Number of Sinks	Number of Showers	Painting Room Area (m2)
Electrical Outlets Number														
Safety Equipments														
Fire Alarm System														
Fire Extinguishers														
First Aid Kit														
Wall Finishing Type														
Wall Isolation														
Teachers Room Area														
(Computer +LCD)														
Equipment Room Area														
Number of Closets														
Number of Lockers														
Teaching Space Area														
Practical Space Area														
Clean up Room Area														
Cold Water														
Hot Water														
Number of Sinks														
Showers Number														
Painting Room Area														