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Engineering Approach with Quality Function Deployment for an ABET Accredited Program: A Case Study

Francis Francis*

Department of Mechanical Engineering, Notre Dame University-Louaize, Zouk Mosbeh, Lebanon
*Corresponding author: ffrancis@ndu.edu.lb

Abstract Quality Function Deployment (QFD) is a systematic approach used by companies and organizations to meet customer requirements. The success of a QFD analysis is largely based on the quality of the voice of the customer, namely the customer requirements and their importance ratings. On the other hand, ABET, incorporated as the Accreditation Board for Engineering and Technology, Inc., is a non-governmental organization that accredits post-secondary education programs. In this paper, QFD is applied to a major course from the mechanical engineering program where, Course Learning Outcomes are considered as the Voice of the Customers (WHAT) and Student Outcomes issued by ABET are the technical requirements (HOW). The objective of this paper is to pave a clear road to faculty members and engineering institutions to fulfil ABET requirements.

Keywords: *quality function deployment, house of quality, Accreditation Board for Engineering and Technology, Inc., course learning outcomes*

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1. Introduction

1.1. The History of Quality Function Deployment (QFD)

Quality Function Deployment (QFD) is a literal translation of the Japanese words **hinshitsu kino tenkai**, but was initially translated as quality function evolution in 1978 by Dr.L.T.Fan . At the first QFD seminar in the United States Mr Masaaki Imai felt that the term evolution inappropriately connoted the meaning of “change” and that **hinshitsu tenkai** was better translated as quality deployment. Although deployment had militaristic implications in Japanese, in this usage, it was entirely acceptable. And so the term Quality Function Deployment was born [1].

In the 1950s and 1960s the concept of Total Quality played a vital role in Japanese manufacturing development based on the insights of W.Edwards Deming, Joseph Juran, Armand Feigenbaum and others from the United States and Japan. After the introduction of quality of conformance, it became clear by the end of the 1960s that the quality of design also needed to be improved. In the beginning, fishbone charts were used to identify customer demands and to establish design quality [2].

In 1972, Nishimura and Takayanagi have developed a matrix of customer’s demands and quality characteristics, known as quality chart. Dr. Shigeru Mizuno, Dr. Yoji Akao and other quality experts in Japan then developed the tools and techniques of QFD and organized them into a comprehensive system to assure quality and customers satisfaction in products and services [3].

In 1978 the Japanese Standards Association published a book focused on QFD case studies. In the early1980s, Dr Akao integrated QFD with value engineering and other tools for cost deployment, new technology, reliability engineering and bottleneck engineering [9]. In October 1983, Dr Akao introduced QFD to the United States in a short article that appeared in Quality Progress, the monthly journal of the American Society for Quality Control (ASQC) [4].

QFD became widely known in the United States through the efforts of Don Clausing, of Xerox and Bob King of GOAL/QPC. Italy was the first European country to implement QFD, hosting the 1st European QFD Symposium in 1993.

The initial applications were centered in the automotive industry, primarily in product planning and design, product improvements, but rarely new product development. QFD as a tool was domiciled in the technical functions such as engineering, product planning and process engineering.

Shortly thereafter the scope of QFD applications was extended to include functions such as research and development, marketing, customer service, human resources and manufacturing. Consequently it is now also utilized for organizational assessment, internal services and problem solving. A few case studies have shown that QFD is mainly used in enterprises, which have a comprehensive approach to Quality Management [5].

The number of QFD case studies continues to increase as well as the variety of situations, in which QFD is employed, expands. In the last several years, interest in QFD has spread around the world. Today, QFD can be regarded as an international established method. A very important added value for the usage of QFD is the development of Environmentally Conscious QFD (ECQFD) aiming to develop a product under environmental considerations [6].

2. The Concept of Quality Function Deployment

There are several definitions for QFD. The definition of Akao states that QFD is the converting of customer's demands (WHATs) into quality characteristics (HOWs) and developing a quality plan for the finished product by systematically deploying the relationships between customer demands and the QCs, starting with the quality elements in the product plan. Later, QFD deploys these WHATs and HOWs relationships with each identified quality element of the process plan and production plan. The overall quality of the product is formed through this network of relationships.

The factors responsible for the successful application of QFD [7] are:

1. The primary requirement is corporate commitment and support from dedicated management. This is the foundation of QFD and it precedes all other requirements. QFD will fail without this committed support.
2. The second requirement that builds upon the first is the need for the QFD team organization and operation to be built upon relevant principles and practices. Team members usually require education and training in these activities if they are to be effective.
3. The third requirement is concerned with the team having a good understanding and working knowledge of problem solving methods, for generating and analysing ideas or collecting and handling numerical data.
4. The fourth requirement is the information support system that is available within the organization and outside the organization that can be used by the team to support its activities.

There are many different approaches to QFD [8], such as:

- The Akao Model
- The Four-Phase Approach
- The Matrix of Matrices Approach
- The International Techne Group, Inc. (ITI) QFD Approach or the Customer Driven Mission Achievement Process (CD-MAP)

3. The Accreditation Board for Engineering and Technology, (ABET) Inc.

ABET, incorporated as the Accreditation Board for Engineering and Technology, Inc., is a non-governmental organization that accredits post-secondary education programs in "applied science, computing, engineering, and engineering technology". The accreditation of these programs occurs mainly in the United States but also internationally. As of October 2012, around 3,278 programs are accredited, distributed over more than 670 universities and colleges in 23 countries. More details including the ABET Accreditation Process are the references [9-14].

4. Case Study

In this paper, the Akao Model is used for the application of QFD which consists mainly of the creation of the House of Quality as follows:

Product: A recent graduate mechanical engineer meeting the needs of market and society. A major mechanical engineering course is selected for analysis to check the relationships between course content and our objective as educational institution which is graduating engineers characterized by maximum number of ABET requirements for accreditation..

The description of the major course is well and clearly stated in the catalogue of the department as follows:

GMEN XXX Joining Processes: Welding, Soldering and Brazing (3.0); 3 cr.

Analysis of various joining processes: mechanisms of surface bonding; welding metallurgy; effect of heat input on resulting microstructures; residual stresses and distortion; welding processes: MIG, TIG, Laser, electron beam, spot welding, resistance welding. *Prerequisite*: MEN XXY.

Customers Requirements: Learning Outcomes of the selected major mechanical engineering course identified by faculty members and approved by department curriculum committee. Each learning outcome has a degree of importance or priority issued by course instructor. It is expressed as a relative scale (typically1-5 or 1-10) with the higher numbers indicating greater importance. One may argue and suggest equal importance to all learning outcomes, but this depends on the nature and type of the course. However, it is important that these values truly represent the course content, rather than any other concerns and beliefs. They are as stated in the syllabus of the course, but hereby (Table 1) rearranged in accordance to the sequence of chapters (see Appendix 1) as follows:

Table 1. GMEN XXX Learning outcomes importance rating

Learning Outcomes	Customer Priority (CP)
Grasp the fundamental principles of the operational safety	10
Distinguish between different joining processes	7
Observe and apply various joining processes	5
Evaluate the quality of joined parts	8
Analyze the effect of joining operations on the material properties	6

Technical Requirements (TR): These are Student Outcomes issued by ABET.

Students' outcomes are developed by ABET Inc. Student outcomes (see Appendix 2) describe what students are expected to know and be able to do by the time of graduation. These relate to the skills, knowledge and behaviors that students acquire as they progress through the program.

In fact nowadays, the term "student outcomes" is subject to different explanations and definitions. It refers typically to either (1) the desired learning objectives or standards that schools and teachers want students to achieve, or (2) the educational, societal, and life effects that result from students being educated. In the first case, student outcomes are the intended goals of a course, program, or learning experience; in the second case, student outcomes are the actual results that students either achieve or fail to achieve during their education or later on in life. The terms learning outcomes and educational outcomes are common synonyms. (See appendix 2).

For a good start of QFD application, an illustration of the main components of the house of quality is in Figure 1 [1] which will be filled in by the items of our case study.

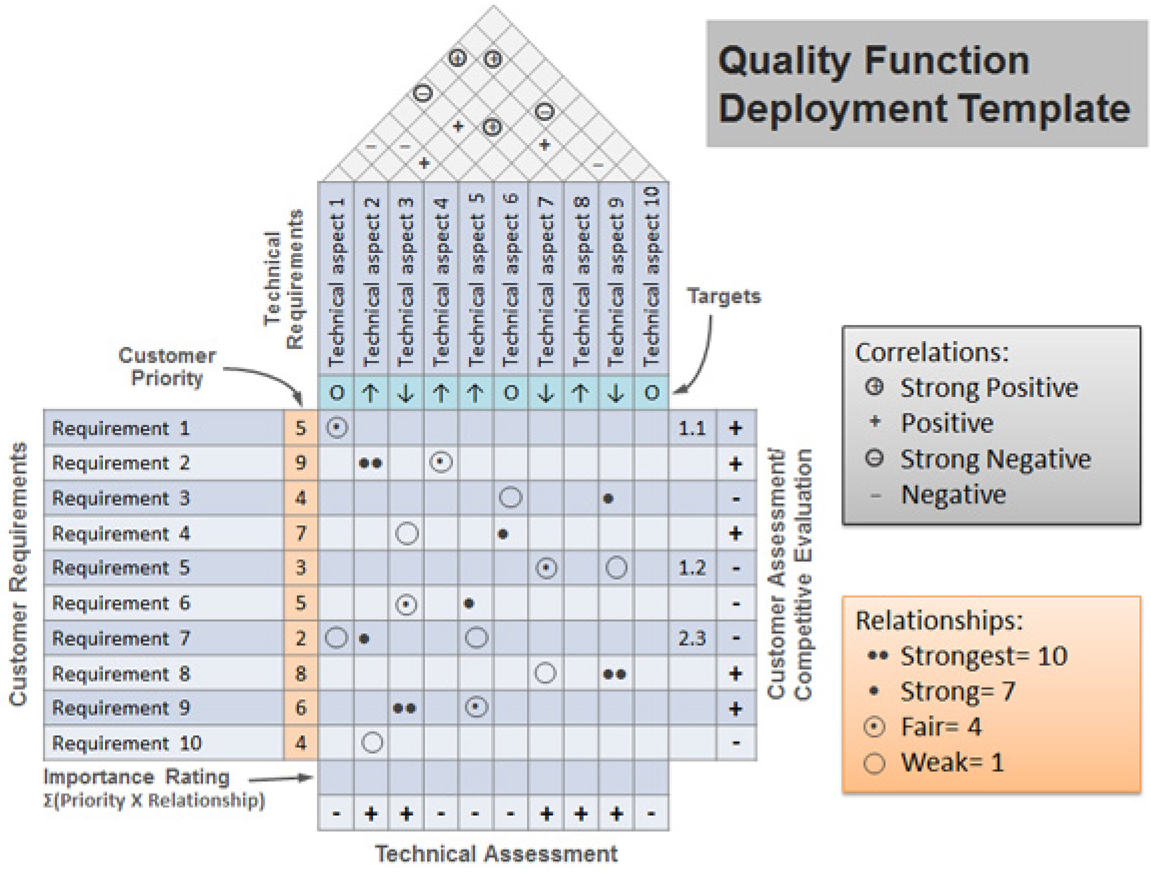


Figure 1. Quality Function Deployment Template

4.1. Filling in the House of Quality

The first key element of any QFD chart is the list of customer requirements (WHAT's). They are already mentioned in Table 1 and prioritized by course instructor. It is important to know that this list can be refined into the next level of detail by elaborating primary requirements to secondary and tertiary requirements [6].

The second key element is the list of technical requirements (HOW's). As stated above in the text these are Student Outcomes issued by ABET Inc.

The third key element of any QFD chart is the RELATIOSHIPS between (WHAT's) and (HOW's). However, attempting to trace the relationships of (WHAT's) and (HOW's) becomes quite confusing. We need a way of untangling this complex web of relationships. One way to reduce this confusion is to turn the HOW list perpendicular to the WHAT list and defining the relationships in a matrix enclosed by the rectangular region. A symbol or its equivalent number (value) is placed at the intersections of the WHAT's and HOW's which are related. This method allows very complex relationships to be depicted and easily interpreted. This also permits us to cross check our thinking. Blank row indicates a certain concept included in the course content is of no benefits to graduate engineer. Also a blank column indicates a certain student outcome is of no relationship with any concept developed in the course. This is against our objective which is graduating engineers characterized by maximum number of ABET requirements for accreditation.

The fourth key element of any QFD chart is the HOW MUCH section. These are the measurements for the HOWs. These target values should represent how good we have to be to satisfy the customer and not necessarily current performance levels. We want HOW MUCH's for two reasons:

- To provide an objective means of assuring that requirements have been met
- To provide targets for further detailed development

The HOW MUCH's therefore provide specific objectives which guide the subsequent curriculum development and modification and afford a means of objectively assessing progress towards accreditation. For this reason the HOW MUCH's should be measurable as much as possible, because measurable items provide more opportunity for analysis and optimization than do non-measurable items. This aspect provides another cross check on our thinking. If most of the HOW MUCH's are not measurable then we have not been detailed and understood enough the ideas behind the HOWs.

In summary, these four key elements (WHAT, HOW, RELATIOSHIPS, HOW MUCH) form the foundation of QFD and can be found on any QFD chart.

4.2. Correlation Matrix

There are several useful extensions to the basic QFD charts which greatly enhance their usefulness. These are used as required, according to the content and purpose of each particular project. The correlation matrix is a triangular table often attached to the HOWs, establishing the correlation between each HOW item. The purpose of this roof-like structure is to identify areas where trade-off decisions and research and development may be required. As in the **Relationship Matrix,** symbols are used to describe the strength and type of the relationships, (Figure 1). We are then able to identify which of the HOWs support one another, and which are in conflict.

In this case study, positive correlations are welcome. This means we determine one HOW supports another HOW. This is important because we may gain some resource efficiencies, for example time, by not duplicating efforts to attain the same result. But also the negative side of such positive correlations is that if we take an action which adversely affects one HOW, it may have a degrading effect on the other.

Negative correlations are those in which one HOW adversely affects the achievement of another HOW. These conflicts are extremely important, they represent conditions in which trade-offs are suggested. In our case, negative correlations do not exist because the HOW s are developed with such purpose.

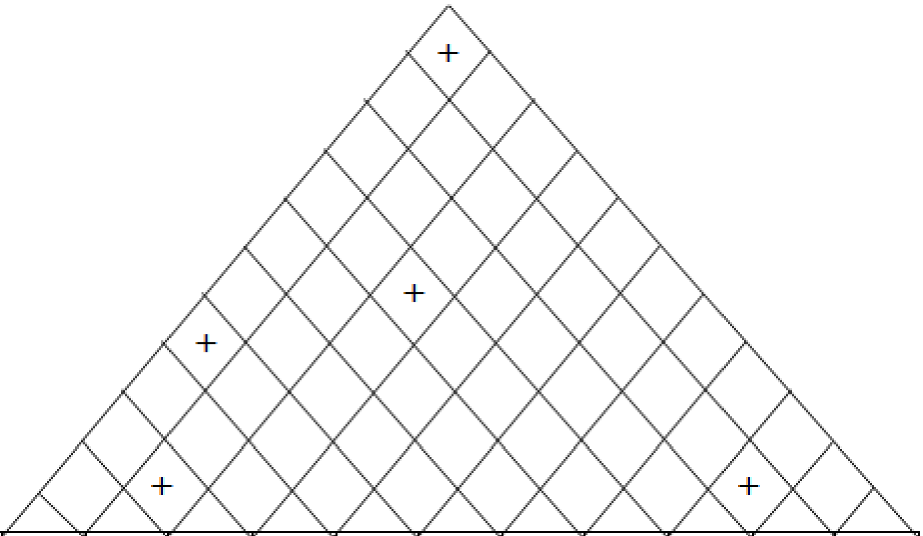
4.3. Analysis of the House of Quality

The House of Quality, Figure 2, is showing several negative results to be treated which are as follows:

a) Four technical requirements (a, d, f, g) are not considered absolutely in this course. The problem becomes very critical when most 400 and 500 level courses miss the same technical requirement.

b) The HOW MUCH shows grade given to each technical requirement. For example, technical requirement (I) has the highest grade. This is our target. However, in quizzes, and exams we test students 'understanding and knowledge of Learning Outcomes of the course. It is proposed to have a clear question in final exam or asking student to write a statement to explain the relationships between the course content and some very important technical requirements.

c) The grades of requirements (b), (j) and (k) are respectively 70, 96, and 32 are considered low and very low. This represents a weak relationship between course content and a valuable number of technical requirements. The problem becomes very serious if these technical requirements are added to (a, d, f, g) requirements.



CP	a	b	c	d	e	f	g	h	i	j	k
10		7	10					4	4	4	
7			7		4			1	10		
5								4	10		
8			10		4			7	4	4	4
6					10			4	7	4	
		70	229		120			147		96	32
	HOW MUCH-Technical Assessment										

TR

Figure 2. The House of Quality

d) Learning Outcomes are prioritized by course instructor. We assume technical requirements have the same importance or priority. By logic, the most important learning outcome should have relationships with the maximum number of technical requirements which is not true in our case. Typically, the first learning outcome has the highest priority and it is meeting five technical requirements. However, the fourth learning outcome is meeting six technical requirements. Here the question of the type, nature, elements and properties of prioritization criteria becomes eligible and very important.

e) It was noted in the Correlation Matrix section that in our case, negative correlations do not exist because the HOW s are developed with such purpose. However, it is important to mention that the absence of one Student Outcome will affect negatively the achievement of other one. Typically, the absence of Student Outcome (g) [An ability to communicate effectively] will make Student Outcome (d) [An ability to function on multidisciplinary teams] not realised.

f) As instructors we have an academic understanding of all Student Outcomes. However, the factors behind the difficulty of achievement of Student Outcome (d) [An ability to function on multidisciplinary teams] can be sometimes psychological based on racism, religion, colour etc. Quality function Deployment has no mechanism to solve such problems, neither the actual procedure followed by some universities and colleges to fulfil ABET requirements.

g) Student outcomes describe what students are expected to know and be able to do by the time of graduation. Assuming we are grading a 200-level course class in accordance with today students' performance. The question is how to evaluate students' knowledge at graduation which may be in seven years? I suggest multiplying the recent grade by a "deterioration coefficient of knowledge with years" which should be less than one. A research should be done in this field to come out with a realistic value for this coefficient.

5. Concluding Remarks

In this paper, the application of the QFD to a mechanical engineering course with a target to meet ABET requirements revealed important issues, steps and changes to be considered by faculty members at both levels: structure and application of the procedure.

Clear criteria are needed for the prioritization of Learning Outcomes developed in the course. The relationships between Learning Outcomes and Student Outcomes, developed by ABET should be clear and correctly evaluated. This will lead to build up the HOW MUCH which will give a weight to each Student Outcome in the course.

Finally, the objective of engineering academic institutions and colleges is to make from student an innovative engineer – person. This is always possible if we treat correctly academic and sometimes psychological factors affecting student's performance.

References

[1] Akao, Y. 1990. Quality Function Deployment: Integrating Customer Requirements into product design, G.H Mazur (trans) Cambridge, M.A: Productivity Press.

[2] Hochman, S. D. and P.A. O'Connell. 1993. "Quality Function Deployment-Using the customer to outperform competition on Environmental Design, "Proceedings of the Electronics and Environment, New York: IEEE.

[3] Cristofari, M., Deshmukh, A. and Wang, B., 1996, "Green QFD". Proceedings of the 4th International Conference on Environmentally conscious design and manufacturing, July 23-25, Cleveland, Ohio.

[4] Zhang, C. et al." Green QFD-II: a life cycle approach for environmentally conscious manufacturing by integrating LCA and LCC into QFD matrices", International Journal of Production Research, March 1999.

[5] Fiksel, J., 1996, Design for Environment, Creating Eco-Efficient Products and Process, (McGraw-Hill).

[6] Francis F. Kaebernick H. 2000."ECQFD-An Approach to Product Planning Under Environmental considerations", ICME, 2000, Sydney, Australia.

[7] Hauser, J. R. and D. P. Clausing. 1988. "The House of Quality", Harvard Business Review, May/June.

[8] Hauser, J. F. 1993. "How Puritan Bennet used the House of Quality," Sloan Management Review, Spring.

[9] Art Slotkin (2010). "A Centennial of Auburn Engineering: From Red Clay to Red Satellite". Auburn Engineering (Auburn University) 19 (2): pp.20-27. Retrieved 2012-01-08. (p.24) ...what we know today as ABET, the accrediting body for college and university programs in applied science, computing, engineering, and technology.

[10] Bucciarelli, Louis L.; Coyle, Eugene; McGrath, Denis (2009). "Chapter 5: Engineering Education in the US and the EU".

[11] ABET (Accreditation Board for Engineering and Technology). Criteria for accrediting engineering programs: Effective for evaluations during the 2002–2003 accreditation cycles. _http://www.abet.org/images/ Criteria/2002-03EACCriteria.pdf_, accessed September 28, 2002.

[12] Adams, J.L. 1991. Flying buttresses, entropy, and o-rings: The world of an engineer. Cambridge: Harvard University Press.

[13] Adamy, D. 1987. Preparing and delivering effective technical presentations. Norwood, MA: Artech House, Inc.

[14] Aldridge, M.D., and L.D. Benefield. 1998. A model assessment plan. ASEE Prism. May–June 1998: 22-28.

Appendix1.

GMEN XXX syllabus

GMEN XXX – Joining Processes: Welding, Soldering and Brazing

Catalog description: Analysis of various joining processes, mechanisms of surface bonding, Welding metallurgy, effect of heat input on resulting microstructures, residual stresses and distortion, welding processes: MIG, TIG, Laser, electron beam, spot welding, and resistance welding.

Pre-requisite: MEN XXY, Manufacturing Processes.

Learning Outcomes and their correlation to Student Outcomes:**

Learning Outcomes	Correlation to Student Outcomes*	
	H	***L***
Distinguish between different joining processes	(c),(i)	(e),(h)
Evaluate the quality of joined parts	(c),(e),(i),(j),(k)	(h)
Grasp the fundamental principles of the operational safety	(b),(c),(h),(i),(j)	
Observe and apply various joining processes	(i)	(h)
Analyze the effect of joining operations on the material properties	(e),(i), (j)	(h)

* **H**: High Correlation **L**: Low Correlation

**(a) – (k) correspond to the Mechanical Engineering Student Outcomes.

Course topics:

No. of weeks	Topic covered	Reading assignment
1	Introduction to Joining Processes, Safety	Chapter 1
3	Fusion-Welding Processes	Chapter 2
3	Solid-State Welding Processes	Chapter 3
3	Brazing and soldering Processes	Chapter 4
3	The Metallurgy of Welding	Chapter5
1	Advanced Welding Processes	Chapter6
1	Special Processes (Robotics in Welding, Welding Pipe and tube)	Chapter7

Assessment measures:

Midterm exam (Chapters: 1, 2,3)	40%
Project	20%
Final Exam (Comprehensive)	40%
Total	100%

Prepared by / date:

XX, September 20xx

Appendix 2.

Student Outcomes

a. Ability to apply mathematics, science and engineering principles.
b. Ability to design and conduct experiments, analyze and interpret data.
c. Ability to design a system, component, or process to meet desired needs.
d. Ability to function on multidisciplinary teams.
e. Ability to identify, formulate and solve engineering problems.
f. Understanding of professional and ethical responsibility.
g. Ability to communicate effectively.
h. The broad education necessary to understand the impact of engineering solutions in a global and societal context.
i. Recognition of the need for and an ability to engage in life-long learning.
j. Knowledge of contemporary issues.
k. Ability to use the techniques, skills and modern engineering tools necessary for engineering practice.