Quality Function Deployment: *A review of methodology and case study*

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Abstract

This paper is intended to provide a broad understanding of Quality Function Deployment (QFD). It examines the development of QFD methodology, from its origins in Japan and adoption in industry to current research in design optimization. A detailed description of the House of Quality (HoQ) matrix is performed with a silent alarm system as a case study. This is an engineering project that aims to use a systems approach to create a safe workshop environment for the hearing impaired. Surveys of QFD users are used to examine its benefits and drawbacks. These conclusions are supported by a second case study: the implementation of QFD in a rubber plant gives insight into the opinion of factory employees in regards to this design process.

Literature Review

Quality function deployment was conceived by Yoji Akao in Japan, in the late 1960s who saw the need for quality control of the design process prior to production and published his ideas in 1972. Mizuno and Furukawa used Akao's theory to improve production at Mitsubishi's Kobe Shipyard. As more companies adopted these procedures, Akao's ideas evolved to form QFD, a methodology that converts user requirements into quality characteristics, and predetermined the quality of the finished product, its individual parts and production processes. (Akao, 1997, Chan and Wu, 2002b)

Toyota adopted QFD and reported a 61% reduction in start up costs from in 1984, in comparison to 1977. After gaining popularity in Japan, Clausing and Hauser published *The House of Quality* in the May-June 1988 Harvard Business Review. QFD gained much attention because of this and was adopted by companies such as Ford, General Motors and IBM. (Chan and Wu, 2002a) Quality function deployment eventually spread worldwide and is now used in wide range of industries.

Theory

The most common form of QFD is known as the Four Phase Model (Chan and Wu, 2002a). Each phase uses a similar matrix to determine the relationship between pairs of parameters that Chan (2002a) calls *WHAT*s and *HOW*s. Five sets of parameters are used: customer requirements, technical measures, parts characteristics, process operations, production requirements. Each of the four consecutive pairs is analysed as a *WHAT vs HOW*. This process is shown in Figure 1.

Quantitative assessment is used to determine the relative importance of these variables. Phase 1, named the 'House of Quality' (HoQ), is especially important as it takes customer needs into account. A detailed HoQ analysis is shown in the silent alarm case study. Phases 2-4 are concerned with improving the quality of production.

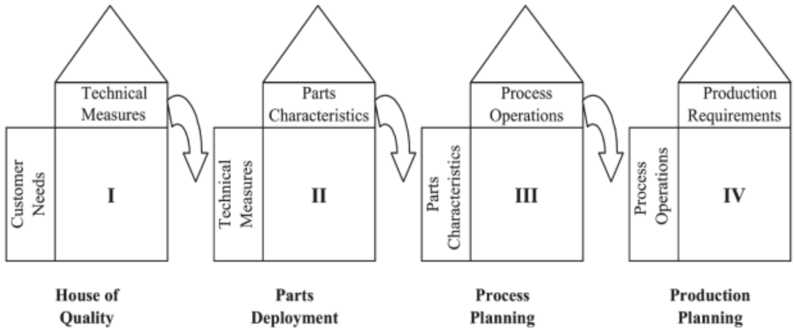


Figure 1. The Four Phase Model of QFD (Chan and Wu, 2002a)

Case Study: *QFD Application to a Silent Alarm System*

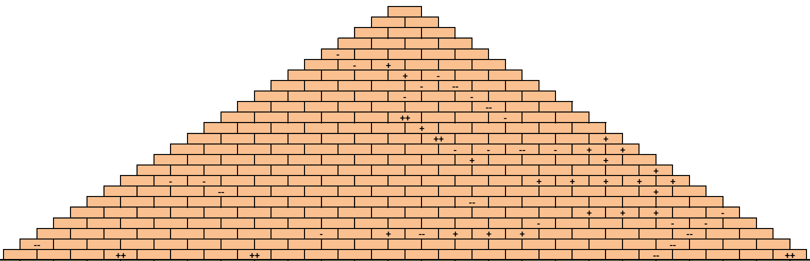
QFD was applied to a systems engineering project: "to use a systems approach to develop an effective silent alarm system that ensures a safe workshop environment for the totally hearing impaired." One design option was a proximity sensing system which involves the user wearing a wristband which vibrates when they are within the vicinity of a potential hazard. Transmitters located near these hazards output a signal that stimulates this vibration. A central unit delivers a different signal which alerts the user in the event of an evacuation. The system's HoQ diagram is shown in Figure 2. What follows is a description of how the matrix was completed.

1. **Customer requirements** were defined and rated from 1-10 and from this their relative importance was calculated.
2. **Technical measures** were listed, including units and direction of improvement. The relationship between these was analyzed in the 'roof' section. (++ ; strong positive,+ ; weak positive,(none) ; no correlation, - ; weak negative, -- ; strong negative)
3. The **planning matrix** was used to determine the final importance of customer requirements. First, competitor products were rated (1-5) by their ability to meet customer requirements. Products fulfilling the scope of the project could not be identified so comparable technologies were critiqued instead. Target ratings (1-5) for the project were made based on competitor ratings and customer requirement importance. Sales points - an indication of how meeting a customer requirement target would increase the attractiveness of the system to potential buyers - were determined (1.00: weak, 1.25: moderate, 1.5: strong) The weighting of each customer requirement was calculated with the formula: $weighting = relative\ importance\ \times$

Target Rating $\times$ *Sales Point*. The final importance of each customer requirement was calculated as its percentage of the total weighting. In QFD methodology, if the company has an existing technology, it will be rated and an improvement factor (IF) determined. ($IF = target\ rating - current\ product\ rating$)

4. **Interrelationships** between each customer requirement and each technical measure were assigned a value (9: strong, 3: moderate, 1: weak, 0: none).
5. The **Technical Matrix** was used to examine the technical measures. A target value for each technical measure and the degree of difficulty (1-10) in achieving this value were determined. Some target values could not be determined, for example - the transmitter signal frequency. However, it was assumed that the difficulty into achieving an appropriate value would be low, and assigned this a value of 1. A technical point (same as sales point) for each technical measure was determined.

   An initial weighing of each technical measure was determined by multiplying its relationship with each customer requirement by the final importance of the customer requirement and summing these products. The final weighing was determined with the formula: $final\ weighting = weighting \times technical\ point \times difficulty$. The final importance was determined as a percentage of the total weighting.



Relative Importance	Importance (1-10)			Technical Measures / Customer Requirements	Central Unit Signal Frequency	Central Unit Signal Amplitude	Transmitter Signal frequency	Tranmitter Signal Amplitude Range	Degree of Accuracy	Waterproof	Conductivity	Toughness	Vibration	Power Consumption - Central Unit	Battery Life - Portable Transmitter	Battery Life - Wristband	Dimensions of Central Unit
				Direction of Improvement	X	↑	X	↑	↓	↑	↓	↑	↑	↓	↑	↑	↓
				Units	Hz	Db	Hz	Db	m	Pa	W/m/K	J/m^3	N/Hz/m	kWh	hours	hours	mxmxm
13.9%	10.0	Performance	reliably alerts user	Functional	9	9	9	9	9	1	1	1	9		9	9	
12.5%	9.0	Performance	reliably alerts user	Reliable	9	9	9	9	9	9	9	9	3	1	9	9	
12.5%	9.0	Performance	lasts long time	Robust			3	3	1	9	9	9	3	1			1
9.7%	7.0	Performance	lasts long time	Accurate	1	3	3	9	9	1	1	1			9	9	1
11.1%	8.0	Performance	lasts long time	Non-Invasive to User	1		1										
8.3%	6.0	Usability	easy to use	Un-obtrusive to User							3		9			3	
8.3%	6.0	Usability	easy to use	Un-obtrusive in workshop	1		1							1	3	3	9
5.6%	4.0	Usability	easy to use	Easily Implemented													9
5.6%	4.0	Usability	easy to implement	Adaptable	3		3	9		1	1	1			1		9
4.2%	3.0	Usability	easy to implement	Cost Effective	1	1	1	1	1	3	3	3	1	9	1	1	3
1.4%	1.0	Usability	looks good	Aesthetics						1	1	1			1	3	1
6.9%	5.0	Usability	cost effective	Long Lifetime						9	9	9	3		3	3	
				Weighting	3.22	3.09	3.82	4.24	3.71	3.79	4.03	3.79	3.41	0.59	4.04	4.28	1.44
				Targets					0.1						24	8	0.5x0.5x0.5
				Technical Points	1.00	1.25	1.00	1.25	1.25	1.25	1.25	1.50	1.50	1.25	1.50	1.50	1.00
				Difficulty (out of 5)	1	1	1	5	3	4	5	8	7	5	7	8	2
				Product	3.2167	3.8661	3.8192	26.524	13.899	18.93	25.218	45.433	35.784	3.6795	42.424	51.363	2.8889
				Final Importance	**0.7%**	**0.8%**	**0.8%**	**5.7%**	**3.0%**	**4.1%**	**5.4%**	**9.8%**	**7.7%**	**0.8%**	**9.1%**	**11.1%**	**0.6%**

Customer Requirements	Dimensions of Transmitter	Dimensions of Wristband	Weight of Central Unit	Weight of Transmitter	Weight of Wristband	Wristband Strap Length Range	Lifespan	Production Cost - Central Unit	Production Cost Transmitter	Production Cost - Wristband	Installation Cost	Installation Time	Planning Matrix: Rating (1-5) GPS Watch	Lark Silent Alarm	Parksafe Sensors	Target Rating	Sales Point (1.00 - 1.25 - 1.50)	Weighting	Importance
Direction of Improvement	↓	↓	↓	↓	↓	↑	↑	↓	↓	↓	↓	↓							
Units	mxmxm	mxmxm	kg	kg	kg	m	years	$	$	$	$ + $/transmitter	hours + hours/transmitter							
Functional							3	3	3	3			0	0	4	5	1.50	1.0417	16.6%
Reliable							9	3	3	3			5	3	3	5	1.50	0.9375	14.9%
Robust	1	1					9	3	3	3			5	3	3	5	1.50	0.9375	14.9%
Accurate							9	3	3	3			1	0	2	4	1.25	0.4861	7.7%
Non-Invasive to User		9			3	9							5	5	5	5	1.50	0.8333	13.3%
Un-obtrusive to User		9			9	3				1			5	5	3	5	1.25	0.5208	8.3%
Un-obtrusive in workshop	9		9	3				1	1		9	9	2	5	3	4	1.25	0.4167	6.6%
Easily Implemented	9	1	9	3	3	3		3	3	3	9	9	1	3	2	3	1.25	0.2083	3.3%
Adaptable	9	1	9	3	3	9		3	3	3	3		1	5	1	3	1.00	0.1667	2.7%
Cost Effective	3	3	3	3	1	1	9	9	9	9	9	1	3	4	1	3	1.25	0.1563	2.5%
Aesthetics	1	9				1				9			5	4	3	4	1.00	0.0556	0.9%
Long Lifetime							9	3	3	3	1	1	5	4	3	5	1.50	0.5208	8.3%
Weighting	1.37	2.30	1.21	0.45	1.35	1.81	4.85	2.34	2.34	2.44	1.28	1.00							
Targets	0.05x0.05x0.02	0.04x0.04x0.01	10	0.25	0.1	0.15-0.3	10												
Technical Points	1.50	1.50	1.00	1.25	1.50	1.25	1.50	1.25	1.25	1.25	1.00	1.25							
Difficulty (out of 5)	7	7	2	5	6	2	9	5	5	5	5	8							
Product	14.354	24.187	2.4179	2.8296	12.134	4.537	65.485	14.646	14.646	15.247	6.4096	10.033							
Final Importance	**3.1%**	**5.2%**	**0.5%**	**0.6%**	**2.6%**	**1.0%**	**14.1%**	**3.2%**	**3.2%**	**3.3%**	**1.4%**	**2.2%**							

Figure 2. House of Quality Analysis of Proximity Sensor System

The HoQ analysis suggests that functionality, reliability and robustness are important customer requirements. Significant technical measures are lifespan and battery life of the wristband and transmitter. This matrix is a powerful tool in tradeoff analysis. For example, the technical measure '*dimensions of transmitter'* has a strong relationship with many other technical measures, so changing its value will have many effects. Reducing this value will have an effect on the technical measure '*battery life of transmitter'* so a tradeoff for optimum design must be determined.

Case Study: *QFD in the Indiar Block Rubber Factory*

Kathiravan et al performed a theoretical application of the QFD process to improve production at the *Indiar Block Rubber Factory* in India. Indiar buys raw rubber from farmers and processes it into 'crumb rubber', which is sold to companies such as Goodyear. They modified the traditional QFD methodology, using employee input to drive later phases of the QFD model. (Kathiravan et al., 2008)

Kathiravan et al were not able to speak to any customers directly. Instead, the factory manager compiled customer feedback such as 'Non uniform drying of ISNR 20' which allowed them to gauge customer requirements.

A product development matrix was used to recommend changes to the production processes. Targets were identified, and detailed procedures for bringing these changes into effect were determined. These were formulated into new protocols for plant workers.

Employee feedback shows their opinion of the QFD process. This comment from the assistant manager of the plant summarises the overall response: *'The methodology is new and good, but its implementation in our industry is little difficult. There are practical problems in implementing it. But, if implemented, it can have fruitful effects. Getting the involvement of all levels of people is rather difficult.'* (Kathiravan et al., 2008, p. 64)

Quality function deployment is a worthwhile process, but a difficult one. This case study suggests that its success depends on the importance that it is given as it requires input from many people.

Discussion

The benefits of performing QFD are dependent on the user and thus vary significantly from company to company. Surveys show 80% of QFD users report quantitative improvements such as a better understanding of customer needs, improved communication within company branches and more efficient decision making. When implemented correctly, QFD has been reported to provide "30-50% reduction in engineering changes, 30-50% shorter design cycles, 20-60% lower start-up costs and 20-50% fewer warranty claims". (Chan and Wu, 2002a)

Cristiano et al (2000) studied the effectiveness of QFD in a large sample of Japanese and US companies, noting significant differences in the way QFD was implemented in the two countries. In the US, QFD was given more support from management, a wide range of inter-departmental involvement and significant attention to consumer data acquisition. US companies reported a higher degree of satisfaction with QFD benefits than Japanese companies, who instead were focused on creating a wider set of matrices. Kathiravan (2008) suggests that some users spend too much effort creating QFD charts, and neglect to properly survey customer needs and communicate effectively between departments. It is these activities which change company thinking and promote teamwork, that make QFD beneficial.

An important aspect of QFD is tradeoff analysis. Examining the relationship between Chan's *HOW*s provides an insight into which targets are important to reach, and where compromises can be made. QFD researchers such as Park and Kim (1998) have used linear regression to determine optimum design solutions, reducing the error inherent in human opinion. Kahraman et al. (2006) improved this model using *fuzzy sets* to account for uncertainty in customer requirements. These methods are not widely used in industry (Cristiano et al., 2000) but promise to improve QFD in the future.

Conclusion

Since its development in Japan, QFD has evolved into a powerful tool for improving product design by focusing on customer requirements. Though it is a process that requires significant attention, performing QFD correctly can yield significant benefits, as shown by Chan et al and Cristiano et al. The employee feedback from Kathiravan's Indiar case study reflects how difficult QFD can be to implement. A detailed description of a HoQ is shown in the application of QFD to the silent alarm project. This highlights the benefits of QFD to tradeoff analysis. Current research into mathematical optimization of tradeoff analysis promises to improve the QFD methodology.

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Peer Review Comments

Ye Wang - u5225572

Demonstrates that formatting requirements have been met:

Honestly speaking, it is a very detailed individual research report on conceptual system design with all formatting requirements appropriate met. When the author has covered all required components with clear clarification, however, it seems that the report exceeds the words limitation. Additionally, there are some little flaws such as a confusing underline in line 7 of page 2 and a repeating of "according to" in the next-to-last line of page 3.

All in all, although some flaws exist, yet they cannot deny the fact that it is an excellent report.

Demonstrates a correct understanding of the theory:

Obviously, the author has a deep understanding of the theory which can be concluded from the HoQ matrix he generated as good application always indicates equally good understand of the theory. Furthermore, what he wrote in discussion section about the inappropriate use of QFD which ignores customer needs and effective communication between departments can be helpful instructions for the practical implementation of QFD theory and it also implies that the author has gained a good understanding of the theory.

Application of the theory to the project:

The author has adopted an excellent application of QFD theory to silent alarm system project. Firstly, the train of thought for the design is given in details then how the HoQ matrix built and the analysis are showed. Besides, a trade-off example is given. But what really amazes me is the comprehensive HoQ matrix he built which is a good application example.

Quality and relevance of bibliography:

The majority of bibliographies are used in literature review and theory and the previous example and one is in discussion section.

In my point of view, all of them are used appropriately no matter for the use of helping author clarify the theory for readers or as factual argument to support author's views.

Suggestions on how could the paper be improved:

1. Reduce some components in literature review and theory and the previous example sections coul d be better,

they do not have to be so detailed. I think just making readers understand is enough.

2. The report could be more perfect if the flaws I mentioned above are eliminated.

3. It tends to be better if superscript instead of bracket could be used for bibliography.

Timothy Heaney – 5196617

Demonstrates that formatting requirements have been met:

Overall formatting is very good. The font and line spacing are used correctly. All the figures are captioned, referenced, and left aligned. Figures are also referred to in the main text. Headings and sub headings are good. I suggest that the main body of text be justified. It is left aligned at the moment. Also the document exceeds the five page limit. To try and reduce the number of pages, the margins could be increased slightly so they are closer to 2cm, which would fit more text on to each page.

Demonstrates a correct understanding of the theory:

Montiel shows a sound understanding of the theory of quality function deployment. The literature review and example case study are both good. If anything, the theory section could be made more concise to try and reduce the page count. The discussion of relevance and benefits of quality function deployment is excellent.

Application of the theory to the project:

QFD theory is applied well to the silent alarm systems engineering project. An extensive house of quality diagram is presented. One minor gripe; far too many technical measures were included in the HoQ. This means the one diagram takes up a whole page. You can't really afford to do this in a 5 page document. This is understandable though, as this can't be edited due to it being a part of the group project and it would probably take up more space if it was explained without the diagram.

Quality and relevance of bibliography:

Harvard referencing is correctly implemented and relevant. The in text referencing is good. In the bibliography don't use 'et al.' List all the authors fully. Only use 'et al.' for in text referencing.

Suggestions on how could the paper be improved:

The flow of ideas could be improved. I suggest switching the order of the two case studies around. The flow would then be history, theory, use in project, use in companies and finally discussion. There are a few grammatical errors scattered throughout the paper. For example the last line of the third paragraph in the literature review and theory section is an incomplete sentence. In the first paragraph of the same section, the final sentence is missing the word ‘what’. I suggest thoroughly proof reading your report by hand before submitting to pick up on minor errors such as this. In terms of which bits to cut due to the length of the paper, possibly make the description of quality function deployment theory more concise. Also, find a way to make the HoQ take up less space. For example maybe rotate it so it only takes up half the page. Even though this would make it unreadable, markers should be able to zoom in on the PDF document to read it.