How to Accurately Use QFD?

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***Abstract*- Quality Function Deployment (QFD) can be applied and analysed to different demands of user; it had been unshakable for 35 years and widely cited by the academic communities and practitioners. When the purpose, application scope and methodology of consideration are varied, it must cause confusion, misuse and affect the benefit of decision-making.**

To effectively address the issue, this study uses qualitative interview, PDCA management cycle and Analytic Hierarchy Process to present a complete application model of QFD allowing users to accurately and efficiently master QFD. The achievement of this study is not only easy to understand, but also allows users to easily grasp the core meaning. Furthermore, it specifically presents directions as guidelines promoting to each department. Thus, enterprises can use this to decrease the risk of failure due to misuse of QFD and also enhance the benefit and quality of decision-making.

Keywords- Quality Function Deployment; Qualitative Interview; PDCA Management Cycle; Analytic Hierarchy Process

I. INTRODUCTION

Since the Quality Function Deployment (QFD) was presented by Y. Akao and S. Mizuno in 1978, there have been quite a few scholars using this methodology in fields like product development, quality management, designing, planning and decision-making. QFD can, through its cross-functional characteristics of a team, help enterprises to predominate customer demand, enhance customer satisfaction, shorten the cycle of research and development, keep company's knowledge, and it can be successfully applied to various industries. Thus, it has been widely used by practitioners and academic communities [1].

As a result, the structure and practice of QFD often demonstrate diversity and complexity under different timing of use, purposes of use and factors of consideration. Such contending phenomena not only makes it harder for users to build quality matrix, show expertise, and obtain support from top management, but also results in misunderstanding of users as to the value and function of QFD. Consequently, it fails to smoothly exploit its benefit to the full and promote to all departments of the company.

To make enterprises and users clearly understand the application scope and usage of QFD and further implement it in each department of the enterprises, this study will, (1) through literature review, promote to all departments of the companies render the using appearance and operation procedure of the traditional QFD; (2) introduce application purpose and structural type of modern QFD; (3) organize to present "information item" and its "methodology" under each structure; (4) through qualitative interview and PDCA management cycle, present "room", "timing/purpose", "information item" and "methodology" in scholars' use of QFD; (5) through questionnaires, show the related strength associating each "information item" with "timing/purpose"; (6) through Analytical Hierarchy Process (AHP), predominate each item of the "information item" and its overall weighted value; (7) build up a complete application model of QFD; and (8) demonstrate the application value and its management implication of the study's achievements to confirm its rationality and exploitability.

II. LITERATURE REVIEW

A. Structure and operation procedure of the traditional QFD

Akao and Mazur (2003) believe that quality chart is the core of QFD and it could effectively rendered the relationship of function and quality characteristics [2]. Thus, it is also known as "House of Quality" (HOQ). Akao (1990) believes the best execution procedure of QFD/HOQ is to (1) decide what kind of "things" to make; (2) predominate target market information and make Quality Function Deployment chart to reflect both the demands and characteristics of that market (VOC, Whats); (3) competitively analyse (Ways); (4) determine the degree of importance of the required quality; (5) list the quality elements and make a quality elements deployment chart (How); (6) conduct an analysis of competing products to see how other companies perform in relation to each of these quality elements; (7) analyse customer complaints (Ways); (8) determine the most important quality elements as indicated by customer quality demands and complaints (Whats); (9) determine the specific design quality by studying the quality characteristics and converting them into quality elements (Whats vs. Hows); and (10) determine the quality assurance method and the test method (How Muches)[3].

Allowing QFD to be effectively executed, Akao (1990) believes that step (2) could be used in coordination with KJ method, brainstorming, and stratification to predominate customers' real demand; and, the Quality Demand Deployment Chart in step (5) could be connected with Quality Characteristics Deployment Chart so as to show the importance degree of the relationship between both. Additionally, to avoid confusion, the quality table could be used in coordination with Pareto Diagram so as to compare the difference of the importance degrees of quality demand and quality characteristics; or, step (9) could be used in coordination with Fishbone Diagrams to assist decision-maker to understand each affecting factor of technology development [3].

Based on the aforementioned usage convention, Hauser and Clausing (1998) believe that HOQ should contain 6 rooms as listed below: (1) Room 1 is used to present customer demand to the function of product/service so as to show customer attributes and its degree of importance; (2) Room 2 is the various engineering characteristics launched in response to customer demand; (3) Room 3 is the relationship matrix of the relationship strength linking customer demand and engineering characteristics; (4) Room 4 presents the relationship matrix of the related strength of each engineering characteristics; (5) Room 5 is, through customer perceptions, to predominate customers' viewpoint on each demand competition and further use such as a basis for assessing needs; (6) Room 6 is used to evaluate the engineering characteristics of competitors by using "objective measures" and total the assessment result of various engineering characteristic as a basis for decision-making [4].

B. The application purpose and implication of modern QFD

With extensive application of QFD, the traditional practice has been unable to meet the use requirement of modern scholars and practitioners. Therefore, scholars will, according to the use of "timing/purpose", modify the "information item" and "methodology" of the traditional QFD to meet the requirements of application scope and benefit. For example, Hsiao and Liu (2005), to establish the customer demand in different markets, created an intelligent decision-making system in order to introduce product variant design and solution meeting market differentiation [5]. Tontini (2007) proposed to integrate the QFD methodology and Kano's model to confirm the important sequence of innovation demand to customer during product development process in order to meet customer's demand for beer mugs [6]. Sørensen et al. (2010) used QFD to master the requirement of planting robot users and the related design parameters promoting the robot's capability of energy-efficiency [7]. Bevilacqua et al. (2012) proposed fuzzy QFD to grasp the characteristics of virgin olive oil valued by customer [8]. Wey and Chiu (2013) integrated QFD and Analytic Network Process (ANP) rendering a design model of pedestrian space for cities with public transit-oriented development to confirm walker's demand for improvement of satisfaction degree on pedestrian space [9]. In order to promote the accuracy of customer demand, Büyüközkan et al. (2007) proposed Fuzzy Group Decision Making Methodology fusing multiple preference styles to meet customer demand of products [10].

By integrating the QFD and AHP, Mayyas et al. (2011) assisted designers, at the stage of conceptual design for ferrite car, to effectively grasp customer demand and further select an appropriate panel material for body-in-white [11]. Taylan (2013) integrated fuzzy QFD and fuzzy grey relational methodology (FGRM) to grasp the customer's attention level on edible oil [12].

Juan et al. (2009) integrated QFD and fuzzy theory to establish a model in selecting residential renovation contractors in order to assist residents to objectively choose renovation contractors [13]. Soroor et al. (2012) integrated QFD, fuzzy logic and AHP to create an intelligent vendor bidding model to automatically select the best suppliers [14].

Karsak et al. (2003) integrated QFD, ANP, and Zero-one goal programming methodology (ZOGP) to consider the importance of technical requirement on product and other multiple objective issues such as customer demand, technical requirement, cost, scalability, and manufacturability and further become a decision application for product designing [15]. Karsak (2004) proposed fuzzy multiple objective programming approach for the consideration of restraints on cost budget and technical difficulty in order to grasp the important degree of each deign goal and further use the degree as a basis of objective decision [16]. To solve the obsession of multiple engineering characteristics and significant uncertainty that QFD failed to manage during the process of complex product designing, Chen and Ngai (2008) integrated QFD and fuzzy theory to propose a comprehensive strategy for the consideration of uncertainty on design and financial factor and further use for decision application [17]. Sener and Karsak (2011) integrated QFD and fuzzy regression and proposed a fuzzy multiple objective strategy structure to improve customer satisfaction, reduce the technical difficulty on engineering characteristics and meet the enterprise's financial budget restraints [18].

Bhattacharya et al. (2005) raised QFD and AHP models from economic viewpoint, to assist manufacturing plants to effectively choose and designate the industrial robot required by operation [19]. Karsak and Özogul (2009) believe that enterprises should consider the characteristics of Enterprise Resource planning (ERP) system needed in the selecting of ERP system. Thus, they integrated QFD, Fuzzy Linear Regression and ZOGP, and further raised a decision structure as a decision tool of enterprise's sound investment on information system [20]. Lin et al. (2010) integrated fuzzy QFD and ANP and proposed a systematic analysis program to master the relationship of environmental production requirements (EPRs) and sustainable production indicators (SPIs) so as to get the best decision, and thereby improve the existing problem for the original equipment manufacturer in Taiwan [21]. Liang et al. (2012) used fuzzy QFD to learn about the priority of Taiwan's international port knowledge management solution [22].

Yang et al. (2003), to master the demand of each imprecision and vagueness during the process of architecture design and construction project, used fuzzy QFD to evaluate construction project and proposed to satisfy customer demand on architecture design [23]. Chou (2004) used QFD to analyse student's view in the nursing department regarding the service quality of nursing education in Taiwan, taking this as the basis for improvement of service quality in institutions [24]. Kuo et al (2011) integrated Kano's model, ANP and QFD to assess outpatient service quality for the elders in Taiwan in order to provide appropriate outpatient services [1].

Bottani and Rizzi (2006) used fuzzy QFD to improve the existing procedure of logistic process accelerating the satisfaction degree on customer service [25]. Lai et al. (2006) integrated QFD and Linear Physical Programming with the consideration of the time of product development and the restriction on cost and production cost, etc. in order to provide optimization flow direction for product designing [26]. Vezzetti et al. (2011), in the product development stage, integrated QFD and the Theory of Inventive Problem Solving (TRIZ) to propose a management method for systematic operation knowledge in order to build up a standard procedure for the operation of knowledge documentation and knowledge management [27].

Wilkinson (2007) used QFD and Failure Modes and Effects Analysis to integrate the virtual and physical test procedures for establishing an effective test and development program, thereby improving cabin noise in trucks [28]. Lee et al. (2008) integrated fuzzy QFD and Kano's Model, and blended the integration into Product Lifecycle Management in order to identify the customer attributes on product demand and master the ambiguous language meaning in questionnaire so as to create more appealing product attributes, optimizing product designs [29]. Melgoza et al. (2012) used QFD and TRIZ to propose the integrated parametric tool on tracheal stent design solving the physical contradiction between geometry and material and further meeting the demand of doctors and patients [30].

C. The diverse style of QFD structures

After having reviewed relevant literature of the aforementioned HOQ structure, it was found that other than the 6 rooms mentioned in the traditional structure, some scholar also proposed room 7 to demonstrate the related strength on customer demand (Room1) [15]. Furthermore, some scholars, with different purposes of use, applied different "information item" and "methodology" to raise the accuracy of information implication and the decision clarity in each room. Overall, HOQ can be classified into six different structures: (1) Rooms 1-7; (2) Rooms 1-6; (3) Rooms 1, 2, 3, 4, 6, and 7; (4) Rooms 1, 2, 3, 4, and 6; (5) Rooms 1, 2, 3, 5, and 6; (6) Rooms 1, 2, 3, and 6.

(1) Rooms 1-7

For example, Karsak et al. (2003) used 1 information item in each of Rooms 1, 2, 3, and 5, 2 in each of Rooms 4 and 7, and 4 in Room 6, making a total of 12 information items. They also used ANP in Rooms 3, 4, 5, and 7 for calculation. In addition, they used super matrix in Room 6 to calculate decision value [15].

(2) Rooms 1-6

For example, Yang et al. (2003) used 4 information in Room 1; 3 information in Room 2; 1 information in each of Room 3, 4 and 5; 2 information in Room 6, adding a total of 12 information items. He also used Fuzzy in Room 1, 3, and 5, 6 [23]. Bottani and Rizzi (2006) used 1 information in each of Room 1, 2 and 3, 4; 3 information in Room 5; 5 information in Room 6 in a total of 12 information items. He also used Fuzzy in Room 3, 4 and 5, 6 [25]. Karsak and Özogual (2009) also use 1 information in Room 1, 2, 3 and 4, 6; 4 information in Room 5, making a total of 9 information items. He also used expert's opinion in Room 1; used Fuzzy Linear Regression in Room 3, 4; used AHP in Room 5 [20]. Sener and Karsak (2011) used 2 information in Room 1; 1 information in each of Room 2, 3 and 4; 3 information in Room 5; 5 information in Room 6 adding a total of 13 information items. He also used ANP in Room 1; used Fuzzy in Room 3 and 6 [18]. Wilkinson (2007) used 2 information in each of Room 1 and 2; 1 information in each of Room 3 and 4; 6 information in Room 5; 5 information in Room 6 adding a total of 17 information items [28]. Melgoza et al. (2012) used 4 information in Room 1; 2 information in Room 2; 1 information in each of Room 3, 4 and 5; 5 information in Room 6 making a total of 14 information items [30].

(3) Rooms 1, 2, 3 and 4, 6, 7

For example, Kuo et al. (2011) used 2 information in Room 1; 1 information in each of Room 2, 3 and 4, 7; 3 information in Room 6 making a total of 9 information items. He also used Kano's model ANP in Room 1 to confirm customer demand and the degree of importance; and, used ANP in Room 3, 4 and 7 to identify the related strength/correlation [1]. Lin et al. (2010) used 2 information in Room 1; 1 information in each of Room 2, 3 and 4, 7; 3 information in Room 6 totally 9 information items. He also used experts' assessment and ANP in Room 1 to confirm customer demand and the degree of importance; and, used Fuzzy ANP (F-ANP) in Room 3, 4 and 7 to identify the related strength/correlation [21]. Wey and Chiu (2013) used 2 information in Room 1; 1 information in each of Room 2, 3, 4 and 6, 7, making a total of 7 information items. He also used ANP for calculation in Room 1 (the degree of importance), 3 and 4, 7; and, used super matrix in Room 6 for calculation of decision value [9].

(4) Rooms 1, 2, 3 and 4, 6

For example, Bevilacqua et al. (2012) used 2 information in each of Room 1 and 2; 1 information in Room 3 and 4; 2 information in Room 6 totally 8 information items. He also used market survey and fuzzy in Room 1 to confirm customer demand and the degree of importance; used fuzzy in Room 3 to show the correlation; and, in Room 6, then used Fuzzy to increase the accuracy [8]. Soroor et al. (2012) used 2 information in each of Room 1 and 6; 1 information in each of Room 2, 3 and 4; making a total of 7 information items. He also used Fuzzy AHP (FAHP) in Room 1 to confirm the degree of importance of customer demand and used Fuzzy in Room 3 to show the correlation. In room 6, he then used Fuzzy to raise the accuracy

[14]. Taylan (2013) used 2 information in Room 1; 1 information in each of Room 2, 3 and 4, 6 making a total of 6 information items. He also used FGRM to confirm the degree of importance of customer demand [12]. Sørensen et al. (2010) used 3 information in each of Room 1 and 6; 1 information in each of Room 2, 3 and 4 making a total of 9 information items. In Room 1, he went through customer interview to identify customer demand, and used experts' assurance in Room 3, 4 to confirm the correlation [7]. Vezzetti et al. (2011) used 2 information in each of Room 1 and 6; 1 information in each of Room 2, 3 and 4 making a total of 7 information items; and, he used questionnaire survey to identify customer demand and the degree of importance [27]. Mayyas et al. (2011) used 2 information in Room 1; 1 information in each of Room 2, 3 and 4; 7 information in Room 6 making a total of 12 information items [11]. Chen and Ngai (2008) used 2 information in Room 1 and 1 information in each of Room 2, 3, and 4; 5 information in Room 6 totally 10 information items. And, he used questionnaire survey and AHP to identify customer demand and the degree of importance [17].

(5) Rooms 1, 2, 3 and 5, 6

For example, Karsak (2004) used 1 information in each of Room 1, 2, and 3; 2 inform in Room 5; 3 information in Room 6, totally 8 information items. And, he used Fuzzy in Room 3 to show correlation [16]. Bhattacharya et al. (2005) used 1 information in each of Room 1, 2 and 3, 5; 2 information in Room 6 in a total of 6 information items. And, he used AHP method in Room 5 to identify the degree of importance of customer demand [19]. Hsiao and Liu (2005) and Lai et al. (2006) used 1 information in each of Room 1, 2, 3 and 5, 6 making a total of 5 information items [5]. Büyüközkan et al. (2007) used 2 information in each of Room 1, 2 and 5, 6; 1 information item in Room 3 in a total of 9 information items. And, he used Focus Group Interviews (FGI) in Room 1 to identify customer demand; used Fuzzy in Room 3 to show correlation; used Fuzzy in Room 6 to raise accuracy [10]. Tontini (2007) used 1 information in each of Room 1, 2, and 3; 4 information in Room 5; 3 information in Room 6; totally 10 information items. And, he used FGI in Room 1 to identify customer demand; used Kano's model in Room 5 [6].

Lee et al. (2008) used two stages on HOQ; among them, he used 1 information in each of Room 1, 2 and 3 of the first stage; 6 information in Room 5; 4 information in Room 6 in a total of 13 information items. At second stage, he used 1 information in each of Room 1, 2 and 3; Room 5 deriving from Room 6 of the first stage with 4 information; 2 information in Room 6; in a total of 9 information items. And, he used questionnaire in Room 1, 2 to identify customer and technical demand [29]. Liang et al. (2012) used 1 information in Room 1 and 3; 2 information in Room 2; 4 information in Room 5; 3 information in Room 6 in a total of 11 information items. And, he used Fuzzy in Room 3 to identify correlation [22].

(6) Rooms 1, 2 and 3, 6

For example, Chou (2004) used 2 information in each of Room 1 and 6; 1 information in each of Room 2 and 3 making a total of 6 information items. And, he used FGI in Room 1, 2 to identify customer and technical demand; used questionnaire in Room 3 to identify correlation [24]. Juan et al. (2009) used 1 information in each of Room 1, 2 and 3, 6 in a total of 4 information items. And, he used questionnaire in Room 1 to verify customer demand; used expert interview method in Room 2 to identify technical demand; used Fuzzy in Room 3 to identify correlation [13].

III. ESTABLISHING A ROUGH APPLICATION MODEL

Learning from the above, scholars complying with different use of "timing/purpose" will modify "room" in the traditional QFD and cite different "information items" and "methodology" to satisfy requirements of practical application and benefit. For this reason, this study, complying with PDCA management cycle, demonstrated to scholars the relationship between "timing/purpose", "information item" and "methodology" in the use of QFD. And, through qualitative interview method, it summarized experts' opinions to further establish a rough application model of QFD serving as a foundation for follow-up study.

A. The procedure of qualitative interview

Because qualitative interview method may bring together experts' and scholars' opinions and conform to the expectation of enterprise and scholars, in this study, therefore, (1) one consultant with over 10 years' experience in coaching QFD and one scholar teaching QFD courses for over 5 years were invited to proceed KJ method more than twice; (2) Among them, the first KJ method not only explains the study's purpose, content and terminology definition but also classifies each item. The second KJ method further proceeded with correction and fine-tuning to some project in addition to the recognition of first result.

Next, this research (3) invites two consultants with over 7 years' experience in coaching QFD and two scholars teaching QFD courses for over 5 years to proceed Focus Group interview method; (4) to assure the rationality of the result obtained from KJ method, proceed adjustment, modification, and reinforcement until a consistent satisfaction is received on the opinion of interview.

Lastly, this research (5) invites three consultants with over 5 years' experience in coaching QFD, four scholars teaching QFD courses for over 5 years and 4 supervisors with experience using QFD for over 5 years from a research and development project team to proceed multiple Delphi questionnaire (adopting Likert 5 point score); (6) after the questionnaires are collected, complies with interquartile range method (Q value) to confirm the overall consistent judgment of the questionnaires [31]; (7) next, uses the average value of appropriate degree (3.5 as basis) from Descriptive Analysis to confirm the appropriateness of each individual question [32]; (8) the survey was ended if the result met the overall consistent requirement of the questionnaire (>70%) [33]. But for the sake of discretion, second confirmation was proceeded after two weeks to ensure the reliability of the research’s achievement.

B. PDCA management cycle

Because in PDCA management cycle, Plan (P) can “identify policy and objective”; Do (execution; D) can “realize plan content”; Check (verification/assessment/monitoring; C) can “verify/assess/monitor the difference between execution and result” and find out where the problem lies; Action (improvement; A) can “proceed analysis, modification or promotion and standardization on each difference found in this stage”. Therefore, enterprises can, through this PDCA management cycle, repeatedly continue on improvement, strengthen constitution and further stride toward the road of success [34].

Therefore, this study complied with this criterion and summarized scholars’ use of “timing/purpose” of QFD and its implication. After having the confirmation by using KJ method twice and Delphi method three times, scholars’ uses of “timing/purpose” of QFD in the PDCA management cycle were discovered. The stage of plan (Plan) mainly consists of 3 items: demand confirmation (P1), demand difference (P2) and activity planning (P3). The stage of execution (Do) consists of 2 items: project selection (D1) and policy execution (D2). The stage of assessment (Check) uses (C) “difference assessment” as a primary purpose. The stage of improvement (Action) uses process revision (A1) and mechanism revision (A2) as a primary purpose (see table 1).

C. A rough application model of QFD

Besides the consideration of “timing/purpose”, this study also used one KJ method, one Focus Group Interview method, and twice Delphi questionnaire survey to proceed with classification and affirmation and further grasp the “information item” used by scholars in each “Room”. The results indicate that Room 1 is often used to show five information items: (a) conceptual demand direction; (b) clear demand factor; (c) decisive demand objective; (d) importance degree of demand (absolute); and (e) importance degree of demand (relative). Room 2 is then used to describe three information items: (a) conceptual technical direction; (b) clear technical function (factor); and (c) decisive technical specification (parameter). In addition, scholars often use three information items in Room 3: (a) item assessment scale; (b) dichotomized scale; and (c) continuous scale. In Room 4, they use four information items: (a) category scale; (b) dichotomized scale; (c) item assessment scale; and (d) continuous scale. In Room 5, they use four information items: (a) satisfaction degree; (b) competition demand assessment; (c) importance degree of demand (absolute); and (d) importance degree of demand (relative). In Room 6, they then use seven information items: (a) decision value (absolute); (b) decision value (relative); (c) decision value (ranking); (d) resource restraint; (e) technical demand assessment; (f) technical objective / specification; and (g) technology assessment. Lastly, they use 2 information items in Room 7: (a) dichotomized scale; and (b) continuous scale. Therefore, there are totally 28 information items (see table 1).

Besides summarizing “timing/purpose” and “information item”, Qualitative Interview method was also used to summarize the “methodology” used by each scholar. After having confirmed by using one KJ method, this study acquired twelve methodologies as illustrated on the upper left of table 1. Among them, “Non-methodology” means that scholars did not indicate what methodology was used in their studies, “FGI” represents that scholars used Focus Group Interview methodology to obtain information, “Customer Interview” represents that scholars acquired information by the method of using questionnaire to interview customers, and “FGRM” represents that scholars used “Fuzzy Grey Relational Methodology” to get information.

It is evident in Table 1 (a rough application model) that when Sørensen et al. (2010) [7] used three information items: “conceptual demand direction”, “clear demand factor” and “importance degree of demand (absolute)” in Room 1, they used the method of “customer interviews (◆)” and “non-methodology (○)”, respectively, to obtain information. Additionally, they also used the “expert assessment (■)” in Room 3 and Room 4 to get information on “item assessment scale” and “category scale” and further used “non-methodology (○)” for the establishment of information on “decision values (absolute)”, “decision values (relative)”, and “decision-value (ranking)”.

In addition, it is also evident in Table 1 that (1) no matter in which Room, it is most frequent that scholars adopts the “non-methodology” to get all the necessary information required in each Room; (2) in Room 1, “FGI” is the frequently applied followed by “questionnaire” and “ANP”; (3) in Room 2, “expert assessment”, “questionnaire” and “FGI” are favorite methodologies; (4) in Room 3, Room 5 and Room 6, the “Fuzzy” is often used; and (5) in Room 4 and Room 7, “ANP” is scholars’ favorite.

Although table 1 only roughly shows that scholars, under “timing/purpose”, use multiple “methodologies” to acquire “information item” in each Room. But for the experienced user of QFD, it can help them to reconfirm the rationality of the method currently used with a stimulating effect on the extended use of new method. In addition, those who never used QFD can use the message of “timing/purpose”, “methodology” and “information items” specifically presented in this table to clearly predominate the use contour and the way of application on QFD.

TABLE 1 A ROUGH APPLICATION MODEL OF QFD

Methodology symbol

1. on-methodology: ○
2. Fuzzy: ●
3. Expert Assessment: ■
4. Market survey: ◇
5. FGI: ◎
6. Customer interview: ◆
7. FGRM: △
8. Questionnaire: *
9. Kano's model: ▼
10. Fuzzy Linear Regression: □
11. AHP: #
12. ANP: ▿

Timing/purpose	Writer (Room →)	**Room 1**					**Room 2**			**Room 3**			**Room 4**				**Room 5**				**Room 6**							**Room 7**	
	Information item	Conceptual demand direction	Clear demand factor	Decisive demand objective	Importance degree of demand (absolute)	Importance degree of demand (relative)	Conceptual technical direction	Clear technical function (factor)	Decisive technical specification (parameter)	Item assessment scale	Dichotomized scale	Continuous scale	Category scale	Dichotomized scale	Item assessment scale	Continuous scale	Satisfaction degree	Competitive demand assessment	Importance degree of demand (absolute)	Importance degree of demand (relative)	Decisive value (absolute)	Decisive value (relative)	Decisive value (ranking)	Resource restraint	Technical demand assessment	Technical objective/specification	Technology assessment	Dichotomized scale	Continuous scale
P1 Demand confirmation	Hsiao and Liu (2005)			○					○	○										○	○								
P1 Demand confirmation	Büyüközkan et al. (2007)		◎	◎			○		○			●							○	○	○		○						
P1 Demand confirmation	Sørensen et al. (2010)	◆	◆		○			○		■			■								○	○	○						
P1 Demand confirmation	Bevilacqua et al. (2012)		○			◇ ●	○	○				●	○									●	○						
P1 Demand confirmation	Wey and Chiu (2013)	○				▿	○					▿				▿					▿								▿
P2 Demand difference	Tontini (2007)			◎					○	○							▼				○	○				○			
P2 Demand difference	Mayyas et al. (2011)	○				○		○		○				○							○		○			○			
P2 Demand difference	Taylan (2013)		○			△		○		○				○							○								
P3 Activity planning	Lee et al. (2008)	*		*				*		○							▼	○	○	○	○	○	○						
P3 Activity planning	Lin et al. (2010)	○				■ #			○			● ▿				▿					○	○	○						● ▿
P3 Activity planning	Vezzetti et al. (2011)		*		*			○		○			○								○	○							
D1 Project selection	Bhattacharya et al. (2005)		○					○		○										#	○	○							
D1 Project selection	Karsak and Özogul (2009)		■						○		□			□				○		#					○				
D1 Project selection	Juan et al. (2009)		*				■					●									●								
D1 Project selection	Liang et al. (2012)	○					○					●							○		●	○	○						
D1 Project selection	Soroor et al. (2012)		○			● #	○					●	○								●		○						
D2 Policy execution	Karsak et al. (2003)			○					○			▿		○	▿	○				▿	○			○			○	○	▿
D2 Policy execution	Karsak (2004)		○						○			●						●	●					○			○		
D2 Policy execution	Chen and Ngai (2008)			*		#			○	○					○							○			○				
D2 Policy execution	Sener and Karsak (2011)			○		#		○				●		○				○						○	○	○	●		
C Difference assessment	Yang et al. (2003)	○	○	○	●		○	○				●	○				●				●								
C Difference assessment	Chou (2004)			◎	*				◎	*											○		○						
C Difference assessment	Kuo et al. (2011)			▼		▿			○			▿				▿					○	○	○						▿

A1 Process revision	Bottani and Rizzi (2006)		○						○			●				●		○		●	●		●	●					
	Lai et al. (2006)		○					○		○														○					
A2 Mechanism revision	Wilkinson (2007)			○	○			○	○	○			○					○							○				
	Melgoza et al. (2012)			○		○		○	○			●	○					○			○	○		○		○	○		

D. The related strength between information item and timing/purpose

Users can, through the "methodology" given by the "information item" of each room according to different uses of "timing/purpose" presented in the rough application model of the aforementioned QFD, select an appropriate method to manipulate QFD. However, in practical use, the "information item" is not fully applicable in a variety of uses of "timing / purpose". In other words, "Information item" corresponding to different "timing / purpose" will create correlation of different strengths.

Therefore, in addition to inviting the 11 experts participating in Delphi questionnaire, 9 experts/scholars who never participate in any questionnaire of the study were invited to carry out questionnaire survey of Likert 9 point scale promoting the degree of identification on information assessed.

The result in Table 2 demonstrates when Plan is in use, the related strength between the "conceptual demand direction" in Room 1 and P1 reaches 94% (=8.5/9.0), the related strength with P2 is 88% (=7.9/9.0), and the related strength with P3 is 62% (=5.6/9.0). This means that the information item of "conceptual demand direction" in Room 1 with the use of "Plan" is best used with "(P1) demand identification", followed by "(P2) demand difference" and "(P3) activity planning".

However, this does not mean that each information item with the use of different "timing/purpose" will show a visible difference in related strength. For example, for the "decision value (absolute)" in Room 6 with various uses of "timing/purpose", the related strength is always 100%(=9.0/9.0). This means that the information item of the "decision value (absolute)" is always necessary even the use of "timing/purpose" is different. In addition, scholars use Rooms 3, 4 and 7 primarily presenting the result of score on two factors and use this as a basis for subsequent calculation and selection. But in Room 3, the related strengths are pretty close when the "item assessment scales" is used with different "timing / purpose".

Relative to Table 1 "a rough application model of QFD," this research clearly prompted the relationship between "Information item", use of "timing/purpose" and "methodology". Table 2 further presents the related strength value when each information item is used with different "timing/purpose". Such value not only distinguishes the applicability of each "information item" used with different "timing/purpose", but also illustrates different effects on the practical use of PDCA management cycle. Therefore, this value can help users avoid misuse of information and further ensure the quality of analysis and decision-making.

TABLE 2 THE RELATED STRENGTH AND WEIGHTED VALUE BETWEEN "INFORMATION ITEM" IN EACH ROOM AND "TIMING/PURPOSE"

	Related strength and weighted value	**Related strength**								**AHP weighted value**	
Room	Timing/purpose	P			D		C	A		In each Room	Overall
		P1	P2	P3	D1	D2		A1	A2		
	Information item	Demand confirmation	Demand difference	Activity planning	Project selection	Policy execution	Difference assessment	Process revision	Mechanism revision		
1 (0.298)	Conceptual demand direction	8.5	7.9	5.6	4.6	3.9	4.4	5.1	4.3	0.144	0.045
	Clear demand factor	5.4	6.3	6.4	5.2	5.9	7.2	7.1	5.2	0.376	0.118
	Decisive demand objective	4.5	5.4	8.2	8.1	8.3	5.2	6.2	7.9	0.252	0.079
	Importance degree of demand (absolute)	6.9	4.2	6.5	5.5	5.4	5.1	5.7	5.6	0.090	0.028
	Importance degree of demand (relative)	4.3	7.6	5.4	6.8	7.8	6.2	4.5	4.3	0.138	0.043
2 (0.224)	Conceptual technical direction	7.9	8.2	4.2	5.9	3.8	5.9	4.3	3.6	0.214	0.044
	Clear technical function (factor)	5.2	4.8	8.1	6.6	8.6	7.1	8.3	6.6	0.434	0.089
	Decisive technical specification (parameter)	3.4	3.9	6.3	8.5	7.4	5.3	5.6	8.4	0.352	0.072
3 (0.196)	Item assessment scale	8.4	8.4	7.9	8.3	8.4	8.6	8.5	8.4	0.514	0.078
	Dichotomized scale	3.2	3.0	3.9	3.9	3.9	3.2	3.2	3.2	0.096	0.015
	Continuous scale	6.4	6.2	5.3	8.5	8.3	8.5	8.2	8.3	0.387	0.058
4 (0.040)	Category scale	3.9	3.8	5.3	8.2	7.3	8.1	8.2	8.3	0.474	0.016
	Dichotomized scale	8.6	8.4	8.1	5.6	3.1	7.5	5.6	5.4	0.141	0.005

	Item assessment scale	3.2	3.2	3.9	3.6	3.9	3.7	3.4	3.6	0.089	0.003
	Continuous scale	4.2	4.2	4.3	6.2	4.3	5.5	5.3	6.4	0.296	0.010
5 (0.065)	Satisfaction degree	6.8	6.4	3.9	6.1	4.2	8.1	7.6	7.4	0.422	0.026
	Competitive demand assessment	4.4	5.3	8.6	5.6	8.7	6.9	4.3	4.6	0.365	0.022
	Importance degree of demand (absolute)	5.9	3.2	5.5	4.5	4.4	4.1	4.7	4.6	0.083	0.005
	Importance degree of demand (relative)	3.3	6.6	4.4	5.8	6.8	5.2	3.5	3.8	0.130	0.008
6 (0.152)	Decision value (absolute)	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	0.273	0.060
	Decision value (relative)	6.3	7.2	6.9	6.4	6.2	7.8	6.5	7.6	0.066	0.015
	Decision value (ranking)	5.3	5.6	7.1	7.5	7.6	7.3	6.3	4.2	0.157	0.035
	Resource restraint	3.2	3.3	6.9	3.2	3.3	2.6	2.3	2.5	0.222	0.049
	Technical demand assessment	4.6	4.4	6.3	5.2	7.3	6.9	5.4	4.3	0.104	0.023
	Technical objective/specification	3.3	3.4	3.5	6.9	6.4	8.3	7.2	8.2	0.076	0.017
	Technology assessment	2.2	2.3	2.4	8.5	7.5	7.2	8.1	7.8	0.104	0.023
7 (0.025)	Dichotomized scale	6.1	6.3	5.8	4.9	5.2	4.6	5.3	5.6	0.360	0.005
	Continuous scale	2.4	2.5	2.3	2.1	2.6	1.7	1.6	2.5	0.640	0.010

IV. ESTABLISHING A COMPLETE APPLICATION MODEL

Though table 2 is able to present the related strength of “information item” with various use of “timing/purpose”, it cannot explain the deference in importance degree of each “information item” in each Room. Therefore, users, while using each Room, are not able to select an appropriate “information item” for use of analysis. For this reason, this study, through AHP analysis, obtains the “AHP weighted value (each room)” and its “AHP weighted value (overall)” that each “information item” is in each Room. By doing this, it can be a reference for users on selection of an appropriate “information item” as they are in the use of each Room.

A. The weighted value of each information item

In the process of AHP method, the 11 aforementioned experts participating in Delphi questionnaire were invited to proceed with the rating of the difference in importance degree between the pairs of “information item” in each room. Meanwhile, “Expert Choice 2000 decision support software” was used to proceed with a consistent check. The results show that the test results of various factors are in compliance with the statement of Saaty (1990) (CR≥0.1), so the achievement of this study (Table 2) is acceptable [35].

Additionally, this study, based on the ideal model of this software, obtained the result as illustrated in Table 2. It is learned from the results that (1) the sequence of the weighted value (importance) of each Room is in the order of Room 1> 2> 3> 6> 5> 4> 7. (2) The sum of the weighted values from the top four ranking Rooms 1, 2, 3, 6 reaches 0.870. It is obvious that these 4 Rooms are very important and indispensable. (3) Viewing from “AHP weighted value (overall)”, the sequence of the top five is in the order of “clear demand factor” in Room 1, “clear technical function (factor)” in Room 2, “decisive demand objective” in Room 1, “item assessment scales” in Room 3, and “decisive technical specification (parameter)” in Room 2. Obviously, these five are the most important ones among all of the “information items”. (4) Viewing the weighted value (“AHP weighted value (each Room)”) of the “information item” separately in each of the 7 Rooms, the most important “information item” in Room 1 is “clear demand factor”. The most important “information item” in each of Rooms 2 – 7 respectively is “clear technical function (factor)”, “item assessment scale”, “category scale”, “ satisfaction degree”, “decision value (absolute)” and “continuous scale”.

The “AHP weighted value (each room)” illustrated in Table 2 is able to clearly explain the difference in importance degree of such “information item” in each Room. Meanwhile, “AHP weighted value (overall)” can also explain the position of importance degree of each “information item” to the overall “information items”. However, viewing the “related strength” value on use of “timing/purpose”, both “AHP weighted values” cannot serve as a reference for selecting of an appropriate use of “timing/purpose”. Therefore, users who want to select more appropriate “information items” while using the same “timing/purpose” under in Room will definitely fail to effectively distinguish and select.

For this reason, this study imitates the method proposed by scholar Bhattacharya et al. (2005), which multiplies the “related strength” of each “information item” under various “timing/purpose” with the “AHP weighted value (each room)” of each “information item”, resulting in “strength weighted value” that each “information item” is in various uses of “timing/purpose”. Taking this into consideration, it can serve as a basis for the comparison and selection of “information items” in each Room.

For example, the “related strength” of “conceptual demand direction” in Room 1 under the “timing/purpose” of P1 (demand confirmation) is 8.5. Meanwhile, the “AHP weighted value (each room)” of this “information item” is 0.144. Multiplying the two values, the “strength weighted value” for each “information item” with various uses of “timing/purpose” is obtained as 1.22 (as illustrated in table 3). Similarly, the “strength weighted value” of the “importance degree of demand (relative)” is then 0.59 (=4.3×0.138).

Therefore, users can, through the values illustrated in Table 3, (1) clearly predominate the best use of time on each “information item” with various uses of purposes. For example, if a user wants to select “conceptual demand direction” in Room 1 as an “information item”, the best use is “timing/purpose” of P1 “demand confirmation”. (2) However, if the user wants to select the best “information item” under the “timing/purpose” of P1 (demand confirmation), then the user should select the “clear demand factor” of which “the strength weighted value” is the first in sequence, instead of the “ importance degree of demand (absolute)” - the fifth in sequence.

B. A complete application model of QFD

Using the content of section 2.3 in the literature for further analysis, it was found that scholars, while using different “timing/purpose”, will choose different Rooms to proceed analysis. Therefore, this study again proceeds KJ method twice, one Focus Group Interview and one Delphi questionnaire. The result was that under “timing/purpose” of P1 (demand confirmation), the majority of scholars will adopt three types of structures: “structure 3” (that is Room 1, 2, 3, 4, 6, and 7)”, “structure 4” (that is Room 1, 2, 3, 4, and 6)” and “structure 5” (that is Room 1, 2, 3, 5, and 6”. In addition, under the “timing/purpose” of A1, scholars will adopt two types of structures, including “structure 2” and “structure 6”.

The “structure” will remind users the Rooms and the number of Rooms that should be used in the application of QFD. Meanwhile, the “methodology” commonly used under “information item” also directly affects users on the accuracy of selecting method. Therefore, this study uses KJ method twice to re-organize and summarize the “information item” under “structure” and the “methodology” into Table 3 in order to allow users to grasp complete information for use. In addition, Table 3 is able to specifically present those that must be predominated in the use of QFD such as “timing/purpose”, “structure”, “information item” and its “methodology” required by each Room, and it is able to distinguish the “strength weighted value” under each “information item” and “ timing/purpose”. With the five aforementioned important messages, this study, therefore, calls this table “a complete application model of QFD”.

It is found in table 3 that (1) other than C and A, each “timing/purpose” has “structure 4” (Room 1, 2, 3, 4, and 6) and “structure 5” (Room 1, 2, 3, 5, and 6). Thus, the structure has the widest range of use. (2) The “methodology” used by each “information item” is different. For example, the “clear demand factor” in Room 1 adopts 4 methodologies including customer interview, FGI, questionnaire, and expert assessment. Meanwhile, “decisive demand objective” adopts 3 methodologies including FGI, Kano’s model and questionnaire. (3) “Methodology” is not required by all “information items”. For example, “category scale and item assessment scale” in Room 4, “importance degree of demand (absolute)” in Room 5, “decision value (relative) and decision value (ranking)” in Room 6, and “dichotomized scale” in Room 7 do not use any “methodology”. (4) The priority sequence among the “clear demand factor” in Room 1, “clear technical function (factor)” in Room 2, and “satisfaction degree” in Room 5 rank the first in 6 out of 8 different uses of “timing/purpose”. Therefore, those three “information items” are widely used under various “timing /purpose”. (5) The “item assessment scale” in Room 3, “category scale” in Room 4, “decisive value (absolute)” in Room 6 and “dichotomized scale” in Room 7 rank the first in any use of “timing/purpose”. This means these four “information items” are required in all uses of “timing/purpose”.

Users who want to use Table 3 to proceed QFD method can follow the following steps: (1) select “timing/purpose” according to the purpose of use; (2) with such purpose, select “structure type” coped for the use; (3) select the required Rooms based on the “structure type”; (4) complying with the demand purpose of the enterprise, select the most suitable “information item” in each Room; and (5) based on the enterprise’s capability of processing information, select the “methodology” that can be processed under each “information item” to proceed analysis.

For example, a user wants to use QFD to proceed operation assessment, he/she should (1) under “timing/purpose”, select “C (difference assessment)”; (2) in C, choose “structure type 6”; (3) that means in “Room”, select Room 1, 2, 3 and 6; (4) because customer intention is the sole purpose to learn, select “clear demand objective” and “importance degree of demand (absolute)” in Room 1, select “clear technical function (factor)” in Room 2, select “item assessment scale” in Room 3, and select “decision value (absolute)” and “technology assessment” in Room 6; and (5) because the enterprise is unable to manage higher level of mathematical capability, questionnaire is chosen for processing of analysis on “information item”.

TABLE 3 THE COMPLETE APPLICATION MODEL OF QFD

Room	Information item	Use Methodology	Timig	P						D				C		A			
			Purpose	P1		P2		P3		D1		D2				A1		A2	
			Structure	3/4/5[*1]		4/5		3/4/5		2/4/5/6		1/2/4/5		2/3/6		2/6		2	
1	Conceptual demand direction	Customer interview		1.22[*2]	2[*3]	1.14	3	0.81	3	0.66	4	0.56	4	0.63	4	0.73	3	0.62	3
	Clear demand factor	Customer interview, FGI, Questionnaire, Expert assessment		2.03	1	2.37	1	2.41	1	1.96	2	2.22	1	2.71	1	2.67	1	1.96	2
	Decisive demand objective	FGI、Kano’s model、Questionnaire		1.13	3	1.36	2	2.07	2	2.04	1	2.09	2	1.31	2	1.56	2	1.99	1
	Importance degree of demand	Questionnaire		0.62	4	0.38	5	0.59	5	0.50	5	0.49	5	0.46	5	0.51	5	0.50	5

	(absolute)																	
	Importance degree of demand (relative)	Fuzzy、AHP、ANP、FGRM	0.59	5	1.05	4	0.75	4	0.94	3	1.08	3	0.86	3	0.62	4	0.59	4
2	Conceptual technical direction	Expert assessment	1.69	2	1.75	2	0.90	3	1.26	3	0.81	3	1.26	3	0.92	3	0.77	3
	Clear technical function (factor)	Questionnaire	2.26	1	2.08	1	3.52	1	2.86	2	3.73	1	3.08	1	3.60	1	2.86	2
	Decisive technical specification (parameter)	FGI	1.20	3	1.37	3	2.22	2	2.99	1	2.60	2	1.87	2	1.97	2	2.96	1
3	Item assessment scale	Questionnaire, Expert assessment	4.32	1	4.32	1	4.06	1	4.27	1	4.32	1	4.42	1	4.37	1	4.32	1
	Dichotomized scale	Fuzzy linear regression	0.31	3	0.29	3	0.37	3	0.37	3	0.37	3	0.31	3	0.31	3	0.31	3
	Continuous scale	ANP、Fuzzy	2.48	2	2.40	2	2.05	2	3.29	2	3.21	2	3.29	2	3.17	2	3.21	2
6	Decision value (absolute)	Fuzzy、ANP	2.46	1	2.46	1	2.46	1	2.46	1	2.46	1	2.46	1	2.46	1	2.46	1
	Decision value (relative)		0.42	5	0.48	4	0.46	5	0.42	7	0.41	7	0.51	7	0.43	7	0.50	6
	Decision value (ranking)		0.83	2	0.88	2	1.11	3	1.18	2	1.19	2	1.15	2	0.99	2	0.66	3
	Resource restraint	Fuzzy	0.71	3	0.73	3	1.53	2	0.71	4	0.73	5	0.58	6	0.51	6	0.56	5
	Technical demand assessment	Fuzzy	0.48	4	0.46	5	0.66	4	0.54	5	0.76	4	0.72	4	0.56	4	0.45	7
	Technology specification/objective	Fuzzy	0.25	6	0.26	6	0.27	6	0.52	6	0.49	6	0.63	5	0.55	5	0.62	4
	Technology assessment	Fuzzy	0.23	7	0.24	7	0.25	7	0.88	3	0.78	3	0.75	3	0.84	3	0.81	2
4	Category scale		1.85	1	1.80	1	2.51	1	3.89	1	3.46	1	3.84	1	3.89	1	3.93	1
	Dichotomized scale	Fuzzy linear regression	1.21	3	1.18	3	1.14	3	0.79	3	0.44	3	1.06	3	0.79	3	0.76	3
	Item assessment scale		0.28	4	0.28	4	0.35	4	0.32	4	0.35	4	0.33	4	0.30	4	0.32	4
	Continuous scale	ANP、Fuzzy	1.24	2	1.24	2	1.27	2	1.84	2	1.27	2	1.63	2	1.57	2	1.89	2
5	Satisfaction degree	Fuzzy、Kano’s model	2.87	1	2.70	1	1.65	2	2.57	1	1.77	2	3.42	1	3.21	1	3.12	1
	Competitive demand assessment	Fuzzy	1.61	2	1.93	2	3.14	1	2.04	2	3.18	1	2.52	2	1.57	2	1.68	2
	Importance degree of demand (absolute)		0.49	3	0.27	4	0.46	4	0.37	4	0.37	4	0.34	4	0.39	4	0.38	4
	Importance degree of demand (relative)	ANP、Fuzzy、AHP	0.43	4	0.86	3	0.57	3	0.75	3	0.88	3	0.68	3	0.46	3	0.49	3
7	Dichotomized scale		2.20	1	2.27	1	2.09	1	1.76	1	1.87	1	1.66	1	1.91	1	2.02	1

	Continuous scale	ANP、Fuzzy	1.54	2	1.60	2	1.47	2	1.34	2	1.66	2	1.09	2	1.02	2	1.60	2

Remark: *1: Structure 1 (Room 1-7), Structure 2 (Room 1-6), Structure 3 (non-Room 5), Structure 4 (non-Room 5, 7), structure 5 (non-Room 4, 7), structure 6 (non-Room 4, 5, 7).

*2: is the "strength weighted value" resulting from multiplying the "related strength" and "AHP weighted value (each room)".

*3: is the ranking of suitable sequence of each "information item" in each Room when use with various "timing/purpose".

V. CONCLUSION

In order to guide users to accurately use QFD and to further enhance the application value of this method, this study, in addition to archived the documentation achievement, further relocated such achievement and methodology to the PDCA management cycle. This paper demonstrates the five types of information to be used by scholars when they use this methodology so as to establish "a complete application model of QFD".

As said by the experts/scholars interviewed, this study will help users, from the aspect of "management application", to (1) understand the operation procedure and implication of the traditional QFD; (2) realize scholars' diverse application scopes and structures; (3) allow users to inquire and apply easily; (4) avoid the hesitation and groping during application process; and (5) promote it to all departments of the entire company. From the aspect of "management mechanism", it can, (1) through the use of "timing/purpose" of PDCA management cycle, establish the mechanism of use/selection in each department; (2) establish data collection mechanism based on the difference of importance degree of "information item"; and (3) discover the insufficient capability of current use on "methodology" so to establish educational training mechanism. In addition, from the aspect of "management decision", it can (1) evaluate the rationality of information currently used to decide whether to add or delete; (2) assess the correctness of the method currently used to improve decision quality; and (3) embrace the information required by decision in the operation procedure in order to raise the convenience of decision and further extend to all departments of the company.

In conclusion, this model can assist the experienced user to identify the rationality and effectiveness of current practice; assist new users to quickly grasp the overall structure and follow direction of QFD. It can also assist all departments to fully import QFD technology in the improvement of various business.

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