A Case Study on The Implementation of Quality Function Deployment (QFD) in The Canal Reconstruction along Crude Oil Pipeline in Indonesia[1]

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Abstract

Changing in scope during construction phase is the most common problems causing project delays among Indonesian contractors. Most of the scope changing is due to poor engagement with customer and to a failure in identifying customers' needs during project scoping.

This paper aims to examine the aptness of QFD using HOQ in project planning and designing to guarantee that both the project requirements and project scope accommodate all the customer requirements, and to demonstrate the use of QFD during construction phases in a real project management implementation as control tools in the project construction.

The result of the QFD implementation using HOQ showed that 25 detailed final project scopes were developed from traditionally-generated nine project scopes.

It is concluded that the QFD is proven as a quality road map tools to help a project manager navigate the planning and construction process in project management. In addition, QFD is useful as smart sensitivity check when there are changes in the project requirements as all evolution in design is recorded from the beginning so that any alteration during the process of project planning is traceable.

Keywords: *Quality Function Deployment, Customer Requirements, House of Quality*

Introduction

Changing project scope during construction phase is common in Indonesia, with most of additional scopes inserted during the construction phase. The change always results in additional project cost and leads to project delay. To avoid both additional cost and project delay, some contractors will simply accept the additional scope of work by compromising quality, that is, by selecting minimal acceptable quality material in order to reduce cost and to recognize the substantial quality immediately after the work is complete is difficult. In one of the researches in the past, the author

[1] *This paper was prepared as a result of a course delivered by Dr Paul Giammalvo of PT Mitratata Citragraha in Jakarta, Indonesia. The paper was submitted to the Association for the Advancement of Cost Engineering International (AACEi) in partial fulfillment of the Certified Cost Professional (CCP) requirements.* http://www.aacei.org/cert/whatCertOffers.shtml .

analyzed 40 projects from 10 contractors in Indonesia to assess the project performances and root causes of project delays.

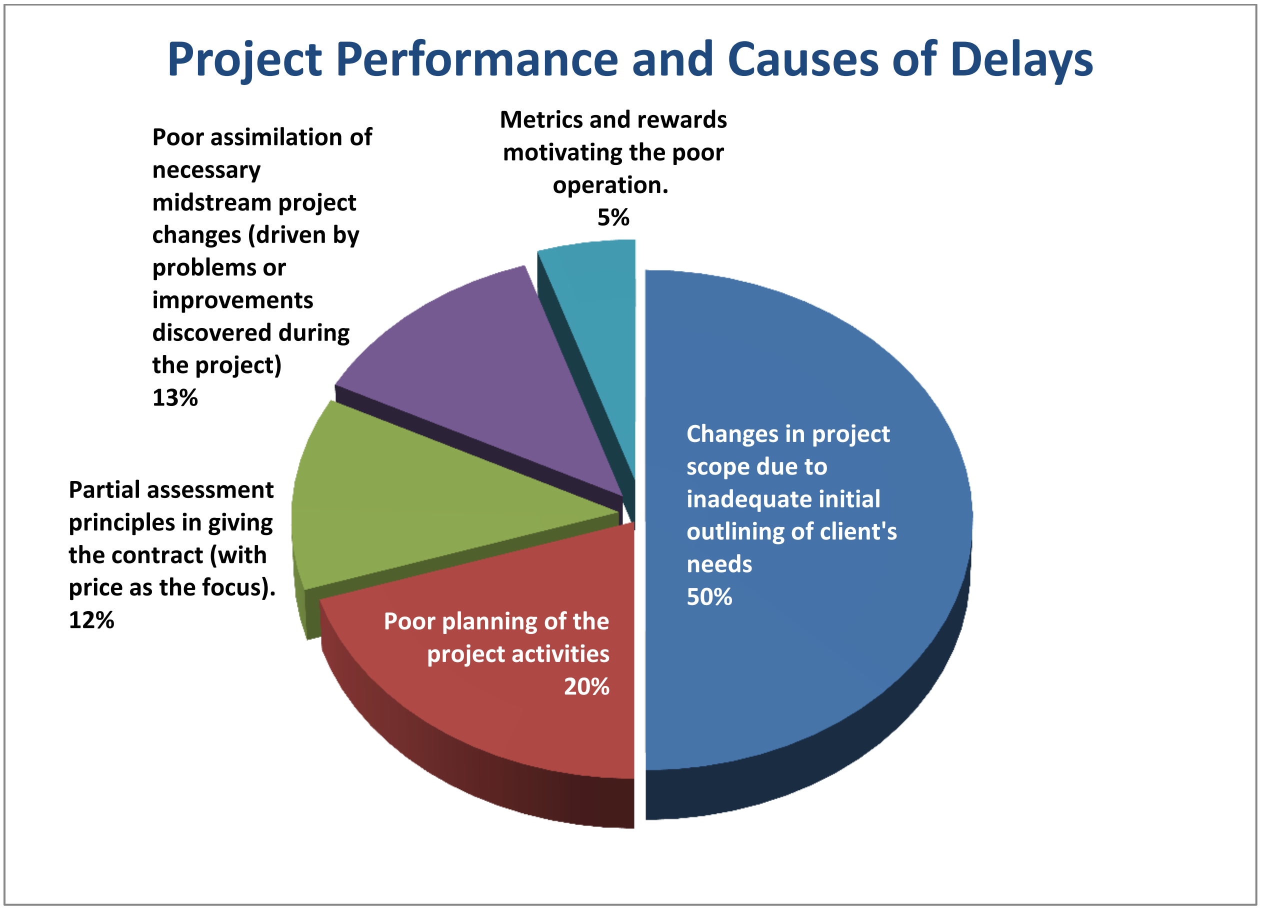


Figure 1 –Project Performance and Causes of Delay[2]

More specifically, the research shows that most project delays are due to changes in project scope and project objectives, which are the direct results of poor outlining of customer needs from the start. Such a poor identification of customer/stakeholder will lead to changes in project scope and any scope changes during the construction phase will result in project delay.

Objective of Study

In this paper, the author attempts to examine the general applicability of the QFD method in a construction project, especially throughout the planning and designing, to ensure all customer demands are included in project requirement and scope. In particular, the author tries to demonstrate the QFD implementation during construction phases in project management as

[2] Author's previous research

control tools throughout the project construction phase. The technique used is the House of Quality (HOQ), and to achieve this objective, the author adopted a three-stage research method:

1. Reviewing the framework of the QFD
2. Describing the steps of using QFD
3. Reporting a case study on the QFD implementation in a real project

Quality Function Deployment (QFD): A Summary

QFD is a method for quality assurance in identifying customer requirements (Voice of Customer, hereinafter VOC) and transferring them through the design and technical requirements (Voice of Engineer, hereinafter VOE) of every project management phase and construction processes. It is also known as integrated managerial method in improving and assuring the alignment of construction development and elements of design with the general requirements of construction project. In QFD, both voice of customer and the prioritization of customer requirements to create high quality products are highly emphasized from the start of the designing phase. QFD also represents a systematic method to map the VOE into definite, assessable parameters of both process and product through a set of matrices as well as other qualitative and quantitative procedures.

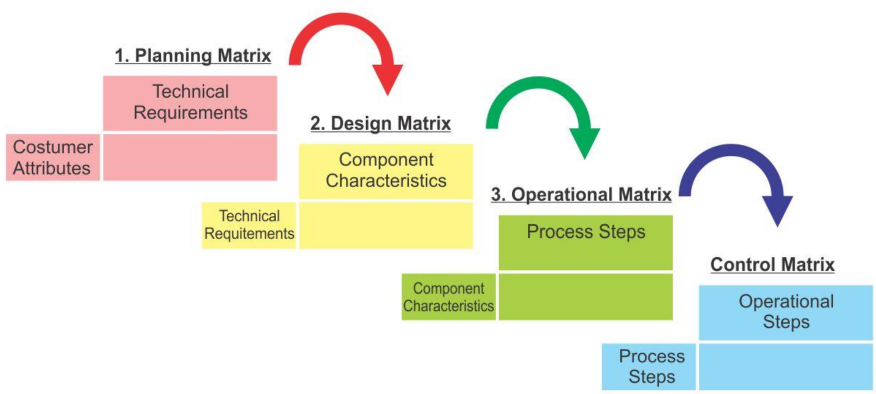


Figure 2 – The Four Phases of QFD[3]

QFD brings the voice of customer (VOE) systematically to the level of detailed operations. QFD translates the VOC into voice of engineer (VOE), which translates further to subsequent component characteristics, stages and operational procedures (Figure 2). The tool for such translation is called "House of Quality (HOQ)" (Figure 3), represented by a matrix delineating the inter-functional planning and communications.

[3]Yang*et al*.(2003). Coloring by the author of this paper for visibility and item differentiation from one another.

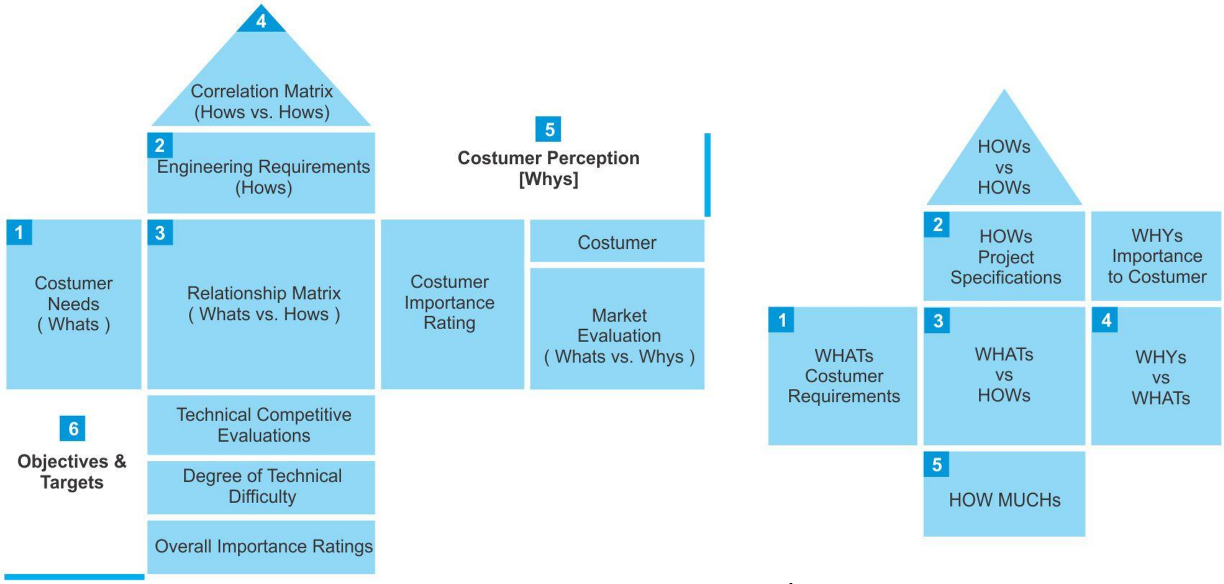


Figure 3– House of Quality[4]

QFD shows a structured methodology to accomplish the VOC. Meanwhile, considered as QFD's most important part, HOQ is primarily developed by identifying the VOE for the product/service that are needed to meet VOC and through specifying the relationship between them.

As shown in Figure 3, the HOQ is developed using six elements:

1. Customers' requirements and assessment (Voice of Customers)
2. Engineering and technical requirements (Voice of Engineers)
3. The relationship or effect of the engineering requirements on customer's needs (center)
4. The technical correlations of engineering requirements (shown by the roof part)
5. Customer perceptions as well as market benchmark study
6. Design objectives/priorities and targets.

House of Quality results offer the basic design with specific information related to product/service enhancements to be implemented in an attempt to fulfill the voice of customer (Figure 3). HOQ helps a project manager during construction phase to properly identify and respond to voice of customer, more thorough up-front planning, and to cut the cycle time through less design revisions and better communication across functions.

[4] Al-Aomar, et al., (2012). Coloring by the author to differentiate number from items.

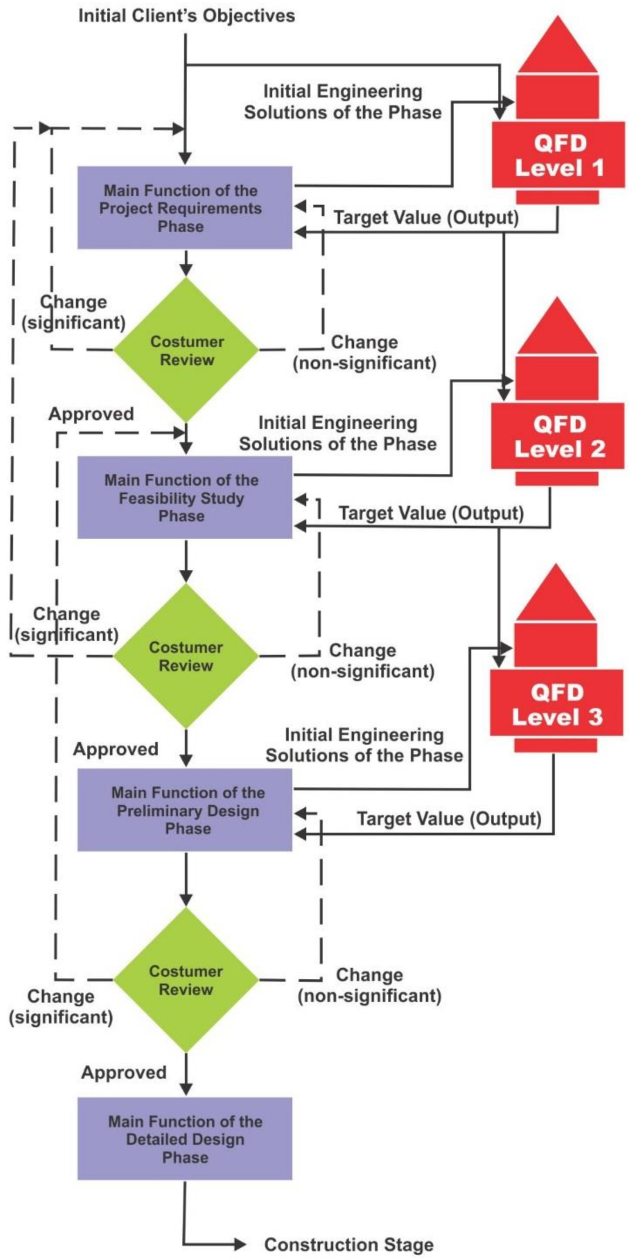


Figure 4–Process of Project Planning as Represented in QFD[5]

To follow Tsuen-Ho,[6] a representation diagram combining the process in QFD and that in the project planning is illustrated in Figure 4. Part of the diagram in green and indigo is the process of project planning while that in red is the QFD process. The idea of the representation is that it is possible to use QFD method in line with each project planning stage so that the quality of the output of each stage can be enhanced.

[5] Govers,Cor P. M. (2000). Coloring by the author of this paper to clarify and differentiate items from one another
[6] Tsuen-Ho (2011).

One should note that the diagram left out QFD in the phase of detailed designing as in the phase, the functions aimed to the project decision should have taken its final shape. The remaining work includes the development of construction drawing and formulation of engineering specifications and details, which convert the plan into contract papers. Thus, the QFD use is limited to discrete purposes only.

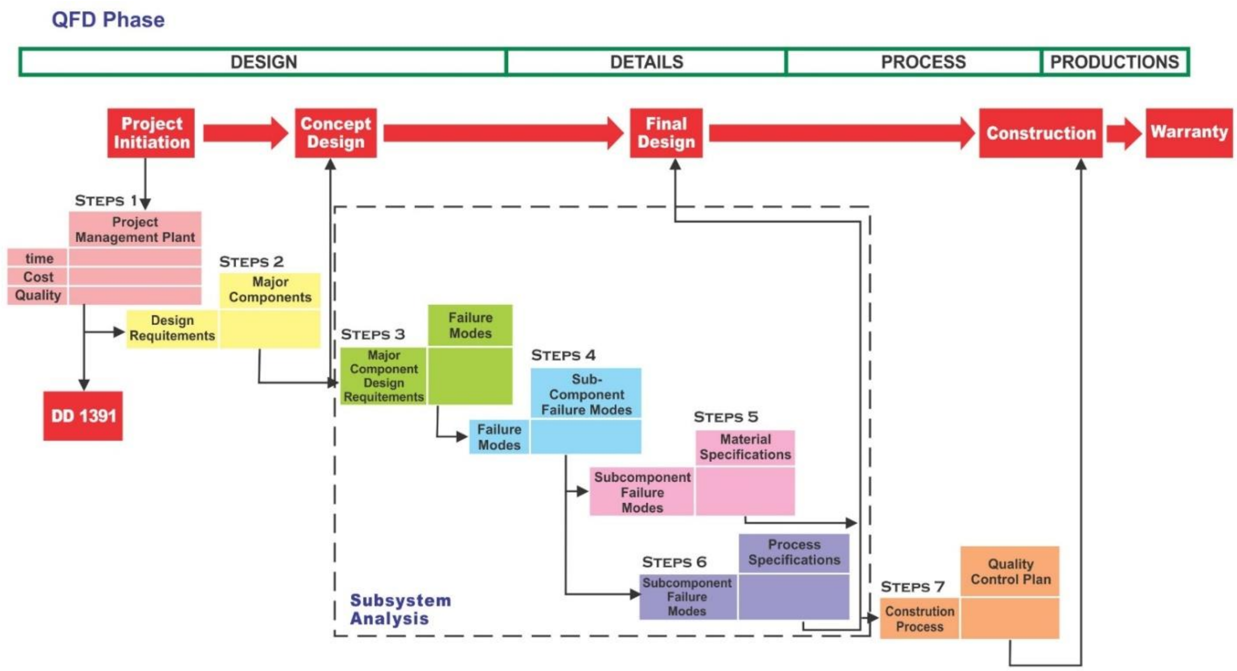


Figure 5 – QFD Implementation by Project Phase[7]

In the planning and designing phases, the client's idea is translated into a complete design. Such translation process will include planning and design, while the construction and implementation phase is broken down into bidding, procurement and construction, set up expenses, project process, and project finalization. The sub-stages can be in the form of sequences, where the end of one sub-stage means the start of the subsequent sub-stage, or there may be some overlapping between sub-stages. In addition, some of the sub-stages may be brought together with others or, on certain project, may not be performed at all.[8]

Steps of QFD Implementation

On House of Quality Matrix, the use of Quality Function Deployments includes five steps:

[7] *ibid*
[8] Ahmed et al, (2003)

1. Identifying the voice of consumer (WHATS) (Figure 2)

The project team works together on defining the product that reflects the clients' needs in their own language, as well as the grade that they demand of the product they want. The voice of customer is drawn from various customer surveys, focused group discussion, and surveys of the satisfied/dissatisfied groups. Apart from targeting the end-user, the surveys also include non end-users groups, for example, property agencies and maintenance and operational staffs. The panel consolidates the pointers (by crossing out identical points and grouping the demands by affinity) and put them on the matrix's left. For a clearer description, each WHAT item has to be supplied with into one or more alternate points. As shown in Figure 6, a client's needs for good house are refined. Attention has to be carefully paid during the consolidation to maintain the voice of consumer in its original sense.

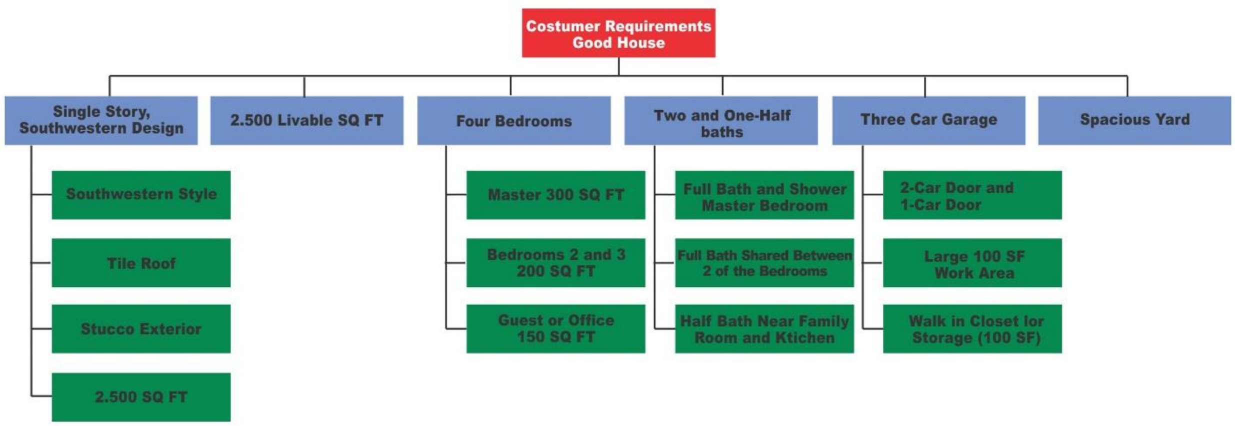


Figure 6– Defining Customer What[9]

2. Listing the project characteristics that will meet the voice of customer (HOWs) (Figure 3)

Project team determines which specifications are applicable for the project. VOC is then translated into VOE by faithfully referring to the consumer needs. HOWs represent things that the organization can control to make sure they can meet the VOC. After reviewing the various technical specifications, the panel assigns a value for each requirement that meets the VOC. The last thing to do in this step includes an evaluation to the relationship among HOWs (Figure 7), in which some correlations scales are assigned: zero (non-existent), strongly negative, negative, positive, or strongly positive.

Negative correlation occurs when a rise in one side makes another side go down, while positive correlation occurs when arise in one part will enhance the other. It is helpful to predict the consequences when a tradeoff between specifications is needed.

[9] Dodd (1997).

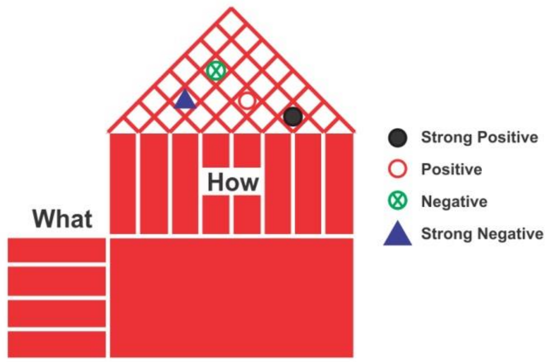


Figure 7– Correlation Matrix[10]

3. Determining the Relationship between Client's Needs (WHATs) and Project Characteristics (HOWs)

In this step, comparison between VOC and project specifications is carried out to decide how well the project details meet the voice of customer. Correlations between the two are regarded either strong, medium, or weak, represented by a value of 1, 3, or 9consecutively (Figure 8). Deficiencies(where customer demands are not satisfied by any specifications, or where unnecessary specifications reflect none of the customer requirements) are identified.

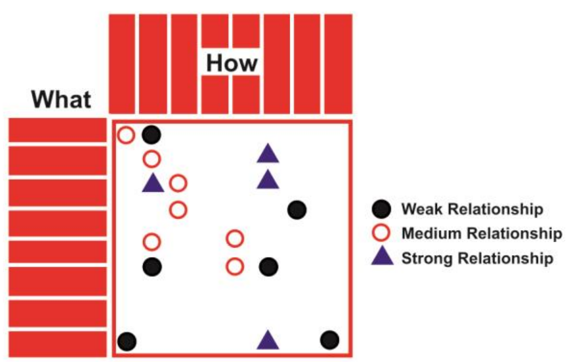


Figure 8–Whats vs Hows[11]

4. Evaluating the Market (WHYs)

The VOC that represents the customer requirements (WHATs) are graded from 1(least important) to 5 (most important) according to the customer point of view. Together with the customer, the team works to prioritize the list (Figure 3), with special attentions paid to make sure that no two customer-demands get the same scale of importance; otherwise,

[10] *Ibid.* Coloring by the author of this paper to clarify the border areas and symbols of correlations are reworked throughout this paper for consistency purposes.
[11] *Ibid.* Coloring and symbols by the present author.

none is eventually put into priority. The team will often use a technique of asking themselves 'if we have to fulfill just one demand, what would that be'. In addition, competitive evaluations are often employed to emphasize some exploitable shortcomings and strengths in the whole decision making process. Finally, to determine how the VOC (WHATs) is going to be prioritized, the team has to use the WHYs.

5. Determining the Targets (HOW MUCHs)

It means determining the target specification standards (HOW MUCHs) that represent the main concerns (WHYs). For each specification, Importance Factors (IFs) is assigned through multiplying all consolidated correlation rates as established in Step 3 by its scale of importance as in Step 4. Furthermore, IF is used to identify the most important product requirements to meet VOC and thus stricter controls has to be given. In succeeding stages of the QFD, the HOW MUCHs is used as the priority rating in deploying the HOWs (Figures 9). The final product, seen against the customer requirements, should represent a higher quality in terms of meeting the VOC and a lower cost in terms of creating product with too high specifications or requiring extra work to overcome an insufficiency.

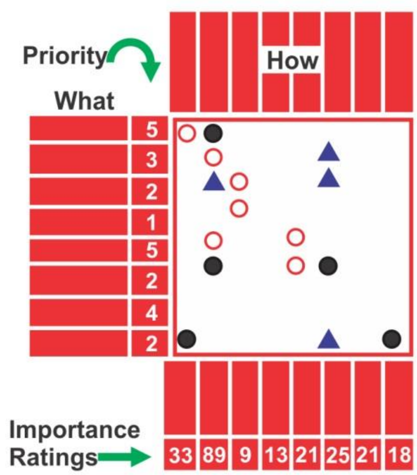


Figure 9– Importance Rating to Determine HOW MUCHs[12]

QFD Implementation in Real Project (Case Study)

Project A is used as a case study to implement QFD in a real setting in an attempt to assess the benefits from QFD implementation. The Project started in the beginning of 2014 with a project scope to improve an existing canal along a crude oil pipeline of 1 km in the center of a new city in Indonesia. The existing canal was not proper and too close to the public facilities. It is dangerous for two reasons, namely the pipe temperature is very high and the pipe location is near the settlement

[12] *Ibid.* Coloring by the author of this paper to increase the visibility of each item while symbols are reworked for consistency.

or public facilities. At the beginning, traditional method was used during the project scope development, but then a shift to adopt QFD was taken by deploying the House of Quality (HOQ) technique. Data are collected using questionnaire from project stakeholder. The output of House of Quality – Level 1 (hereinafter HOQ-1) are used as HOQ-2's WHATs section. The existing crude pipeline did not have proper canal for anticipation in case of leak and oil spill. A more appropriate canal will prevent the oil spill and waste from the residents in the center of city.

House of Quality-Level 1 (HOQ-1)

Both QFD model and workflow are shown in Figure 4. Data from project stakeholder is inputted to the project requirements. The process starts by collecting the original VOC to develop the HOQ's ''what'' section. The weights are given to each requirement using a scaled score from 1 (minor importance) to 5 (most important).

Table 1 –The HOQ-1 "What" Section[13]

"What" section		Importance Rate	Remarks
Scope			
S1	Improve existing canal along crude oil pipeline	5	Main objective of the highest importance
S2	Construct fencing along oil pipeline	5	
Budget and Cost			
C1	Capital Expenditure Budget < $2,2 Million	4	Already proposed and approved by GOI
Delivery Schedule			
DS1	Project completion before the closing of 2015	5	Intolerable as in the beginning of 2016, the government will open local market near the canal
Land			
L1	Best to locate within existing canal	3	Depends on technical review
L2	Minimize or no additional land required	3	
Safety and Technical			
ST1	Design along crude oil pipeline for 1 km length	4	To prevent whether there is pipe leak and oil spill incident near the existing home resident
ST2	The canal need 10 meter distance from home resident	4	
Regulatory and Environmental			
RE1	Control and minimize environmental impact	2	Less important since the project naturally creates minor disturbance

Table 1 describes "What" section of the HOQ-1. During this section, the questionnaire is also distributed to Engineer as project stakeholder in terms of gathering and exploring several engineering solutions or alternatives that can answer the project requirements. Engineering solutions or Voice of Engineer will become the components of the "how" section. Table 2 describes a summary of voice of engineer that will become the "how" section in the house of quality. The

[13] Table template taken from Ahmed et al. (2003), table items by the author

relationships are categorize into three numerical scale system: blank (no relationship), 3 (weak), 6 (moderate), and 9 (very strong). We use the following equations to calculate the importance weighing and the relative weight:

$$Technical\ Importance(i) = \sum_{i}^{n} scaleofimportance(i)xcorrelation\ (\ i\ )$$

Equation 1 – Technical Importance equation

$$RelativeWeight\ (\ \mathrm{i}\ ) = \frac{technicalimportance(i)x\ 5}{Max\ [\ technicalimportance(i)]}$$

Equation 2 – Relative Weight equation

Table 2 – "How" Section and Direction of Improvement Level 1[14]

	"How" section (voice of engineer/technical requirements)	Movement of target value
Scope		
S1	Modify existing canal using concrete material	use quality materials
S2	Install double expanded metal fencing in the right and left pipe along crude oil pipeline	
S3	Install special ornament design in fencing every 10 meters	Additional cost on ornament design
S4	Need to engage project stakeholder using 3D WBS and BIM method	Ensuring all project requirements include in scope
Budget and Cost		
C1	Upgrade existing canal would cost $ 1,2 Million	Less cost the better
C2	Install double fencing would cost $ 0.5 Million	
C3	HES mitigation cost about $ 0.3 Million	
C4	Secure project contingency plan about $ 0.2 Million (10 % of total cost)	
Schedule		
SC1	Complete FEED by end of Feb 2015	Earlier 20% of original schedule the better
SC2	Complete Project by mid of Dec 2015 to anticipate before new year holiday.	
Land		
L1	To site project within existing canal	No improvement in performance
L2	Use additional land around 1 meter length between canal and existing road of home resident	
Safety and Technical		
ST1	Design along crude oil pipeline for 1 km as a safety recommendation compliance calculation (nearby = 20,000 home resident)	The safer the better since large of cost risk impact of environmental issue
ST2	As per safety recommendation compliance need 10 meter distance from home resident with fencing barricade	
ST3	As per safety recommendation compliance need sewerage near pipeline to canal in every 10 meter.	
ST4	As per safety recommendation compliance need digital warning sign using solar panel in every 20 meter connect with pipe pressure & temperature transmitter	
Regulatory and environmental		
RE1	Environmental mitigation measures to control nuisance	The stricter the better
RE2	As per safety recommendation need to train 20 representative of resident in twice a year for evacuation procedure whether the warning sign showing danger with red sign.	

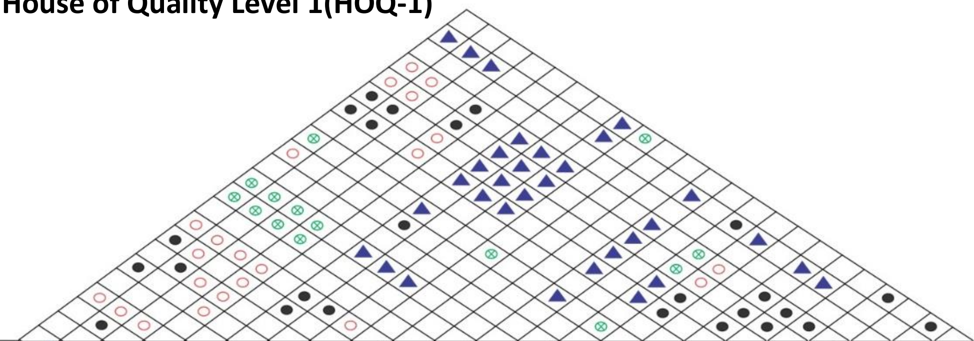
[14] Table template from Ahmed, *et al.* (2007), table items by the author

Figure 10– House of Quality Level 1(HOQ-1)[15]

For Technical Correlation :
Strong Positive = ●
Positive = ○
Negative = ⊗
Strong Negative = ▲

For Relationship Matrix :
Very Strong = 9
Moderate = 6
Weak = 3
No Relationship = Blank

For Importance Rate :
Utmost important = 5,4,3,2,1 = Least important



VOICE OF ENGINEER / ENGINEERING SOLUTIONS "HOW"

VOICE OF CUSTOMER / CUSTOMER NEEDS "WHAT"

				Scope				Cost				Schedule		Land		Safety & Technical				Reg & Environmental	
				S1	S2	S3	S4	C1	C2	C3	C4	SC1	SC2	L1	L2	ST1	ST2	ST3	ST4	RE1	RE2
			Importance Rate	Modify existing canal using concrete material	Install double expanded metal fencing in the right and left pipe along crude oil pipeline	Install special ornament design in fencing every 10 meters	Need to engage project stakeholder using 3D WBS and BIM method	Upgrade existing canal = $ 1,2 M	Install double fencing = $ 0.5 M	HES mitigation = $ 0.3 M	Project contigency plan = $ 0.2 M (10 % of total cost)	Complete FEED by end of Feb 2015	Complete Project by mid of Dec 2015 to anticipate before new year holiday.	To site project within existing canal	Use additional land around 1 meter length between canal and existing road of home resident	Design along crude oil pipeline for 1 km as a safety recommendation compliance calculation (nearby = 20,000 home resident)	As per safety recommendation compliance need 10 meter distance from home resident with fencing barricade	As per safety recommendation compliance need sewerage near pipeline to canal in every 10 meter.	As per safety recommendation compliance need digital warning sign using solar panel in every 20 meter connect with pipe pressure & temperature transmitter	Environmental mitigation measures to control nuisance	As per safety recommendation need to train 20 representative of resident in twice a year for evacuation procedure whether the warning sign showing danger with red sign.
		Movement of Target Values						↓	↓	↓	↓	↓	↓		↓	↑	↑	↑	↑	↑	↑
Scope	S1	Improve existing canal along crude oil pipeline	5	9			6	9			3	3	9	6	6	9	6	9		6	
	S2	Construct fencing along oil pipeline	5		9	6	6		9	3		6	9	6		9	9		9		6
Cost	C1	Capital Expenditure Budget < $2,2 Million	4	6	6	6	3	6	6	6	6	6	9	6	9	6	3	9	9	3	9
Schedule	SC1	Completion of project by the closing of 2015	5	6	9	9	9	3			6	6	9			6	3	9	9		
Land	L1	Best to locate within existing canal	3	9			3							9		9	6	6	6	6	6
	L2	Minimize or no additional land required	3	6			6	6			3			9	6	9	6	6	6	9	9
Safety & Technical	ST1	Design along crude oil pipeline for 1 km length	4	9	9		6	9	9	6				9	6	9	9	6	6	6	6
	ST2	The canal need 10 meter distance from home resident	4	9	9		6	9	9	6				9	6	9	9	6	6	6	6
Reg & Envr.	RE1	Control and minimize environmental impact	2	6	6		6			9					9			6	6	9	9
		Technical Importance		228	198	99	204	174	141	105	78	99	171	210	150	270	210	222	222	153	177
		Relative Weight of "HOW"		5	3	1	4	3	2	2	1	1	3	4	3	5	4	5	5	3	3

[15] Modeled after the HOQ generic template; table items by the author

The result of the first round of House of Quality is shown in Figure 10. The roof part of HOQ represents the interactions or conflict among the components in the "How" section. We need to manage and identify the conflicts, whether two elements are in conflict or not. In case where there are two conflicting elements of "How", an enhancement of one element will mean the other being reduced in its importance. The roof tools help project team in recognizing the conflicting situation earlier to stay away from wasting of resources. The way the author defines which element needs more improvement and which one could be slightly traded off is subject to the element's weight. A few of the major items in the section of technical correlation (the HOQ roof) can be discussed as follows:

1. Scope 1 and 2 are no relationships, since there is no correlation between the improvement to the existing canal and installing an expanded metal fencing
2. Scopes 2 and 3 have strong positive correlations. We cannot install ornament if we did not finalize the installation of the expanded metal fencing.
3. Cost 1 and 4 have strong positive correlation, since there will cost impact on project contingency plan if there is an increase on cost of upgrading existing canal.
4. Scope 1 and Schedule 2 have negative correlations. The schedule will delay/ behind schedule of project completion if the modification of the existing canal does not finish on time. However, modifying the existing canal by using concrete material will take more time.
5. All scope items positively correlate to cost item and negatively correlate to schedule item.
6. Environment 1 and 2 are a negative function of Cost 3.
7. Project contingencies correspond to the percentage of the total cost.

House of Quality-Level 2 (HOQ-2)

House of Quality Level 2 is shown in Figure 12. In developing the HOQ-2, the VOE in HOQ-1ispassed on to HOQ-2's "What" section. The same process and analysis like those in HOQ-1 are repeated in the other section of HOQ-2.

Table 3 – "What" Section Level 2[16]

	"How" section (voice of engineer/ technical requirements)	Movement of target value
Scope		
S1	Modify existing canal using concrete materials	use quality materials
S2	Install double expanded metal fencing in the right and the left pipe along crude oil pipeline	
S3	Install special ornament design in fencing every 10 meters.	Additional cost on ornament design
S4	Need to engage project stakeholder using 3D WBS and BIM method	Ensuring all project requirements include in scope
Budget and Cost		
C1	Upgrade existing canal would cost $ 1,2 Million	Less cost the better
C2	Install double fencing would cost $ 0.5 Million	
C3	HES mitigation = $ 0,3 M	
C4	Project contingency plan = $ 0.2 M (10% of total cost)	
Schedule		
SC1	Complete FEED by end of Feb 2015	Earlier 20% of original schedule the better
SC2	Complete Project by mid of Dec 2015 to anticipate before new year holiday.	
Land		
L1	To site project within existing canal	No improvement in performance
L2	Use additional land around 1 meter length between canal and existing road of home resident	
Safety and Technical		
ST1	Design along crude oil pipeline for 1 km as a safety recommendation compliance calculation (nearby = 20,000 home resident)	The safer the better since large of cost risk impact of environmental issue
ST2	As per safety recommendation compliance need 10 meter distance from home resident with fencing barricade	
ST3	As per Safety recommendation compliance need sewerage near pipeline to canal in every 10 meter	
ST4	As per safety recommendation compliance need digital warning sign using solar panel in every 20 meter connect with pipe pressure & temperature transmitter	
Regulatory and environmental		
RE1	Environmental mitigation measures to control nuisance	The stricter the better
RE2	As per safety recommendation need to train 20 representative of resident in twice a year for evacuation procedure whether the warning sign showing danger with red sign	

[16] Table template from Ahmed *et al.*(2003), table items by the author

Table 4 – "How" Section and Direction of Improvement Level 2[17]

	"How" section (voice of engineer/technical requirements)	Movement of target value
Scope		
S1	Cleaning and transporting existing canal waste to landfill	use quality concrete materials
S2	Conduct excavation works of existing canal for 2 meter depth	
S3	Leveling the existing canal and fencing ground	
S4	Conduct fabrication work	
S5	Conduct pouring and concrete	Additional cost on ornament design
S6	Conduct welding works	
S7	Gather input from project stakeholder on PBS, ABS, ZBS and also 3D Animation Drawing	
S8	Install sewerage for every 10 meter near pipeline as waterways to canal	Ensuring all project requirements include in scope
S9	Conduct cable excavation from existing pressure and transmitter to 50 location of digital warning signs	
S10	Install cable connection and connect to digital warning signs	
Budget and Cost		
C1	Using Existing Contract of Work Unit Rate Including material supplied by contractor cost $ 1.2M	Less cost the better
C2	Project Management Cost $ 0.2M if project on time and $0.1M if project delayed	
C3	Contract for evacuation procedure training by third party cost $0.15M twice a year for 2 years using train the trainer method	
C4	FEED cost $0.1M, Project Contingencies cost $0.125, Site investigation and others cost $0.2M	
C5	Contract for digital warning signs works including material supplied by contractor cost $0.2M	
Schedule		
SC1	FEED deliver on 20 Feb, Conduct Class 1 Schedule Estimate by 25 Feb & Finalize detail WBS, OBS and CBS by 30 Feb	Earlier 20% of original schedule the better
SC2	Contract Award for digital warning sign works by 15 March	
SC3	Complete fencing works by 10 September & Complete digital warning signs works by 10 November	
SC4	Complete sewerage installation by 20 June & Complete canal works by 30 October	
SC5	Conduct Placed Into Service by 10 December & Project Close Out by 10 Jan 2016	
Land		
L1	All within the existing premises	No improvement in performance
Safety and Technical		
ST1	HBS team do recalculation and recommend 1.05 km need to be covered (Canal &Fencing).	More safer more better since large of cost risk impact of environmental issue
ST2	Design for expanded metal fencing 2 meter height from the runway fence & sewerage with diameter 0.5 meter	
ST3	Design for digital warning sign for 1.5 meter squared each with siren speaker sound coverage 1 km	

[17] Table template from Ahmed *et al.* (2003), table items by the author

Regulatory and environmental		
RE1	Dust, Noise & Traffic impact during construction	More stringent the better
RE2	Need to engage with contractor and hire local communities with percentage 20% as per local Government Regulation	
RE3	Conduct evacuation procedure training for 20 representatives of resident twice a year with train the trainer method	
RE4	Environmental Monitoring and Assurance	

Results of the QFD Implementation

It is from the output of two iteration of the House of Quality that the project gradually formed. There are more than 25 details of project requirements yielded from nine basic project requirements. These 25 detailed project requirements will become the preliminary project objectives. All of the elements of QFD result will become the important input as quality assurance during developing the project scope, WBS, resource and detailed project requirements. WBS will describe the resources needed, activity dependencies, cost, risk mitigation and project schedule.

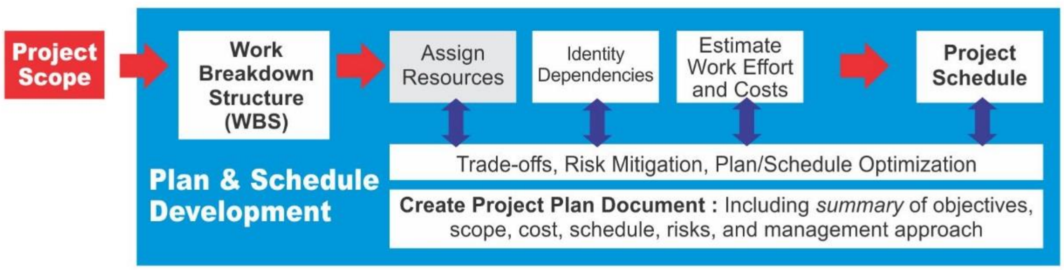


Figure 11 – Steps in developing a Work Breakdown Structure (WBS)[18]

[18]ProjectConnection and ICS Group (2008).

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For Relationship Matrix :
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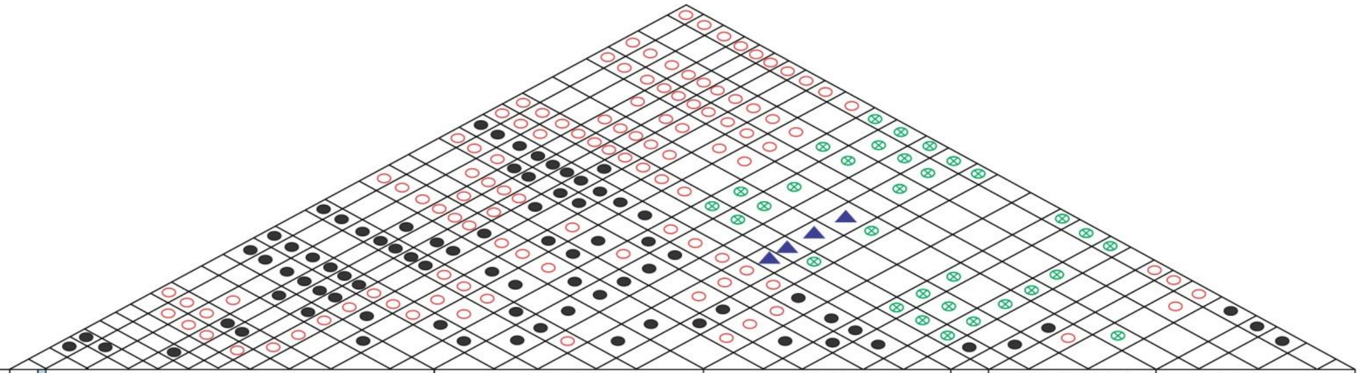
For Importance Rate :
Utmost important = 5,4,3,2,1 = Least important



		VOICE OF ENGINEER / ENGINEERING SOLUTIONS "HOW"		Scope										Budget & Cost					Schedule					Land	Safety & Technical			Reg & Environmental			
				S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	C1	C2	C3	C4	C5	SC1	SC2	SC3	SC4	SC5	L1	ST1	ST2	ST3	RE1	RE2	RE3	RE4
		VOICE OF CUSTOMERS / CUSTOMER NEEDS "WHAT"	Importance Rate	Cleaning and transporting existing canal waste to landfill	Conduct excavation works of existing canal for 2 meter depth	Levellling the existing canal and fencing ground	Conduct fabrication work	Conduct pouring and concrete	Conduct welding works	Gather input from project stakeholder on PBS, ABS, ZBS and also 3D Animation Drawing	Install sewerage for every 10 meter near pipeline as waterways to canal	Conduct cable excavation from existing pressure and transmitter to 50 location of digital warning signs	Install cable connection and connect to digital warning signs	Using Existing Contract of Work Unit Rate including material supplied by contractor cost $ 1.2 M	Project Management Cost $ 0.2 M if project on time and $ 0.1 M if project delayed	Contract for evacuation procedure training by third party cost $ 0.15 M twice a year for 2 years using train the trainer method	FEED cost $ 0.1 M, Project Contingencies cost $ 0.125, Site investigation and others cost $ 0.2 M	Contract for digital warning signs works including material supplied by contractor cost $ 0.2 M	FEED deliver on 20 Feb, Conduct Class 1 Schedule Estimate by 25 Feb & Finalize detail WBS, OBS and CBS by 30 Feb	Contract Award for digital warning sign works by 15 March	Complete fencing works by 10 September & Complete digital warning signs works by 10 November	Complete sewerage installation by 20 June & Complete canal works by 30 October	Conduct Placed Into Service by 10 December & Project Close Out by 10 Jan 2016	All within the existing premises	HES team do recalculation and recommend 1.05 km need to be covered (Canal & Fencing).	Design for expanded metal fencing 2 meter height from the runway fence & sewerage with diameter 0.5 meter	Design for digital warning sign for 1.5 meter squared each with siren speaker sound coverage 1 km	Dust, Noise & Traffic impact during construction	Need to engage with contractor and hire local communities with percentage 20% as per local Government Regulation	Conduct evacuation procedure training for 20 representatives of resident twice a year with train the trainer method	Environmental Monitoring and Assurance
		Movement of Target Values		↑						↑				↓		↓	↓	↓	↓	↓	↓	↓	↓		↑	↑	↑	↓	↑	↑	↑
Scope	S1	Modify existing canal using concrete materials	5		9	9	9	9		9	6			9	9		9		9		6	9	9	9	9	6		9	3		9
Scope	S2	Install double expanded metal fencing in the right and the left pipe along crude oil pipeline	3			9	9	6	9	9		9	6	9	9		9	6	9		9	6	9	9	9	9	9	9	3		9
Scope	S3	Install special ornament design in fencing every 10 meters	1				9		6	9				9	9		9		9		9		9			9		3			9
Scope	S4	Need to engage project stakeholder using 3D WBS and BIM method	4				9	6	6	9	9			6	6		6	6	9	3			6	9		9	9	3	3	3	9
Budget & Cost	C1	Upgrade existing canal = $ 1,2 M	3	9	9	9	9	9	6	3	9			9	9		9		9	3		9	9	9	9	9		9			9
Budget & Cost	C2	Install double fencing = $ 0.5 M	2			9	9	9	9	3	3	6	3	9	9		9	3	9	3	9		9	9	9	9		9			9
Budget & Cost	C3	HES mitigation = $ 0.3 M	2	9								9	9			9	3	9			9	9	9	6			9			9	9
Budget & Cost	C4	Project contigency plan = $ 0.2 M (10 % of total cost)	1							3		9	9			9	9	9			9	9	9	9			9		3	9	9
Schedule	SC1	Complete FEED by end of Feb 2015	1							9	9	9			9		9	9	9												
Schedule	SC2	Complete Project by mid of Dec 2015 to anticipate before new year holiday	3	6	9	9	9	9	9	9	9	9	9	9	9			9	9	6	9	9	9		9				3	3	6
Land	L1	To site project within existing canal	4	6	9	6				6	3													9							3
Land	L2	Use additional land around 1 meter length between canal and existing road of home resident	3	3	3			9		6					9		9		9		9		9	9				9			9
Safety & Technical	ST1	Design along crude oil pipeline for 1 km as a safety recommendation compliance calculation (nearby = 20,000 home resident)	5							6															9	3		9			9
Safety & Technical	ST2	As per safety recommendation compliance need 10 meter distance from home resident with fencing barricade	4			3				6			3					6	9							9		9			9
Safety & Technical	ST3	As per safety recommendation compliance need sewerage near pipeline to canal in every 10 meter	5							6	9	6														9					9
Safety & Technical	ST4	As per safety recommendation compliance need digital warning sign using solar panel in every 20 meter connect with pipe pressure & temperature transmitter	5							6					9		9									6	9			9	9
Reg & Envr	RE1	Environmental mitigation procedures to control disturbance	3	6				6	6	3															9			9	9		9
Reg & Envr	RE2	As per safety recommendation need to train 20 representative of resident in twice a year for evacuation procedure whether the warning sign showing danger with red sign	3							6						9		3									9			9	9
		Technical Importance		114	144	180	189	204	138	354	192	132	90	177	258	54	246	144	261	45	165	144	231	237	216	273	162	267	75	120	471
		Relative Weight of "HOW"		2	2	3	3	4	2	5	3	2	1	3	5	1	4	2	5	1	3	2	4	4	4	5	3	5	1	2	2

Figure 12 – House of Quality Level 2 (HoQ-2)[19]

[19] *ibid*

The inter-relationships between the requirements/customer needs ("what") and the engineering solutions/voice of engineer ("how") indicate that all requirements are fully addressed. Using the QFD, we can secure and maintain the utmost customer requirements. For example, the scope of improving existing canal will require the team to excavate for two meters deep as per recommendation by Safety/HES Team. Finalizing install double expanded metal fencing scope 2 of HOQ-2 is required before installing the digital warning signs on fencing. A brief overview at the section of ''schedule'' in Figure12 can help projecting how, by using the QFD workflow, the solution and tradeoffs is possible. The comparative weight for "FEED deliver on 20 Feb, Conduct Class 1 Schedule Estimate by 25 Feb & Finalize detail WBS, OBS and CBS by 30 Feb"(schedule 1), and "Complete fencing works by 10 September & Complete digital warning signs works by 10 November (schedule 3)are 5 and 3, respectively, indicate that their importance is high. As a result, if we didn't pay more attention to that schedule, it will impact to schedule 5, the project close out will delay more to longer than 10 January 2016. A brief smart sensitivity check can be easily conducted when there are changes. For example, as per recommendation by safety/HES team, the project team needs to install sewerage in every 10 meter, and then the contractor has to fabricate sewerage at the fabrication area. The changes on schedule, scope, technical components on the one side and the environment and cost on the other side are immediately noticeable through HOQ. Having fully implementing every element of initial objectives and as all outputs can be traceable to their origins and that each target value is reasonable, the project team concluded that the QFD has fulfilled all the criteria of the logic test.

Comments from Output Target Value

Both HOQ-1 and HOQ-2 show that the target value of cost has changed, and is not the same as the detailed result of iteration process in HOQ-2. The proposed budget amounted to $ 2.2 M with the detail iteration result from HOQ-1 : Cost 1 ($ 1.2 M) + Cost 2 ($ 0.5 M) + Cost 3 ($ 0.3 M) + Cost 4 ($ 0.2 M) = Total Cost ($ 2.2 M). It is different from the detail iteration result from HOQ-2 : Cost 1 ($ 1.2 M) + Cost 2 ($ 0.2 M or 0.1 M) + Cost 3 ($ 0.15 M) + Cost 4 ($ 0.1 M + $ 0.125 M + $ 0.2 M) + Cost 5 ($ 0.2 M) = Total Cost ($ 2.175 M or $ 2.075 M). The difference between the proposed cost of $ 2.2 M and the detail iteration result from HOQ-2 $ 2.175 M or $ 2.075 M – informs the accurate estimation of the proposed cost. QFD method helps to breakdown the cost and shows the change of additional scope as per HES Team and Project Stakeholder Recommendation. The project contingencies cost has already covered that additional cost. From the project management point of view, the cost will be $ 2.075 M if the project is on time or it will cost $ 2.175 M if the project is delayed.

The target value of schedule also changed. The proposed project will complete before the end of 2015. HOQ-1 detail iteration tells the project schedule will finish by mid of Dec 2015 but HOQ-2 detail iteration tells the project will finish by 10 January 2016. The QFD method helps Project Manager with the detail breakdown schedule so that the contractor has to allocate 1-month warranty time after project handover on 10 December 2015, after which the project will close on 10 January 2016.

Sometimes, small changes made by project stakeholder/HES team during project planning and design are not identified in the established project planning. Indeed, recognizing the impact by a small alteration on the entire project is difficult because of the project's complexity nature and the multitude of relationships between various components in the project. Nevertheless, QFD offers a roadmap for overall project navigation. QFD help any project manager in the planning process to encounter all project deficiencies in project A. QFD has enabled not only to identify signs of deficiencies much easily and earlier but also to conveniently track the project shortcomings to their origins. Therefore, the project stakeholder and the project manager would have been prepared to take necessary early measures to anticipate the project's potential loss.

Conclusion

This paper demonstrates the implementation of quality function deployment (QFD) as tools to provide roadmap for steering the planning process and keeping the voice of customer (VOC) recorded and traceable. From Project A case study in Indonesia, the implementation of QFD using HOQ in enhancing the process of project planning and designing can be summarized as follows.

First, voice of customer is fully addressed, in which 25 detailed project scopes were developed from nine traditionally-generated project scopes, whose scale range from 1 (less important) to 5 (most important). In other words, QFD method prevented or minimizedthe project scope from changing during the construction phase.

Second, the process of developing QFD matrix could facilitate communications across various involved. It broke the communication barriers between project stakeholders and project manager as well as among the team members. Such good communications could help in enhancing the overall project results.

Third, QFD could become a brilliant tool for assessing various project options, settling a variety of incompatible project requirements and setting up measurable targets of project performance. In addition, all outputs were traceable to their origins and were checkable for any alterations to any points during the process of project design and planning.

Therefore, the validity and applicability of the QFD model on the construction project has been fully supported.

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