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新產品設計規劃之模糊品質機能展開建構模式

A Fuzzy Quality Function Deployment Constructing Model for New Product Design Planning

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摘要

品質機能展開是新產品設計規劃的一項重要工具。新產品設計開發團隊可以藉此清楚地知道顧客的期望與需求，並且有系統的評估所提供的產品或服務是否符合顧客的需求。評估顧客需求的重要性評分是 QFD 展開的重要程序。最近的研究指出，在 QFD 的應用上，解讀顧客需求的議題仍然有待改善。此外，在現行 QFD 的研究中，有關各項需求之間相互影響的議題，幾乎僅聚焦在設計需求的分析上，忽略了各項顧客需求之間經常具有相關性，特別是新產品的各項顧客需求經常被視為都具有高度的重要性。本研究利用模糊理論提出一個結合顧客、競爭與價值等三項觀點的評估模式以獲得客戶需求的重要性評比，同時，考慮顧客需求的交互影響及設計需求的交互影響，以獲得 QFD 關係矩陣。依據上述的結果將可獲得 QFD 各項設計需求的重要性評比。最後，以案例說明所提出之方法較傳統的 QFD 建構模式可獲的較佳的客戶滿意度。

關鍵字：品質機能展開、新產品設計規劃、顧客需求、模糊理論

Abstract

Quality function deployment (QFD) is an important tool in processing new product design planning in order to maximum customer satisfaction. The team members of QFD have to recognize the customers' need and expectation clearly with QFD and evaluate systematically the product or service planning whether conform to customers' requirements. Evaluating the important score of each customer requirement is a leading procedure to QFD activity. The recent research argued that one of the major difficulties to QFD is interpreting the customers' voice. Furthermore, in terms of the interactive influence of customer requirements issues were almost ignored in the existing studies on which only discussed the influence for design requirements in the relevant QFD researches. However, in early stage of new product development, the interactive influence of each customer requirement is prevailed practically due to each customer requirement is beheld very important entry. Unlike existing research, this study considers three different perspectives, the customer, competition, and value perspectives, to evaluate the importance scores of CRs. To cope with the vague and uncertain nature of the new product planning stage, fuzzy approaches are adopted using the modified fuzzy Delphi method, entropy and value analysis methods. In addition, different to prior studies, this paper not only considers the relationships among DRs but takes the relationships among CRs into account to determine the normalized relationship between CRs and DRs, and also proposes a modified normalized relationship between CRs and DRs to overcome the weakness of the existing models. Based on an illustrative example, the proposed methods indicate that the total degree of customer satisfaction achieved is greater than with the previous methods.

Keywords: quality function deployment (QFD), new product design planning, customer requirements, fuzzy set theory

前言

品質機能展開是一個重要的新產品設計與開發工具。新產品開發團隊可以藉此清楚地知道顧客的期望與需求，並且有系統的評估所提供的產品或服務是否符合顧客的需求 [1]。根據過去的研究發現，QFD 應用於新產品設計規劃，能有效的將顧客需求轉換成產品設計開發過程的決策參考資訊，以有效的縮短產品開發時間，降低設計變更的次數，快速回應顧客的需求，有助於提高顧客滿意度 [1-4]。Carnevalli and Miguel [3] 指出有關解讀顧客需求的研究，過去所採用的研究方法，大部分都採用 Kano 模式、模糊邏輯(fuzzy logic)、腦力激盪法(brainstorming)與因果關係圖(cause and effect diagrams)等工具或方法來處理解讀顧客需求的問題。但是，有關顧客需求的解讀議題仍有待改善。此外，從過去的文獻中很少發現考慮顧客需求相互影響的相關研究。有關各項需求之間的相互影響之議題的研究，幾乎僅聚焦在設計需求的分析上。因此，本研究提出一個考慮顧客需求相互影響的 QFD 建構模式，以改善解讀顧客需求的問題。當顧客需求可以被清楚的解讀，對於決定設計需求、顧客需求與設計需求的相關性的強度及相關資源的分析將更貼近顧客的期望，對於提升整體顧客滿意度將有較佳的成效。在新產品設計規劃階段，很多的產品開發資訊都處在不確定的情況下，甚至顧客本身對於產品的需求也無法確切的掌握。模糊理論由於具有解決不確定性問題的特質，且被廣泛的應用在 QFD 的問題上[5-8]，本研究採用模糊理論來改善並克服客戶需求資訊於新產品設計規劃階段不確定的問題。

研究目的

QFD 的優點就是藉由收集顧客的需求進而發展出滿足顧客需求的設計需求項目，藉由決定顧客需求與設計需求之間的關係強度，獲得各項設計需求的重要性評比。雖然設計需求的重要性評比對於產品規劃的結果是否符合顧客的期望，扮演相當重要的角色，但是，有關解讀顧客需求的議題仍然有待改善。本研究利用 QFD 做為新產品設計規劃的工具，考慮顧客、競爭、與價值等不同的觀點評估客戶需求的重要性，同時進一步考慮各項顧客需求交互影響因素，利用模糊理論的相關方法，以獲得 QFD 關係矩陣。利用上述的結果將可獲得設計需求的重要性評比，由設計需求的重要性平將可釐清各項顧客需求之目標設定，有助於決策者決定滿足客戶需求的設計規劃，以有效的縮短產品開發時間，並提高顧客滿意度。

文獻探討

品質機能展開相關之研究報告非常豐富，且廣泛的分佈在各種不同地領域。有關顧客需求權重方面相關的研究，Kano 概念模式搭配顧客的問卷調查，常應用於決定顧客需求[1, 5, 9, 10]。Kasak [11] 和 Chen and Ko [6]將顧客與潛在顧客視為專家，利用模糊德菲法(fuzzy Delphi method)，藉由收集不同顧客的意見來決定顧客需求的重要性權重。模糊德菲法的應用，視客戶與潛在客戶為專家，較適合企業對企業之間的商務模式。層級分析法 (analytic hierarchy process，AHP) 與網路分析程序 (analytic network process，ANP)也常被應用於決定顧客需求的重要性評分 [12-16]。考量新產品設計規劃階段，顧客需求的知識仍屬於內隱知識 (tacit knowledge) 的狀態，AHP 視各項顧客需求為相互獨立，忽略了各項顧客需求之間存在交互影響的可能性，也是 AHP 方法在應用上的限制。ANP 雖然考慮了各項顧客需求交互作用的影響，但是對於不同顧客在相同顧客需求的差異性，卻無法有效的處理。Myint [17] 提出以利用類神經網路 (artificial neural networks，ANNs) 的技術決定顧客需求的權重。在新產品設計規劃的初期，類神經網路系統恐怕不易獲得適當的學習資料。另外，類神經網路系統黑箱(black box)處理的方式，對於 QFD 關係矩陣與相關矩陣的等中介資料的運用，恐較無法得知其影響性。Silva *et al.* [18] 利用價值分析 (value analysis，VA) 的技術

與概念發展每項顧客需求對產品機能 (function) 的需求與成本評價，最後經由價值評價決定顧客需求的重要性評比。然而結合 QFD 顧客需求與 VA 的具體量化模式仍未見提出，恐怕還是受到主觀決策的限制。

在產品開發初期，各項產品需求都被視為具有高度的重要性，Chan and Wu [19] 認為從顧客端很困難取得各項顧客需求相互影響。然而，忽略各項顧客需求之間的交互影響潛藏著誤解顧客聲音的風險，可能導致後續決定 QFD 的設計需求與關係矩陣無法滿足顧客對產品開發的期望。ANP 是最常用來處理顧客需求具相互影響的方法[14-16]，顧客需求之間的相關性在 ANP 的運算上只被視為是超級矩陣的一項準則元素，對於瞭解顧客需求與設計需求的實際相關強度，恐怕無法提供有用的參考資料，這意味著，解讀顧客需求的議題仍有待克服。

研究方法

新產品設計規劃的活動中，本研究發展出一套考慮顧客需求交互影響之品質機能展開的建構模式。首先，本研究考慮三種評估觀點，分別是顧客、競爭與價值進行顧客需求重要性評分的評估。

1. 顧客觀點

本研究考慮現有顧客與潛在顧客對各項客戶需求的重要性進行評估，利用修改後之模糊德菲法[20]結合 Bojadziev. and Bojadziev''s [21]一致性條件，以獲得各項顧客需求的重要性評比。其步驟如下:

步驟一: 請現有顧客與潛在顧客針對各項 CR 進行評比，其表示式如下

$$\tilde{k}_{i,e}=\left[\left(k_{i,e}\right)^{\mathrm{L}*},\left(k_{i,e}\right)^{\mathrm{M}*},\left(k_{i,e}\right)^{\mathrm{U}*}\right],\ e=1,2,\ldots,E;\ i=1,2,\ldots,I, \tag{1}$$

在 (1) 式中，e 代表評估者，“L*”, “M*”, “U*”代表評估結果$\tilde{k}_{i,e}$最低、最有可能與最高的水平。

步驟二: 計算各項評估的平均值，同時考量不同評估者的重要性權重ν_e。

$$\tilde{\bar{k}}_i=\left[\left(\bar{k}_i\right)^{\mathrm{L}*},\left(\bar{k}_i\right)^{\mathrm{M}*},\left(\bar{k}_i\right)^{\mathrm{U}*}\right]=\left[\frac{\sum_{e=1}^{E}\nu_e\left(k_{i,e}\right)^{\mathrm{L}*}}{\sum_{e=1}^{E}\nu_e},\frac{\sum_{e=1}^{E}\nu_e\left(k_{i,e}\right)^{\mathrm{M}*}}{\sum_{e=1}^{E}\nu_e},\frac{\sum_{e=1}^{E}\nu_e\left(k_{i,e}\right)^{\mathrm{U}*}}{\sum_{e=1}^{E}\nu_e}\right] \tag{2}$$

將$\tilde{\bar{k}}_i$的結果寄給每位評估者，並進行第二輪的評估。

步驟三: 依據$\tilde{\bar{k}}_i$，每位評估者提供修正後的評估

$$\tilde{k}'_{i,e}=\left[\left(k'_{i,e}\right)^{\mathrm{L}*},\left(k'_{i,e}\right)^{\mathrm{M}*},\left(k'_{i,e}\right)^{\mathrm{U}*}\right],\ e=1,2,\ldots,E;\ i=1,2,\ldots,I. \tag{3}$$

利用 (2) 計算第二輪的評估結果的平均值，再利用 (4) 式判斷第一輪的與第二輪評估結果的一致性。

$$d\left(\tilde{\bar{k}}_i,\tilde{\bar{k}}'_i\right)=0.5\left\{\max\left[\left|\left(\bar{k}_i\right)^{\mathrm{L}*}-\left(\bar{k}'_i\right)^{\mathrm{L}*}\right|,\left|\left(\bar{k}_i\right)^{\mathrm{U}*}-\left(\bar{k}'_i\right)^{\mathrm{U}*}\right|\right]+\left|\left(\bar{k}_i\right)^{\mathrm{M}*}-\left(\bar{k}'_i\right)^{\mathrm{M}*}\right|\right\} \tag{4}$$

步驟二與步驟三需持續進行，直到$d\le 0.2$。

步驟四: 如果已達$d\le 0.2$，回到步驟一。

最後，可以獲得$\tilde{k}'_i=\left[\left(k'_i\right)^{\mathrm{L}*},\left(k'_i\right)^{\mathrm{M}*},\left(k'_i\right)^{\mathrm{U}*}\right]\in[0,1]$之各項 CR 的重要性評比。

2. 競爭觀點

在企業對企業的商業模式下，競爭觀點利用資訊熵 (entropy) [22] 的方法決定各項 CR 的賣點。考慮每家公司有不同的客戶與競爭對手，針對各項 CR 之滿意績效，請顧客 t 評估其供應商ψ，$\psi=1,\ldots,\Psi,\ i=1,\ldots,I$ 的成績，假設其結果如(5) 所示。接著考慮顧客 t 與供應

商 ψ 的關係水準 $\nu_{\psi,t}$ ，利用(6) 以獲得各項 CR 之滿意績效結果。

$$\begin{bmatrix} \tilde{y}_{11,t} & \cdots & \tilde{y}_{1I,t} \\ \vdots & \tilde{y}_{\psi i,t} & \vdots \\ \tilde{y}_{\Psi 1,t} & \cdots & \tilde{y}_{\Psi I,t} \end{bmatrix} = \begin{bmatrix} (y_{11}^{L*}, y_{11}^{M*}, y_{11}^{U*})_t & \cdots & (y_{1I}^{L*}, y_{1I}^{M*}, y_{1I}^{U*})_t \\ \vdots & (y_{\psi i}^{L*}, y_{\psi i}^{M*}, y_{\psi i}^{U*})_t & \vdots \\ (y_{\Psi 1}^{L*}, y_{\Psi 1}^{M*}, y_{\Psi 1}^{U*})_t & \cdots & (y_{\Psi I}^{L*}, y_{\Psi I}^{M*}, y_{\Psi I}^{U*})_t \end{bmatrix}, \tag{5}$$

其中

$$\left(y_{\psi i}^{L*'}, y_{\psi i}^{M*'}, y_{\psi i}^{U*'}\right) = \left(\frac{\sum_{t=1}^{T} \nu_{\psi,t} \cdot \left(y_{\psi i}^{L*}\right)_t}{\sum_t \nu_{\psi,t}}, \frac{\sum_{t=1}^{T} \nu_{\psi,t} \cdot \left(y_{\psi i}^{M*}\right)_t}{\sum_t \nu_{\psi,t}}, \frac{\sum_{t=1}^{T} \nu_{\psi,t} \cdot \left(y_{\psi i}^{U*}\right)_t}{\sum_t \nu_{\psi,t}} \right) \tag{6}$$

依據(5)，(6)的結果，利用資訊熵[22]的概念轉換各項 CR 之滿意績效為賣點。

$$\begin{aligned} \widetilde{SP}_i &= \left[SP_i^{L*}, SP_i^{M*}, SP_i^{U*}\right] \\ &= \left[\sum_{\psi=1}^{\Psi} y_{\psi i}^{L*'} \cdot \mathbf{log}\left(\frac{1}{y_{\psi i}^{U*'}}\right), \sum_{\psi=1}^{\Psi} y_{\psi i}^{M*'} \cdot \mathbf{log}\left(\frac{1}{y_{\psi i}^{M*'}}\right), \sum_{\psi=1}^{\Psi} y_{\psi i}^{U*'} \cdot \mathbf{log}\left(\frac{1}{y_{\psi i}^{L*'}}\right) \right]. \end{aligned} \tag{7}$$

3. 價值觀點

在新產品設計規劃階段，各項顧客需求之機能價值 $\tilde{w}_{i,e}$ 與成本 C_i^* 的評估存在模糊不確定性，本研究利用模糊德菲法進行 $\tilde{w}_{i,e}$ 與 C_i^* 的評估。各項顧客需求之價值目標可表示為：

$$\tilde{V}_i = \left(V_i^{L*}, V_i^{M*}, V_i^{U*}\right) = \left[\frac{\left(\overline{w}_i'\right)^{L*}}{\left(C_i^*\right)^{U*}}, \frac{\left(\overline{w}_i'\right)^{M*}}{\left(C_i^*\right)^{M*}}, \frac{\left(\overline{w}_i'\right)^{U*}}{\left(C_i^*\right)^{L*}} \right] \quad i=1,\ldots,I. \tag{8}$$

$\tilde{V}_i$ 越大表示第 i 項顧客需求的價值目標越高，反之則越低。

本研究擬採用模糊運算的方法，整合上述規劃矩陣中各種觀點的評估結果以獲得各項顧客需求的重要性評比。

$$\tilde{K}_i = \tilde{k}_i' \otimes \widetilde{SP}_i \otimes \tilde{V}_i \quad i=1,\ldots,I. \tag{9}$$

為了簡化 QFD 設計需求重要性的運算模式，(9)之結果可以利用(10)予以解模糊。

$$K_i' = \frac{\sum_i \alpha_i \cdot \left(K_i\right)_{\alpha_i}}{\sum_i \alpha_i}, \quad \text{i = 1, …, I.} \tag{10}$$

其中，α代表不同信賴水準，$\alpha \in [0, 1]$。

其次，本研究提出一個考慮顧客需求交互影響之 QFD 關係矩陣。首先，在 Chen and Weng [23]的模式中

$$\left(R_{ij}'\right)_\alpha^L = \frac{\sum_{\zeta=1}^{J} \left(R_{i\zeta}\right)_\alpha^L \left(T_{\zeta j}\right)_\alpha^L}{\sum_{\zeta=1}^{J} \left(R_{i\zeta}\right)_\alpha^L \left(T_{\zeta j}\right)_\alpha^L + \sum_{\substack{\phi=1 \\ \phi \neq j}}^{J} \sum_{\zeta=1}^{J} \left(R_{i\zeta}\right)_\alpha^U \left(T_{\zeta\phi}\right)_\alpha^U}, \tag{11a}$$

$$\left(R_{ij}'\right)_\alpha^U = \frac{\sum_{\zeta=1}^{J} \left(R_{i\zeta}\right)_\alpha^U \left(T_{\zeta j}\right)_\alpha^U}{\sum_{\zeta=1}^{J} \left(R_{i\zeta}\right)_\alpha^U \left(T_{\zeta j}\right)_\alpha^U + \sum_{\substack{\phi=1 \\ \phi \neq j}}^{J} \sum_{\zeta=1}^{J} \left(R_{i\zeta}\right)_\alpha^L \left(T_{\zeta\phi}\right)_\alpha^L}. \tag{11b}$$

如果 $\sum_{\substack{\phi=1 \\ \phi \neq j}}^{J} \sum_{\zeta=1}^{J} \left(R_{i\zeta}\right)_\alpha^U \left(T_{\zeta\phi}\right)_\alpha^U = 0$ 或 $\sum_{\substack{\phi=1 \\ \phi \neq j}}^{J} \sum_{\zeta=1}^{J} \left(R_{i\zeta}\right)_\alpha^L \left(T_{\zeta\phi}\right)_\alpha^L = 0$ 則 $\left(R_{ij}'\right)_\alpha^L = 1$ 或 $\left(R_{ij}'\right)_\alpha^U = 1$。很明顯是不合理的正規化運算結果。本研究提出以下模式修正此問題點並將顧客需求交互影響也納

入關係矩陣，其運算模式如(11a)、(11b) 、(12a) 與 (12b)所示。

$$\left({}^{*}R'_{ij}\right)_{\alpha}^{L}=\begin{cases}\dfrac{\sum_{\zeta=1}^{J}\left(R_{i\zeta}\right)_{\alpha}^{L}\left(T_{\zeta j}\right)_{\alpha}^{L}}{\sum_{\zeta=1}^{J}\left(R_{i\zeta}\right)_{\alpha}^{L}\left(T_{\zeta j}\right)_{\alpha}^{L}+\sum_{\substack{\phi=1\\ \phi\neq j}}^{J}\sum_{\zeta=1}^{J}\left(R_{i\zeta}\right)_{\alpha}^{U}\left(T_{\zeta\phi}\right)_{\alpha}^{U}}, \text{ and}\\ R_{ij}^{L}, \text{ if } \sum_{\substack{\phi=1\\ \phi\neq j}}^{J}\sum_{\zeta=1}^{J}\left(R_{i\zeta}\right)_{\alpha}^{U}\left(T_{\zeta\phi}\right)_{\alpha}^{U}=0\end{cases} \tag{12a}$$

$$\left({}^{*}R'_{ij}\right)_{\alpha}^{U}=\begin{cases}\dfrac{\sum_{\zeta=1}^{J}\left(R_{i\zeta}\right)_{\alpha}^{U}\left(T_{\zeta j}\right)_{\alpha}^{U}}{\sum_{\zeta=1}^{J}\left(R_{i\zeta}\right)_{\alpha}^{U}\left(T_{\zeta j}\right)_{\alpha}^{U}+\sum_{\substack{\phi=1\\ \phi\neq j}}^{J}\sum_{\zeta=1}^{J}\left(R_{i\zeta}\right)_{\alpha}^{L}\left(T_{\zeta\phi}\right)_{\alpha}^{L}}.\\ R_{ij}^{U}, \text{ if } \sum_{\substack{\phi=1\\ \phi\neq j}}^{J}\sum_{\zeta=1}^{J}\left(R_{i\zeta}\right)_{\alpha}^{L}\left(T_{\zeta\phi}\right)_{\alpha}^{L}=0\end{cases} \tag{12b}$$

$$\left(R''_{ij}\right)_{\alpha}^{L}=\begin{cases}\dfrac{\sum_{\zeta=1}^{I}\left(L_{i\zeta}\right)_{\alpha}^{L}\left({}^{*}R'_{\zeta j}\right)_{\alpha}^{L}}{\sum_{\zeta=1}^{I}\left(L_{i\zeta}\right)_{\alpha}^{L}\left({}^{*}R'_{\zeta j}\right)_{\alpha}^{L}+\sum_{\substack{\phi=1\\ \phi\neq i}}^{I}\sum_{\zeta=1}^{I}\left(L_{\phi\zeta}\right)_{\alpha}^{U}\left({}^{*}R'_{\zeta j}\right)_{\alpha}^{U}}, \text{ and}\\ \left({}^{*}R'_{ij}\right)_{\alpha}^{L}, \text{ if } \sum_{\substack{\phi=1\\ \phi\neq i}}^{I}\sum_{\zeta=1}^{I}\left(L_{\phi\zeta}\right)_{\alpha}^{U}\left({}^{*}R'_{\zeta j}\right)_{\alpha}^{U}=0\end{cases} \tag{13a}$$

$$\left(R''_{ij}\right)_{\alpha}^{U}=\begin{cases}\dfrac{\sum_{\zeta=1}^{I}\left(L_{i\zeta}\right)_{\alpha}^{U}\left({}^{*}R'_{\zeta j}\right)_{\alpha}^{U}}{\sum_{\zeta=1}^{I}\left(L_{i\zeta}\right)_{\alpha}^{U}\left({}^{*}R'_{\zeta j}\right)_{\alpha}^{U}+\sum_{\substack{\phi=1\\ \phi\neq i}}^{I}\sum_{\zeta=1}^{I}\left(L_{\phi\zeta}\right)_{\alpha}^{L}\left({}^{*}R'_{\zeta j}\right)_{\alpha}^{L}}.\\ \left({}^{*}R'_{ij}\right)_{\alpha}^{U}, \text{ if } \sum_{\substack{\phi=1\\ \phi\neq i}}^{I}\sum_{\zeta=1}^{I}\left(L_{\phi\zeta}\right)_{\alpha}^{L}\left({}^{*}R'_{\zeta j}\right)_{\alpha}^{L}=0\end{cases} \tag{13b}$$

利用(8)與(12)之結果，即可決定各項 DR 之重要性評比。

$$\left(\tilde{W}_{j}\right)_{\alpha}=\left[\left(W_{j}\right)_{\alpha}^{L},\left(W_{j}\right)_{\alpha}^{U}\right]=\left[\frac{\sum_{i=1}^{I}K'_{i}\cdot\left(R''_{ij}\right)_{\alpha}^{L}}{\sum_{i=1}^{I}K'_{i}},\frac{\sum_{i=1}^{I}K'_{i}\cdot\left(R''_{ij}\right)_{\alpha}^{U}}{\sum_{i=1}^{I}K'_{i}}\right]. \tag{14}$$

在顧客觀點與價值觀點分別評估各項 CR 之重要性水平與價值。

結果與討論

本研究利用一個 T^2BGA 半導體封裝的案例驗證所提出之方法的實用性。首先，由 QFD 團隊進行顧客需求的搜集，假設 CR 包括“產品輪廓” (CR_1), “散熱績效” (CR_2), “電性績效” (CR_3), “可靠度” (CR_4), and “共平面性” (CR_5). 利用圖二之各種語意量辭作為各類評估的參考依據，分別針對顧客、競爭與價值等三個觀點進行 CRs 之重要性、賣點與價值的評估。依據(1)-(8)的方法分別獲得表一到表六的結果。其中，表一與表二，分別表示利用模糊德菲法所獲得之第一輪與第二輪 CRs 之重要水平評估結果。並且在第二輪的評估結果獲得滿足

(4)之收斂條件。表三與表四分別代表 CRs 之績效滿意度評估結果與轉換後的賣點。表五與表六分別表示利用模糊德菲法所獲得之第一輪與第二輪 CRs 之價值評估結果。同樣的，在第二輪的評估結果獲得滿足(4)之收斂條件。依據上述的評估結果，利用(9)、(10)可以獲得各項 CRs 的重要性評分，經正規化轉換後，其結果分別為[0.043, 0.305, 0.206, 0.377, 0.069]。

其次，QFD 團隊依據 CRs 建立 T^2BGA 之 HOQ (如圖三所示)，並利用(12)-(14) 獲得各項 DR 之重要性結果(如表七所示)。為比較本研究所提出之以三種不同觀點評估顧客需求較傳統單一觀點更深化了解顧客的聲音，本利用 Chen and Weng [23]所提出之顧客滿意度模式求解經 HOQ 所獲致顧客滿意度結果(如圖四所示)。

由圖四的結果顯示，本研究所提出以三種不同觀點評估顧客需求之方法，可獲得較佳的顧客滿意度。

結論

品質機能展開是新產品設計規劃的一項重要工具。本研究利用模糊理論提出一個結合顧客、競爭與價值等三項觀點的評估模式以獲得 QFD 客戶需求的重要性評比，以提升對顧客需求的了解，同時，考慮顧客需求的交互影響及設計需求的交互影響，及提出改善現行研究有關 QFD 關係矩陣不合理出之解決方法。依據上述的結果獲得 QFD 各項設計需求的重要性評比。由一個半導體封裝的實例驗證所提出之方法較傳統的 QFD 建構模式可獲的較佳的客戶滿意度。

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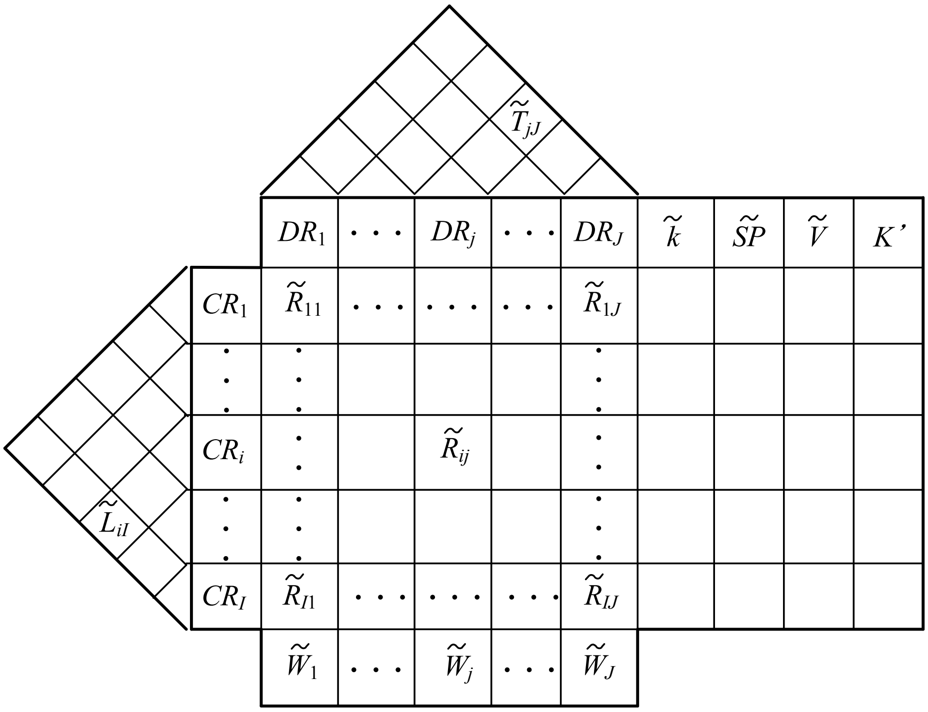
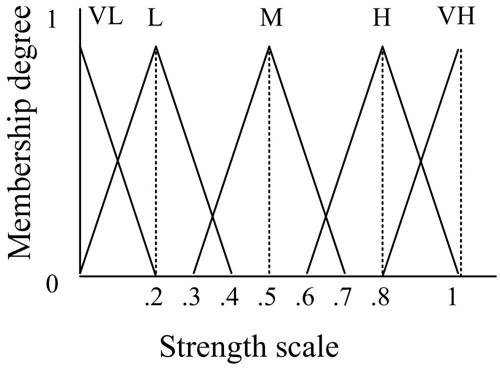
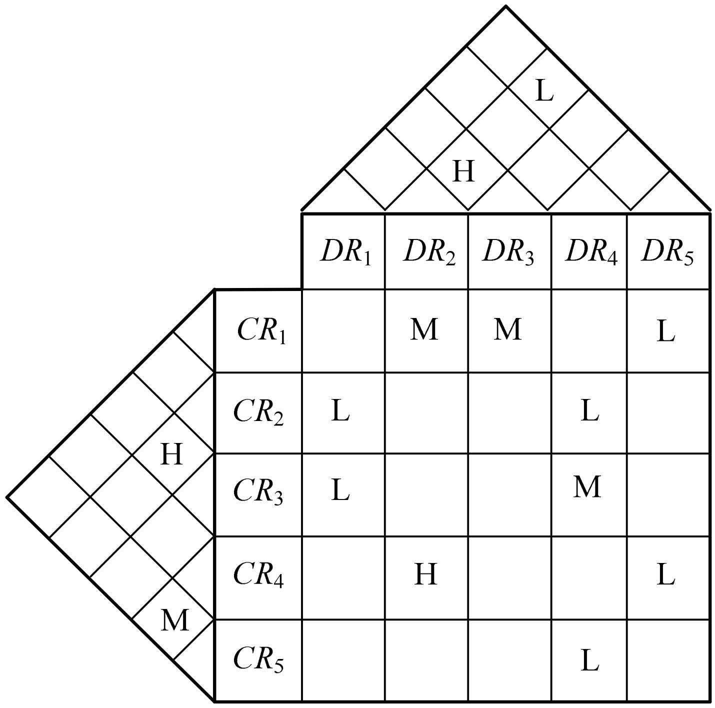


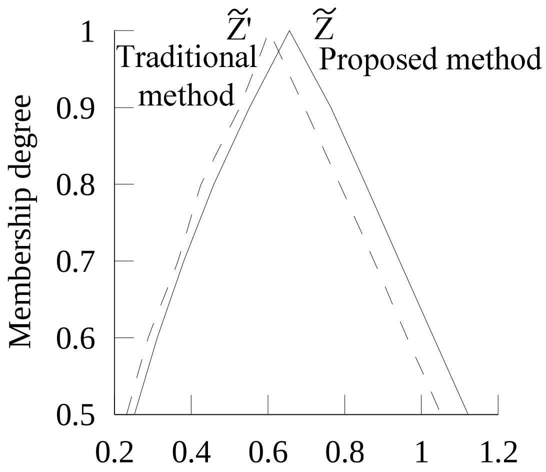
圖一: 品質屋架構圖



圖二: 各種語意量辭之歸屬函數



圖三: T^2BGA 之品質屋



圖四: 不同研究方法之客戶滿意度之歸屬函數

表一: 第一輪 CRs 之重要水平評估結果

Customer	CR_1	CR_2	CR_3	CR_4	CR_5
$Cust_1$	L	M	L	H	VL
$Cust_2$	L	M	VL	H	L
$Cust_3$	VL	H	M	M	L
$Cust_4$	M	L	L	H	M
$Cust_5$	L	L	L	VH	VL
$Cust_6$	L	M	H	M	VL
$Cust_7$	M	M	L	L	VL
$Cust_8$	VL	M	VL	M	L

表二:　第二輪 CRs 之重要水平評估結果

Customer	CR_1	CR_2	CR_3	CR_4	CR_5
$Cust_1$	L	M	L	H	L
$Cust_2$	L	M	L	H	L
$Cust_3$	L	M	M	M	L
$Cust_4$	L	L	L	H	L
$Cust_5$	L	M	L	VH	L
$Cust_6$	L	M	M	H	VL
$Cust_7$	M	M	L	M	VL
$Cust_8$	L	M	L	H	L

表三: CRs 績效滿意度評估結果

Customer1						
supplier	CR_1	CR_2	CR_3	CR_4	CR_5	weight
$comp_1$	VH	M	M	H	VH	1.5
$comp_2$	VH	M	M	H	H	1.2
$comp_3$	VH	M	M	H	H	1
Customer2						
supplier	CR_1	CR_2	CR_3	CR_4	CR_5	weight
$comp_1$	VH	M	M	H	VH	1.5
$comp_2$	VH	M	M	M	H	1.5
$comp_3$	H	M	M	M	M	1
Customer3						
supplier	CR_1	CR_2	CR_3	CR_4	CR_5	weight
$comp_1$	VH	M	M	H	VH	1.2
$comp_2$	VH	M	M	M	VH	1
$comp_3$	VH	M	M	H	VH	1.8
Customer4						
supplier	CR_1	CR_2	CR_3	CR_4	CR_5	weight
$comp_1$	VH	M	M	H	VH	1.5
$comp_2$	VH	M	M	H	VH	1
$comp_3$	VH	M	M	H	H	1

表四: CRs 之賣點評估結果

supplier	SP_1^{L*}	SP_1^{M*}	SP_1^{U*}	SP_2^{L*}	SP_2^{M*}	SP_2^{U*}	SP_3^{L*}	SP_3^{M*}	SP_3^{U*}	SP_4^{L*}	SP_4^{M*}	SP_4^{U*}	SP_5^{L*}	SP_5^{M*}	SP_5^{U*}
$comp_1$	0	0	0.097	0.029	0.151	0.418	0.029	0.151	0.418	0	0.078	0.222	0	0	0.097
$comp_2$	0	0	0.097	0.029	0.151	0.418	0.029	0.151	0.418	0.022	0.124	0.318	0	0.047	0.164
$comp_3$	0	0.018	0.120	0.029	0.151	0.418	0.029	0.151	0.418	0.010	0.098	0.258	0.011	0.073	0.204

表五: 第一輪 CRs 之價值評估結果

Customer	CR_1	CR_2	CR_3	CR_4	CR_5
$Cust_1$	M	H	VH	H	H
$Cust_2$	M	VH	H	H	M
$Cust_3$	H	H	H	M	H
$Cust_4$	M	H	H	H	M
$Cust_5$	H	H	VH	M	M
$Cust_6$	M	H	H	M	M
$Cust_7$	M	H	H	H	H
$Cust_8$	M	VH	VH	M	H

表六: 第二輪 CRs 之價值評估結果

Customer	CR_1	CR_2	CR_3	CR_4	CR_5
$Cust_1$	M	H	VH	H	M
$Cust_2$	M	VH	H	M	M
$Cust_3$	M	VH	VH	M	H
$Cust_4$	M	H	VH	H	M
$Cust_5$	H	VH	VH	M	M
$Cust_6$	H	H	H	M	H
$Cust_7$	M	H	H	M	H
$Cust_8$	M	VH	VH	H	M

表七 $\tilde{W}_j$ 在不同α 水平的下限與上限值

α	W_1^L	W_1^U	W_2^L	W_2^U	W_3^L	W_3^U	W_4^L	W_4^U	W_5^L	W_5^U
1	0.257	0.257	0.170	0.170	0.018	0.018	0.229	0.229	0.184	0.184
0.8	0.200	0.313	0.143	0.198	0.016	0.021	0.189	0.273	0.130	0.241
0.6	0.145	0.368	0.120	0.228	0.013	0.023	0.150	0.318	0.084	0.298
0.4	0.093	0.420	0.099	0.257	0.011	0.026	0.115	0.364	0.047	0.348
0.2	0.044	0.468	0.081	0.285	0.009	0.029	0.084	0.411	0.020	0.389
0	0	0.511	0.066	0.311	0.008	0.032	0.055	0.459	0	0.420

國科會專題研究計畫成果報告撰寫格式

99 年 5 月 5 日本會第 304 次學術會報修正通過

一、說明

國科會基於學術公開之立場，鼓勵一般專題研究計畫主持人發表其研究成果，但主持人對於研究成果之內容應負完全責任。計畫內容及研究成果如涉及專利或其他智慧財產權、違異現行醫藥衛生規範、影響公序良俗或政治社會安定等顧慮者，應事先通知國科會不宜將所繳交之成果報告蒐錄於學門成果報告彙編或公開查詢，以免造成無謂之困擾。另外，各學門在製作成果報告彙編時，將直接使用主持人提供的成果報告，因此主持人在繳交報告之前，應對內容詳細校對，以確定其正確性。

本格式說明之目的為統一成果報告之格式，精簡報告內容之篇幅以 4 至 10 頁為原則，完整報告內容之篇幅不得少於 10 頁。

成果報告繳交之期限及種類（精簡報告、完整報告、期中精簡報告、期中完整報告等），應依本會補助專題研究計畫作業要點及專題研究計畫經費核定清單之規定辦理。

二、報告格式：依序為封面、目錄（精簡報告得省略）、中英文摘要及關鍵詞、報告內容、參考文獻、計畫成果自評、可供推廣之研發成果資料表、附錄。

(一)報告封面：請至本會網站（http：//www.nsc.gov.tw）線上製作（格式如附件一）。

(二)中、英文摘要及關鍵詞 (keywords)。

(三)報告內容：包括前言、研究目的、文獻探討、研究方法、結果與討論（含結論與建議）…等。

(四)計畫成果自評部分：請就研究內容與原計畫相符程度、達成預期目標情況、研究成果之學術或應用價值(簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性)、是否適合在學術期刊發表或申請專利、主要發現或其他有關價值等，作一綜合評估，並請至本會網站線上製作。（格式如附件二）

(五)頁碼編寫：請對摘要及目錄部分用羅馬字 I 、II、 III……標在每頁下方中央；報告內容至附錄部分請以阿拉伯數字 1.2.3.……順序標在每頁下方中央。

(六)附表及附圖可列在文中或參考文獻之後，各表、圖請說明內容。

(七)可供推廣之研發成果資料表：

1.研究計畫所產生之研發成果，應至國科會科技研發成果資訊系統（STRIKE 系統，https://nscnt66.nsc.gov.tw/strike/）填列研發成果資料表（如附件三），循執行機構行政程序，由研發成果推廣單位（如技轉中心）線上繳交送出。

2.每項研發成果填寫一份。

(八)若該計畫已有論文發表者(須於論文致謝部分註明補助計畫編號)，得作為成果報告內容或附錄，並請註明發表刊物名稱、卷期及出版日期。若有與執行本計畫相關之著作、專利、技術報告、或學生畢業論文等，請在參考文獻內註明之。

三、計畫中獲補助國外或大陸地區差旅費、出席國際學術會議差旅費或國際合作研究計畫差旅費者，須依規定分別撰寫心得報告，並至本會網站線上繳交電子檔，心得報告格式如附件四、五、六。

四、報告編排注意事項

(一)版面設定：A4 紙，即長 29.7 公分，寬 21 公分。

(二)格式：中文打字規格為每行繕打（行間不另留間距），英文打字規格為 Single Space。

(三)字體：以中英文撰寫均可。英文使用 Times New Roman Font，中文使用標楷體，字體大小以 12 號為主。

附件四

國科會補助專題研究計畫項下出席國際學術會議心得報告

日期：99年 6 月20日

計畫編號	NSC 98-2410-H-168-002-		
計畫名稱	新產品設計規劃之模糊品質機能展開建構模式		
出國人員姓名	柯文長	服務機構及職稱	崑山科技大學資訊管理系助理教授
會議時間	99 年 6 月 15 日至 99 年 6 月 18 日	會議地點	泰國
會議名稱	（中文） （英文)2010 International Conference on Technology Innovation and Industrial Management		
發表論文題目	（中文） （英文）A Fuzzy Quality Function Deployment Constructing Model for Product Planning		

一、參加會議經過

1. 開幕由主辦學校 Kasetsart University 校長 Vudtechai Kapilakanchana 致詞
2. 開幕另邀請泰國前代理總理呂文基先生致歡迎詞
3. 本次研討會邀請三位企業界人士擔任 Keynote speaker，其中包括 Microsoft 泰國分公司 Director， S-One Telecom 及 KOM-EKO 的 CEO。分別介紹泰國在資通訊領域及波蘭在資源與廢棄物處理的發展現況與未來的展望。
4. 本次研討會有以下幾個 session: 人力資源與知識管理，品質與績效管理，創新管理、資通訊應用、價值基礎與當代管理、知識管理與組織、投資與財務管理、程序管理與最佳化、策略管理、決策支援管理系統、文化與協同管理。

二、與會心得

本次活動由泰國 Kasetsart University 管理學院與工程學院合辦，透過跨院係的合作，希望由來自全球各地的學者以全球的觀點共同討論技術、創新與工業管理的相關議題，並在企業管理、經濟、工程、心理學、資訊等領域分享及溝通研究的成果與發現。這次活動的主題由於橫跨多個領域，在大會議題主軸上，發表的內容十分多元，令人較印象深刻的是創新管理與綠能領域的結合，對於個人未來的研究方向亦多有啟發。

第一次參加海外的國際研討會，與國內舉辦的國際研討會最大的差異是可以體會當地文

化、開闊國際視野與當地主辦學校的研究者接觸並分享經驗與研究心得。接觸了一些來自歐洲包括芬蘭、波蘭、印度與司洛伐尼亞的學者，他們的口音，很難聽懂，但是可以充分感受到這些學者樂意分享研究成果的熱情與對研究成果的自信。相較於國內學者的沉穩內斂是相當不同的風範。在本次活動與主辦學校 Kasetsart University 管理系主任 Kiriya Kulchanarat 有所交談與認識，並因此認識 Journal of Information Privacy and Security 主編 Professor Chuleeporn Changchit 與 Industrial Management & Data Systems information 主編 Professor Binshan Lin。

感謝國科會的補助，讓後進能有這個機會參與這次的國際研討會，獲益良多。

三、考察參觀活動(無是項活動者略)–無

四、建議

無

五、攜回資料名稱及內容

1. 研討會論文集 CD
2. 研討會論文摘要集 (紙本)

六、其他

1. 由於初次或國科會補助出席國際會議，在發表的會議論文中疏漏致謝部分，在此特表達由衷的歉意。本研究成果未來發表於國際期刊時，必當加入致謝與補助計畫編號。

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A FUZZY QUALITY FUNCTION DEPLOYMENT CONSTRUCTING MODEL FOR PRODUCT PLANNING

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ABSTRACT

Quality function deployment (QFD) is an important and useful tool in processing new product design planning in order to maximum customer satisfaction. Product planning is the first deploying process in QFD activities for a new product development (NPD). Recognizing and ranking the importance levels of customer requirements (CRs) are vital issues due to the explicit and implicit voices of the customer leading the determinations of design requirements (DRs) and the relationship between CRs and DRs in the QFD activities for product planning. Unlike the existing researches, this study considers three different perspectives, including customer perspective, competition perspective and value perspective, to evaluate the importance levels of CRs. To cope with the vague and uncertainty nature in product planning stage, fuzzy approaches are adopted in the proposed methods which including the modified fuzzy Delphi, entropy and value analysis methods with the concept of α-cut. Besides, dissimilar to prior studies which ignored the interactive influences between CRs themselves, this paper not only consider the relationship between DRs themselves but also take the relationship between CRs themselves into account to determine the relationship between CRs and DRs. From an illustrative example, the proposed methods indicate that the total degree of customer satisfaction achieved is greater than the previous methods.

Keywords**:** quality function deployment (QFD), fuzzy set theory, product planning, customer requirements

1. INTRODUCTION

Quality function deployment (QFD) is a useful customer-driven tool for new product development (NPD), devoted to translating customer requirements (CRs) into well communication to leading better efficiency in the downstream processes of NPD for maximizing customer satisfaction [5, 6]. A general QFD process consists of four phases which is start with CRs to product design requirements (DRs) and then translating DRs into critical part characteristics (PCs) (or sub-system), engineering process parameters (PPs), and establishing production requirements (PRs) in ending process for a NPD. House of quality (HOQ) is consists of relevant information on CRs, DRs, the relationships between CRs themselves, the relationships between DR themselves, and the relationship between CRs and DRs. Based on the relevant outcomes above, the importance ratings of DRs can be determined. Furthermore, QFD team can figure out the fulfillment level to each DR to achieve the maximum customer satisfaction. Chan and Wu [7] and Carnevalli and Miguel [5] argued that interpreting and analyzing the customer voice is one of the major difficulties in

QFD application. This study attempts developing methods to elaborate the understanding of CRs for enhancing customer satisfaction.

To this purpose, this study considers three different perspectives to interpreting and analyzing the CRs including the customer perspective, the competition perspective and the value perspective, respectively, to determine the importance levels of CRs. In the customer perspective, a modified fuzzy Delphi method is proposed to determine the importance level to each CR based on the current and potential customers' response and feedback. In regard to the competition perspective, the relative performance between firm and its competitors are analyzed to determine the sales point of each CR using the concept of information entropy with fuzzy means. As for the value perspective, the worth and the cost of CRs are considered to establish the value level for each CR to reflect firm position. Finally, combining three different perspective considerations above, the importance scores of CRs can be determined.

In general, the relationship degree in HOQ is expressed on a scale or point system such as 1-3-9 or 1-5-9, representing linguistic statements such as "weak", "moderate", and "strong", respectively [15]. But, QFD members usually experienced the predicament to accumulate experiment, information and knowledge about the influence of DRs because the lack of information or language hedge from the CRs during product planning stage [8, 9]. These considerations have led to the application of fuzzy approaches which are essential in addressing the diversity and imprecision issues in determining the relationships in HOQ [8-14, 19]. Dissimilar to existing studies which only focused the interactive influences of the relationship between DRs themselves to determine the relationship between CRs and DRs, this paper not only considers the relationship between DRs themselves but also take the relationship between CRs themselves into account to determine the relationship between CRs and DRs to obtain a more adequate and realistic relationship levels between CRs and DRs.

Based on the outcomes of importance levels of CRs and relationship levels between CRs and DRs, the fulfillment level of the each DR to maximize customer satisfaction can be achieved. In the following section, the CRs analyzing approaches with three different perspectives are introduced to determine the importance score of each CR. In Section 3, a fuzzy HOQ construction model is developed to determine the performance levels of DRs that will be produced maximum customer satisfaction. An example of a semiconductor packing case is given to demonstrate the proposed approaches in Section 4. Finally, the concluding remarks are summarized in Section 5.

2. THE CUSTOMER REQUIREMENTS ANALYZING APPROACHES

As mentioned previous, the determination of importance score of each CR is an important issue for enhancing customer satisfaction. In the existing literature, Kano's model [18] is considered to classify customer demand attributes due to some customer requirements more important to the customer than others [25, 29, 30]. Karsak [19] and Chen and Ko [10, 11] applied the fuzzy Delphi method to determine the fuzzy importance scores of CRs. Büyüközkan and Feyzioğlu [3] and Büyüközkan et al. [4] considered multiple preference ways and fused different expressions into a uniform group decision approach to reflect CRs assessment with fuzzy set theory in the collaborative circumstance. In addition, the importance ranking of CRs is argued as multi-criteria decision making issue, some researchers applied analytic hierarchy process (AHP), or fuzzy AHP to determine the importance ranking of CRs in QFD application [1, 22, 23]. However, the existing literature above only focuses on unique perspective, i.e., importance to customer to determine the importance scores of CRs. Lai et al. [24] emphasized the competition perspective besides the importance to customer perspective to ranking CRs importance levels.

To elaborate the understanding of CRs for enhancing customer satisfaction, this study considers three different perspectives to determine CRs' importance scores, including the customer perspective, the competition perspective and the value perspective, respectively. To cope with the vague nature of customer requirements evaluation processes, fuzzy approaches are used to each evaluation way. The relevant decision-making approaches in the each perspective are discussed as follows.

2.1 Customer perspective

Customer perspective is a common sense for determining the importance levels of CRs. In this point of view, the consideration focused on each CR how important to customer. In this study, the current customers and potential customer are regarded as the experts who assess the importance degree to each CR. To aggregate experts' assessment, the fuzzy Delphi method [20] is applied to determine the importance levels of CRs. In original rule, the assessment from each expert is assigned with the same weight in fuzzy Delphi processes [19]. This study proposes the modified fuzzy Delphi method to deal with the different weighting consideration to determine importance scores of CRs. The relevant steps are described as follows.

Step 1. Each expert provides the assessment of importance scores of CRs. Suppose that a triangular fuzzy number is assigned to the format of assessment as:

$$\tilde{k}_{i,e} = \left[\left(k_{i,e}\right)^{\mathrm{L}*}, \left(k_{i,e}\right)^{\mathrm{M}*}, \left(k_{i,e}\right)^{\mathrm{H}*} \right],\ e = 1, 2, \ldots, \mathrm{E};\ i = 1, 2, \ldots, I, \tag{1}$$

where $\tilde{k}_{i,e}$ is described by linguistic terms and defined as the fuzzy subsets of [0, 1] and denoted the importance score of CR_i by the expert e; the indexes "L*", "M*", "H*" represent the lowest, the most likely and the highest level of $\tilde{k}_{i,e}$.

Step 2. Computing the weighted-average of all $\tilde{k}_{i,e}$, the formulation is expressed as

$$\tilde{\bar{k}}_i = \left[\left(\bar{k}_i\right)^{\mathrm{L}*}, \left(\bar{k}_i\right)^{\mathrm{M}*}, \left(\bar{k}_i\right)^{\mathrm{H}*} \right] = \left[\frac{\sum_{e=1}^{\mathrm{E}} w_e \left(k_{i,e}\right)^{\mathrm{L}*}}{\sum_{e=1}^{\mathrm{E}} w_e}, \frac{\sum_{e=1}^{\mathrm{E}} w_e \left(k_{i,e}\right)^{\mathrm{M}*}}{\sum_{e=1}^{\mathrm{E}} w_e}, \frac{\sum_{e=1}^{\mathrm{E}} w_e \left(k_{i,e}\right)^{\mathrm{H}*}}{\sum_{e=1}^{\mathrm{E}} w_e} \right], \tag{2}$$

where i = 1, 2, …, I; w_e represents the importance weight of current or potential customer e. Calculating the differences between $\tilde{k}_{i,e}$ and $\tilde{\bar{k}}_i$, and then, return to each expert for the next re-evaluation run.

Step 3. Taking the differences in the prior step as a reference base, each expert provides a revised linguistic variable (if necessary) of the importance scores as

$$\tilde{k}'_{i,e} = \left[\left(k'_{i,e}\right)^{\mathrm{L}*}, \left(k'_{i,e}\right)^{\mathrm{M}*}, \left(k'_{i,e}\right)^{\mathrm{H}*} \right],\ e = 1, 2, \ldots, \mathrm{E};\ i = 1, 2, \ldots, I. \tag{3}$$

The weighted-average $\bar{\tilde{k}}'_i$ can also be determined using (2). The difference between $\bar{\tilde{k}}'_i$ and $\bar{\tilde{k}}_i$ can be calculated using a distance measure as below [2]:

$$d\left(\bar{\tilde{k}}_i, \bar{\tilde{k}}'_i\right) = 0.5\left\{ \max\left[\left| \left(\bar{k}_i\right)^{\mathrm{L}*} - \left(\bar{k}'_i\right)^{\mathrm{L}*} \right|, \left| \left(\bar{k}_i\right)^{\mathrm{H}*} - \left(\bar{k}'_i\right)^{\mathrm{H}*} \right| \right] + \left| \left(\bar{k}_i\right)^{\mathrm{M}*} - \left(\bar{k}'_i\right)^{\mathrm{M}*} \right| \right\} \tag{4}$$

Step 2 and *Step* 3 could be repeated until the distance measure becomes reasonably close to meet the consensus criteria. The consensus criteria is assumed to be a small distance, such as $d \le 0.2$.

Step 4. If there is any change or update information that may lead to start a new evaluation-round process from *Step* 1.

Finally, the assessment consequences of importance degree to CRs can be obtained and expressed as a triangular fuzzy number $\tilde{k}'_i = \left[\left(k'_i\right)^{\mathrm{L}*}, \left(k'_i\right)^{\mathrm{M}*}, \left(k'_i\right)^{\mathrm{H}*} \right]$.

2.2 Competition perspective

Facing the short life-cycles and global dynamic competition environment, taking the competition perspective into account for improving the understanding of CRs is an essential and vital deliberation. Cohen [15] defined a sales point is the ability to sell the product or service, based on how well each customer requirement is satisfied.. In traditional practice, the sales point is set as a crisp value such as 1.5, 1.25 and 1 to reflect the strong, moderate and none sales point to competitors. In competition analysis, considering that a company has many customers and competitors in the competition market, the different customer will set various satisfaction weights to different suppliers based on how well the product or service is met its expectation. In this study, a sales point evaluation is based on a performance standpoint of customer satisfaction to each CR. Suppose that $\tilde{Y}_{\psi i,t}$ is a triangular fuzzy number represented the *t*th customer who evaluates the satisfaction performance of ψ th supplier on *i*th CR. Therefore, $\tilde{Y}_{\psi i,t}$ can be expressed as

$$\tilde{Y}_{\psi i,t} = \begin{bmatrix} \tilde{y}_{11,t} & \cdots & \tilde{y}_{1I,t} \\ \vdots & \tilde{y}_{\psi i,t} & \vdots \\ \tilde{y}_{\Psi 1,t} & \cdots & \tilde{y}_{\Psi I,t} \end{bmatrix} = \begin{bmatrix} (y_{11}^{\mathrm{L}*}, y_{11}^{\mathrm{M}*}, y_{11}^{\mathrm{H}*})_t & \cdots & (y_{1I}^{\mathrm{L}*}, y_{1I}^{\mathrm{M}*}, y_{1I}^{\mathrm{H}*})_t \\ \vdots & (y_{\psi i}^{\mathrm{L}*}, y_{\psi i}^{\mathrm{M}*}, y_{\psi i}^{\mathrm{H}*})_t & \vdots \\ (y_{\Psi 1}^{\mathrm{L}*}, y_{\Psi 1}^{\mathrm{M}*}, y_{\Psi 1}^{\mathrm{H}*})_t & \cdots & (y_{\Psi I}^{\mathrm{L}*}, y_{\Psi I}^{\mathrm{M}*}, y_{\Psi I}^{\mathrm{H}*})_t \end{bmatrix}, \quad \text{and} \tag{5}$$

$$\left(y_{\psi i}^{L*}, y_{\psi i}^{M*}, y_{\psi i}^{H*}\right)_t = \left(y_{\psi i}^{L*} = \frac{\sum_{t=1}^{T} \nu_{\psi,t} \cdot \left(y_{\psi i}^{L*}\right)_t}{\sum_t \nu_{\psi,t}}, y_{\psi i}^{M*} = \frac{\sum_{t=1}^{T} \nu_{\psi,t} \cdot \left(y_{\psi i}^{M*}\right)_t}{\sum_t \nu_{\psi,t}}, y_{\psi i}^{H*} = \frac{\sum_{t=1}^{T} \nu_{\psi,t} \cdot \left(y_{\psi i}^{H*}\right)_t}{\sum_t \nu_{\psi,t}} \right) \quad (6)$$

where $\psi = 1,...,\Psi,\ t = 1,...,T,$ and $\nu_{\psi,t}$ represents the weights of performance satisfaction of tth customer to ψth supplier; $\nu_{\psi,t} \in [0,1]$. The assessment of customer satisfaction performance $\tilde{y}_{\psi i,t}$ is described by linguistic terms and defined as the fuzzy subsets of [0, 1] and surveyed from each customer who concerned the product development.

Once the customer satisfaction performance is collected and treated using (5) and (6), the sales point of a firm can be determined by (7).

$$\begin{aligned} \tilde{S}P_i &= \left[SP_i^{L*}, SP_i^{M*}, SP_i^{H*}\right] \\ &= \left[\sum_{\psi=1}^{\Psi} y_{\psi i}^{L*} \cdot \mathbf{log}\left(\frac{1}{y_{\psi i}^{H*}}\right), \sum_{\psi=1}^{\Psi} y_{\psi i}^{M*} \cdot \mathbf{log}\left(\frac{1}{y_{\psi i}^{M*}}\right), \sum_{\psi=1}^{\Psi} y_{\psi i}^{H*} \cdot \mathbf{log}\left(\frac{1}{y_{\psi i}^{L*}}\right)\right]. \end{aligned} \quad (7)$$

Eq. (7) is considered the concept of entropy in information theory [28].

2.3 Value perspective

Understanding what customer values within CRs is the third perspective for determining the importance score of CRs. DeSarbo et al. [16] noted that performing customer value analysis to articulate the "voice of customer" is applied in more and more firms. This study concerned the economics value which is defined by Elias [17] and expressed as worth w_i divided by cost C_i^* of the each CR.

$$V_i = \frac{w_i}{C_i^*},\ i=1,\ldots,I. \quad (8)$$

where w_i represents each current and potential customer's perception on CR$_i$; C_i^* is the initial cost evaluated by QFD team to CR$_i$ for the new product planning. Same as the customer perspective stage, to address the fuzzy nature in worth and initial cost evaluation to each CR, the modified fuzzy Delphi method is employed to determine the worth $\tilde{w}_{i,e}$ of CR$_i$. $\tilde{w}_{i,e}$ is described by linguistic terms and defined as the fuzzy subsets of [0, 1] and provided by the expert (customer) *e*. Assuming the assessments of the worth and the initial cost to CR$_i$ are $\left[\left(\overline{w}'_{i,}\right)^{L*}, \left(\overline{w}'_i\right)^{M*}, \left(\overline{w}'_i\right)^{H*}\right]$ and $\left[\left(C_i^*\right)^{L*}, \left(C_i^*\right)^{M*}, \left(C_i^*\right)^{H*}\right]$, respectively, then eq.(8) can be modified as

$$\tilde{V} = \left(V_i^{\mathrm{L}*}, V_i^{\mathrm{M}*}, V_i^{\mathrm{H}*}\right) = \left[\frac{\left(\overline{w}_i'\right)^{\mathrm{L}*}}{\left(C_i^*\right)^{\mathrm{H}*}}, \frac{\left(\overline{w}_i'\right)^{\mathrm{M}*}}{\left(C_i^*\right)^{\mathrm{M}*}}, \frac{\left(\overline{w}_i'\right)^{\mathrm{H}*}}{\left(C_i^*\right)^{\mathrm{L}*}}\right] \; i=1,\ldots,I. \tag{9}$$

Once the assessments of customer perspective, competition perspective and value perspective are determined, the fuzzy importance score of CR$_i$ can be expressed as

$$\tilde{K}_i = \tilde{k}_i' \otimes \widetilde{SP}_i \otimes \tilde{V}_i \; i=1,\ldots,I. \tag{10}$$

where the symbol $\otimes$ represents the fuzzy multiplication operator. To treat fuzzy multiplication, a fuzzy set can fully and uniquely be represented by its α-cuts [21]. For example, the α-cut of the fuzzy set $\tilde{V}_i$ at the level, $\alpha \in [0,1]$, can be expressed by its lower and upper bounds as $[(V_i)_\alpha^L, (V_i)_\alpha^U]$, which is defined as:

$$\left(V_i\right)_\alpha^L = \inf_{x\in[0,1]} \left\{x \middle| \mu_{\tilde{V}_i}(x) \geq \alpha\right\}, \text{ and} \tag{11a}$$

$$\left(V_i\right)_\alpha^U = \sup_{x\in[0,1]} \left\{x \middle| \mu_{\tilde{V}_i}(x) \geq \alpha\right\} \tag{11b}$$

where $\mu_{\tilde{V}_i}(x)$ is the membership degree of x belonging to $\tilde{V}_i$; the indexes "L", "U" represent the lower and upper bound of $\tilde{V}_i$ at α level, respectively. According to α-cuts and the extension principle in fuzzy set theory [32, 33], the membership function of the fuzzy importance score $\tilde{K}_i$ can be defined by the lower and upper bounds of each α-cut of $\tilde{k}_i'$, $\widetilde{SP}_i$, and $\tilde{V}_i$ as well as formulated as:

$$\left(K_i\right)_\alpha^L = \left(k_i'\right)_\alpha^L \cdot \left(SP_i\right)_\alpha^L \cdot \left(V_i\right)_\alpha^L \text{ and} \tag{12a}$$

$$\left(K_i\right)_\alpha^U = \left(k_i'\right)_\alpha^U \cdot \left(SP_i\right)_\alpha^U \cdot \left(V_i\right)_\alpha^U \tag{12b}$$

For simplification of QFD application, the fuzzy importance score can be defuzzified so as to combine with the modified fuzzy normalized relationship in determining the fuzzy technical importance ratings. The fuzzy mean (FM) method [26] is employed to carry out the defuzzification of $\tilde{K}_i$ due to consider its simplicity and efficiency. The FM method is expressed as

$$D = \frac{\sum_{i=1}^{I} \alpha_i x_i}{\sum_{i=1}^{I} \alpha_i}, \tag{13}$$

where α_i and x_i denote the membership degree and the representative (pre-calculated) numerical value of the ith output, respectively; D is the defuzzification value of interval values [x_i^L , x_i^U], i.e., the ith α-cut of fuzzy number. Based on Mabuchi's idea [27], the representative value of the ith output is defined as the average of lower and upper bounds of the interval by $x_i = \frac{1}{2}\left(x_i^L + x_i^U\right)$. Therefore, the average value of the α-cut of $\tilde{K}_i$ at the α_i level, i.e., $\left(K_i\right)_{\alpha_i} = \frac{1}{2}\left[\left(K_i\right)_{\alpha_i}^L + \left(K_i\right)_{\alpha_i}^U\right]$ is used as the representative value in this study. According to the FM method, the $\tilde{K}_i$ can be defuzzified as

$$K_i' = \frac{\sum_i \alpha_i \cdot \left(K_i\right)_{\alpha_i}}{\sum_i \alpha_i},\ i = 1, \ldots, I. \tag{14}$$

3. A FUZZY HOQ CONSTRUCTION MODEL

In product planning, a QFD team collects a set of CRs, assesses and treats their importance scores as described in prior section afterward a number of appropriated DRs that affect the CRs are identified. Based on CRs and DRs, the relevant relationship matrixes will be assessed in HOQ construction. A HOQ is shown in Figure 1. In Figure 1, R_{ij} denotes the relation level in terms of score between the CR$_i$ and DR$_j$, L_{iI} is the correlation score between CR$_i$ and CR$_I$; T_{jJ} is the correlation score between DR$_j$ and DR$_J$, and W_j represents the importance rating of DR$_j$ which is then applied to determine the fulfillment level of the each DR to maximize customer satisfaction.

Considering the imprecise nature of the relationships evaluation, Chen and Weng [8] proposed the fuzzified formulation as (15a) and (15b) based on Wasserman's idea [31] which considered the relationships between the DRs themselves to determine the normalized fuzzy relationship value between CRs and DRs.

$$\left(R_{ij}'\right)_\alpha^L = \frac{\sum_{\zeta=1}^{J}\left(R_{i\zeta}\right)_\alpha^L\left(T_{\zeta j}\right)_\alpha^L}{\sum_{\zeta=1}^{J}\left(R_{i\zeta}\right)_\alpha^L\left(T_{\zeta j}\right)_\alpha^L + \sum_{\substack{\phi=1\\ \phi\neq j}}^{J}\sum_{\zeta=1}^{J}\left(R_{i\zeta}\right)_\alpha^U\left(T_{\zeta\phi}\right)_\alpha^U},\ \text{and} \tag{15a}$$

$$\left(R_{ij}'\right)_\alpha^U = \frac{\sum_{\zeta=1}^{J}\left(R_{i\zeta}\right)_\alpha^U\left(T_{\zeta j}\right)_\alpha^U}{\sum_{\zeta=1}^{J}\left(R_{i\zeta}\right)_\alpha^U\left(T_{\zeta j}\right)_\alpha^U + \sum_{\substack{\phi=1\\ \phi\neq j}}^{J}\sum_{\zeta=1}^{J}\left(R_{i\zeta}\right)_\alpha^L\left(T_{\zeta\phi}\right)_\alpha^L}, \tag{15b}$$

where $\left(R_{i\zeta}\right)_\alpha^L / \left(R_{i\zeta}\right)_\alpha^U$ denoted the lower/upper bound of the fuzzy relationship $\tilde{R}_{i\zeta}$ at α level for CR_i to DR_ζ, $\left(T_{\zeta j}\right)_\alpha^L / \left(T_{\zeta j}\right)_\alpha^U$ denoted the lower/upper bound of the fuzzy correlation score $\tilde{T}_{\zeta j}$ at α level for DR_ζ to DR_j. In (15a) or (15b), if

$\sum_{\substack{\phi=1\\ \phi\neq j}}^{J}\sum_{\zeta=1}^{J}\left(R_{i\zeta}\right)_{\alpha}^{U}\left(T_{\zeta\phi}\right)_{\alpha}^{U}=0$ or $\sum_{\substack{\phi=1\\ \phi\neq j}}^{J}\sum_{\zeta=1}^{J}\left(R_{i\zeta}\right)_{\alpha}^{L}\left(T_{\zeta\phi}\right)_{\alpha}^{L}=0$, then $\left(R'_{ij}\right)_{\alpha}^{L}=1$ or $\left(R'_{ij}\right)_{\alpha}^{U}=1$. Obviously, the situation above is not reasonable while the original relationship $\tilde{R}'_{ij}=\left[R_{ij}^{L},R_{ij}^{U}\right]$ is evaluated with low or moderate linguistic level. The situation of $\sum_{\substack{\phi=1\\ \phi\neq j}}^{J}\sum_{\zeta=1}^{J}\left(R_{i\zeta}\right)_{\alpha}^{U}\left(T_{\zeta\phi}\right)_{\alpha}^{U}=0$ or $\sum_{\substack{\phi=1\\ \phi\neq j}}^{J}\sum_{\zeta=1}^{J}\left(R_{i\zeta}\right)_{\alpha}^{L}\left(T_{\zeta\phi}\right)_{\alpha}^{L}=0$ will be found while only one DR impact to one CR and no any other DRs correlated with this DR. To improve this critical issue, (15a)

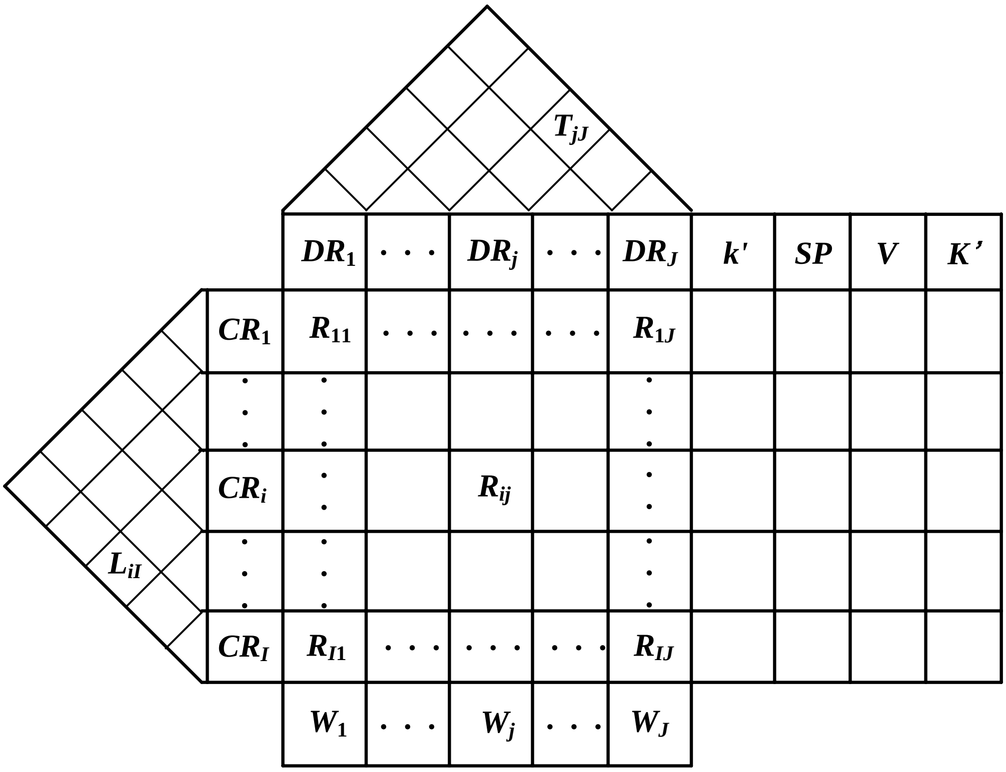

Figure 1. House of Quality

and (15b) should be modified as

$$\left(R'_{ij}\right)_{\alpha}^{L}=\begin{cases}\dfrac{\sum_{\zeta=1}^{J}\left(R_{i\zeta}\right)_{\alpha}^{L}\left(T_{\zeta j}\right)_{\alpha}^{L}}{\sum_{\zeta=1}^{J}\left(R_{i\zeta}\right)_{\alpha}^{L}\left(T_{\zeta j}\right)_{\alpha}^{L}+\sum_{\substack{\phi=1\\ \phi\neq j}}^{J}\sum_{\zeta=1}^{J}\left(R_{i\zeta}\right)_{\alpha}^{U}\left(T_{\zeta\phi}\right)_{\alpha}^{U}}, \text{ and}\\[2ex] R_{ij}^{L}, \text{ if } \sum_{\substack{\phi=1\\ \phi\neq j}}^{J}\sum_{\zeta=1}^{J}\left(R_{i\zeta}\right)_{\alpha}^{U}\left(T_{\zeta\phi}\right)_{\alpha}^{U}=0\end{cases} \tag{16a}$$

$$\left(R'_{ij}\right)_\alpha^U = \begin{cases} \dfrac{\sum_{\zeta=1}^{J}\left(R_{i\zeta}\right)_\alpha^U\left(T_{\zeta j}\right)_\alpha^U}{\sum_{\zeta=1}^{J}\left(R_{i\zeta}\right)_\alpha^U\left(T_{\zeta j}\right)_\alpha^U+\sum_{\substack{\phi=1\\ \phi\neq j}}^{J}\sum_{\zeta=1}^{J}\left(R_{i\zeta}\right)_\alpha^L\left(T_{\zeta\phi}\right)_\alpha^L}. \\ R_{ij}^U,\ \text{if} \sum_{\substack{\phi=1\\ \phi\neq j}}^{J}\sum_{\zeta=1}^{J}\left(R_{i\zeta}\right)_\alpha^L\left(T_{\zeta\phi}\right)_\alpha^L=0 \end{cases} \tag{16b}$$

Besides, considering the influence of the relationships between the CRs themselves $\tilde{L}_{i\zeta}$ to (16a) and (16b), the normalized fuzzy relationship value between CRs and DRs can be further upgraded as

$$\left(R''_{ij}\right)_\alpha^L = \begin{cases} \dfrac{\sum_{\zeta=1}^{I}\left(L_{i\zeta}\right)_\alpha^L\left(R'_{\zeta j}\right)_\alpha^L}{\sum_{\zeta=1}^{I}\left(L_{i\zeta}\right)_\alpha^L\left(R'_{\zeta j}\right)_\alpha^L+\sum_{\substack{\phi=1\\ \phi\neq i}}^{I}\sum_{\zeta=1}^{I}\left(L_{\phi\zeta}\right)_\alpha^U\left(R'_{\zeta j}\right)_\alpha^U}, \\ \left(R'_{ij}\right)_\alpha^L,\ \text{if} \sum_{\substack{\phi=1\\ \phi\neq i}}^{I}\sum_{\zeta=1}^{I}\left(L_{\phi\zeta}\right)_\alpha^U\left(R'_{\zeta j}\right)_\alpha^U=0, \end{cases} \tag{17a}$$

$$\left(R''_{ij}\right)_\alpha^U = \begin{cases} \dfrac{\sum_{\zeta=1}^{I}\left(L_{i\zeta}\right)_\alpha^U\left(R'_{\zeta j}\right)_\alpha^U}{\sum_{\zeta=1}^{I}\left(L_{i\zeta}\right)_\alpha^U\left(R'_{\zeta j}\right)_\alpha^U+\sum_{\substack{\phi=1\\ \phi\neq i}}^{I}\sum_{\zeta=1}^{I}\left(L_{\phi\zeta}\right)_\alpha^L\left(R'_{\zeta j}\right)_\alpha^L}, \\ \left(R'_{ij}\right)_\alpha^U,\ \text{if} \sum_{\substack{\phi=1\\ \phi\neq i}}^{I}\sum_{\zeta=1}^{I}\left(L_{\phi\zeta}\right)_\alpha^L\left(R'_{\zeta j}\right)_\alpha^L=0 \end{cases} \tag{17b}$$

where $\left(L_{i\zeta}\right)_\alpha^L / \left(L_{i\zeta}\right)_\alpha^U$ denoted the lower/upper bound of the fuzzy correlation score $\tilde{L}_{i\zeta}$ at α level for CR_i to CR_ζ. Once the lower and upper bounds of α-cuts of the fuzzy normalized relationship are obtained, the fuzzy technical importance ratings $\tilde{W}_j$ can be simplified and expressed as:

$$\left(\tilde{W}_j\right)_\alpha = \left[\left(W_j\right)_\alpha^L, \left(W_j\right)_\alpha^U\right] = \left[\frac{\sum_{i=1}^{I}K'_i\cdot\left(R''_{ij}\right)_\alpha^L}{\sum_{i=1}^{I}K'_i}, \frac{\sum_{i=1}^{I}K'_i\cdot\left(R''_{ij}\right)_\alpha^U}{\sum_{i=1}^{I}K'_i}\right]. \tag{18}$$

The results from (18) can be employed to find the fulfillment level of the each DR to maximize the overall customer satisfaction.

4. AN ILLUSTRATIVE EXAMPLE

A semiconductor packing case of the turbo thermal ball grid array (T^2-BGA) package is introduced to exemplify the applicability of the proposed methods.

4.1. CRs' importance scores

According to product characteristics and performance specifications of T^2-BGA, a QFD team surveyed and collected the opinions of customers during the product planning stage. Suppose that the CRs are determined as "package profile" (CR_1), "thermal performance" (CR_2), "electrical performance" (CR_3), "reliability" (CR_4), and "co-planarity" (CR_5). Considering the above CRs, three different perspectives are applied to determine the importance scores of CRs.

4.1.1. Customer perspective

In customer perspective, the fuzzy Delphi method is applied to determine the importance levels of CRs. Suppose that a QFD team forwards a questionnaire with linguistic evaluation levels, "very low (VL)", "low (L)", "medium (M)", "high (H)" or "very high (VH)", to eight current and potential customers in order to obtain the importance level of five CRs. The relevant computational procedures are described as follows:

Step 1. The first assessing outcomes are listed in Table 1. The QFD team member has to translate linguistic terms i.e., VL, L, M, H, and VH into the triangular fuzzy numbers as the lowest, the most likely and the highest level set, namely (0, 0, 0.2), (0, 0.2, 0.4), (0.3, 0.5, 0.7), (0.6, 0.8, 1), and (0.8, 1, 1), respectively. For example, in Table 1, the importance levels of the first CR evaluated by the second customer is expressed as $\tilde{k}_{1,2} = (0, .2, .4)$.

Step 2. Computing the weighted-average of all $\tilde{k}_{i,e}$ by (2), assuming the importance weight set to eight current and potential customers is assigned as {1, 0.9, 0.9, 0.5, 0.5, 0.2, 0.2, 0.1} based on their real or potential contribution in business. The producing results of $\tilde{\tilde{k}}_i$ to each CR are (0.049, 0.202, 0.402), (0.293, 0.493, 0.693), (0.091, 0.244, 0.444), (0.512, 0.712, 0.888), and (0.035, 0.147, 0.347), respectively. Then, the differences between $\tilde{k}_{i,e}$ and $\tilde{\tilde{k}}_i$ are calculated and return to each customer for re-evaluation procedure.

Step 3. Same to *Step* 1, each customer provides the revised assessment outcomes which are listed in Table 1. The weighted-average of $\tilde{k}'_{i,e}$ can also be obtained by (2), and then the $\tilde{\tilde{k}}'_i$ of each CR is obtained as (0.014, 0.214, 0.414), (0.265, 0.465, 0.665), (0.091, 0.291, 0.491), (0.547, 0.747, 0.923), and (0, 0.181, 0.381), respectively. The difference between $\tilde{\tilde{k}}'_i$ and $\tilde{\tilde{k}}_i$ is calculated by (4) as 0.023, 0.028, 0.047, 0.035, and 0.035, respectively. The differences between two adjacent averages are all less than to 0.2, therefore, the consensus condition is achieved.

Step 4. If the consensus condition was not obtained, the re-evaluation process would be performed in the next assessment cycle till the consensus condition is achieved.

Table 1. The first/ second round assessment of importance levels of CRs

Customer	CR_1	CR_2	CR_3	CR_4	CR_5
$Cust_1$	L/ L	M/ M	L/ L	H/ H	VL/ L
$Cust_2$	L/ L	M/ M	VL/ L	H/ H	L/ L
$Cust_3$	VL/ L	H/ M	M/ M	M/ M	L/ L
$Cust_4$	M/ L	L/ L	L/ L	H/ H	M/ L
$Cust_5$	L/ L	L/ M	L/ L	VH/ VH	VL/ L
$Cust_6$	L/ L	M/ M	H/ M	M/ H	VL/ VL
$Cust_7$	M/ M	M/ M	L/ L	L/ M	VL/ VL
$Cust_8$	VL/ L	M/ M	VL/ L	M/ H	L/ L

In this case, the fuzzy results $\tilde{\tilde{k}}_i'$ of importance level of CR_i, i=1,…,5, will be used to determine the fuzzy importance scores.

4.1.2. Competition perspective

Suppose that there are three major suppliers and four customers dedicate to T^2BGA development in the competition market. In competition analysis, a company (supplier) survey and asks it's four customers to evaluate the performance levels of each CR for T^2BGA product planning with linguistic evaluation level set {VL, L, M, H, VH} to three major suppliers. Furthermore, inviting customers to provide the corresponding performance satisfaction weights to different suppliers based on how well the product or service is met its expectation. Assuming the performance satisfaction weights are defined as 1.8, 1.5, 1.2, and 1 in this case. Table 2 is listed the outcomes of performance assessment of CRs from customers for T^2BGA product planning. Based on the assessment outcomes in Table 3, the fuzzy sales points of each CR can be determined by (6) and (7) as (0, 0.018, 0.314), (0.087, 0.452, 1.255), (0.087, 0.452, 1.255), (0.031, 0.299, 0.798) and (0.011, 0.120, 0.465). The fuzzy sales point of each supplier is listed in Table 3. In Table 3, the each competitor has the same results of fuzzy sales point at CR_2 and CR_3, that represent there is a good opportunity to be distinguished in the current competition situation by CR_2 and CR_3. Moreover, the third supplier possesses better competition situation at CR_1 and CR_5, while supplier 2 at CR_4 holds the better competition advantage.

4.1.3. Value perspective

To understanding the economic value of CRs, the worth and cost of each CR has to determined. According to the procedures of fuzzy Delphi method, the first round assessment

Table 2. The performance assessing outcomes of CRs

	Customer 1						Customer 2					
supplier	**CR_1**	**CR_2**	**CR_3**	**CR_4**	**CR_5**	**weight**	**CR_1**	**CR_2**	**CR_3**	**CR_4**	**CR_5**	**weight**
$comp_1$	VH	M	M	H	VH	1.5	VH	M	M	H	VH	1.5
$comp_2$	VH	M	M	H	H	1.2	VH	M	M	M	H	1.5
$comp_3$	VH	M	M	H	H	1	H	M	M	M	M	1
	Customer 3						**Customer 4**					
supplier	**CR_1**	**CR_2**	**CR_3**	**CR_4**	**CR_5**	**weight**	**CR_1**	**CR_2**	**CR_3**	**CR_4**	**CR_5**	**weight**
$comp_1$	VH	M	M	H	VH	1.2	VH	M	M	H	VH	1.5
$comp_2$	VH	M	M	M	VH	1	VH	M	M	H	VH	1
$comp_3$	VH	M	M	H	VH	1.8	VH	M	M	H	H	1

Table 3. The outcomes of sales point

supplier	SP_1^{L*}	SP_1^{M*}	SP_1^{H*}	SP_2^{L*}	SP_2^{M*}	SP_2^{H*}	SP_3^{L*}	SP_3^{M*}	SP_3^{H*}	SP_4^{L*}	SP_4^{M*}	SP_4^{H*}	SP_5^{L*}	SP_5^{M*}	SP_5^{H*}
$comp_1$	0.001	0	0.097	0.029	0.151	0.418	0.029	0.151	0.418	0	0.078	0.222	0	0	0.097
$comp_2$	0	0	0.097	0.029	0.151	0.418	0.029	0.151	0.418	0.022	0.124	0.318	0	0.047	0.164
$comp_3$	0	0.018	0.12	0.029	0.151	0.418	0.029	0.151	0.418	0.01	0.098	0.258	0.011	0.073	0.204
$\tilde{SP}_i$	0	0.018	0.314	0.087	0.452	1.255	0.087	0.452	1.255	0.031	0.299	0.798	0.011	0.12	0.465

outcomes are listed in Table 4. Assuming the worth weight set is same to importance weight set to eight current and potential customers based on their real or potential contribution in business. The weighted-average of all $\tilde{w}_{i,e}$ can be obtained by (2), producing results of $\tilde{\tilde{w}}_i$ to each CR are (0.398, 0.598, 0.798), (0.647, 0.847, 1), (0.647, 0.847, 1), (0.481, 0.681, 0.881), and (0.453, 0.653, 0.853), respectively. The calculation result has to send to each participant for second round evaluation. Following the performing step 3 of fuzzy Delphi method, each customer provides the revised assessment outcomes which are listed in Table 4. And then, the weighted-average results of $\tilde{\tilde{w}}'_i$ to each CR are calculated by (2) as (0.349, 0.549, 0.749), (0.712, 0.912, 1), (0.74, 0.94, 1), (0.412, 0.612, 0.812), and (0.398, 0.598, 0.798). Furthermore, the difference between $\tilde{\tilde{w}}'_i$ and $\tilde{\tilde{w}}_i$, i=1,…,5, are calculated by (4) as 0.184, 0.065, 0.033, 0.07, and 0.056, respectively. Obviously, the differences between two adjacent averages are all less than the consensus condition. Consequently, the outcomes of $\tilde{\tilde{w}}'_i$, i=1,…,5, are the final worth results of CRs. Assuming the lowest, the most likely and the highest initial fuzzy cost of CR_i, i=1,…,5, are (0.1, 0.2, 0.3), (0.3, 0.5, 0.7), (0.3, 0.5, 0.7),

Table 4. The first/ second round assessment of the worth of CRs

Customer	CR_1	CR_2	CR_3	CR_4	CR_5
$Cust_1$	**M/ M**	**H/ H**	**VH/ VH**	**H/ H**	**H/ M**
$Cust_2$	**M/ M**	**VH/ VH**	**H/ H**	**H/ M**	**M/ M**
$Cust_3$	**H/ M**	**H/ VH**	**H/ VH**	**M/ M**	**H/ H**
$Cust_4$	**M/ M**	**H/ H**	**H/ VH**	**H/ H**	**M/ M**
$Cust_5$	**H/ H**	**H/ VH**	**VH/ VH**	**M/ M**	**M/ M**
$Cust_6$	**M/ H**	**H/ H**	**H/ H**	**M/ M**	**M/ H**
$Cust_7$	**M/ M**	**H/ H**	**H/ H**	**H/ M**	**H/ H**
$Cust_8$	**M/ M**	**VH/ VH**	**VH/ VH**	**M/ H**	**H/ M**

(0.15, 0.3, 0.45), and (0.1, 0.3, 0.5), respectively, which assessed by QFD team. In the fuzzy sense, the value of CRs then can be determined using (9) which are (1.163, 2.745, 7.49), (1.017, 1.824, 3.333), (1.057, 1.88, 3.333), (0.916, 2.04, 5.413), and (0.796, 1.993, 7.98).

4. 2. DRs' importance rating and total customer satisfaction

Once the importance level, the sales points, and value of CR_i are obtained, all of this outcomes could be transferred into the α-cut expression of the fuzzy sets $\tilde{k}_i'$, $\tilde{SP}_i$, and $\tilde{V}_i$ by (11). For example, $[(V_2)_\alpha^L, (V_2)_\alpha^U]$ = $[1.017+0.807\alpha, 3.333-1.509\alpha]$. Without any biases, the α levels in this paper are evenly distributed in [0, 1]. Let α_ξ denote the ξth level, and $\alpha_\xi = \xi / \lambda$, $\xi \in \{0,1,\cdots,\lambda\}$, thus the distance between each two adjacent levels is equal, i.e. $\alpha_\xi - \alpha_{\xi-1} = \lambda^{-1}$, $\xi \geq 1$. Based on the transformation above, the lower and upper bounds of the fuzzy technical importance score $\tilde{K}_i$, i=1,…,5, at each α level, can be determined by (12). And then, the final results of importance scores of each CR can be defuzzified by (14) as 0.043, 0.305, 0.206, 0.377, and 0.069, respectively.

To responding CRs for customer satisfaction, QFD team determines the corresponding design requirements (DRs) by design feasibility studies. Five DRs are proposed, including "heat slug exposed area" (DR_1), "heat slug attached material" (DR_2), "height of heat slug" (DR_3), "copper pattern" (DR_4), and "molding flow" (DR_5). The relationship between CR_i and CR_j, the relationship between CRs themselves, and the relationship between DRs themselves are evaluated by QFD team with the same linguistic evaluation levels set {VL, L, M, H, VH}. The initial HOQ is set and illustrated in Figure 2. According to the linguistic relationships in Figure 2, the fuzzy normalized relationship at each α-cut can be calculated using (16) and (17). An then, considering the importance scores of each CR, the lower and upper bounds of the fuzzy technical importance ratings $(\tilde{W}_j)_\alpha$, j = 1, 2, …, J, at each α level, can be obtained by (18) for determining the importance priority of each DR. The lower and upper bounds of $(\tilde{W}_j)_\alpha$ at various α levels are listed in Table 5. The results of fuzzy technical importance ratings of DRs can be applied to Chen and Weng's model [8] to determine the performance level of each DR for maximizing customer satisfaction. The fulfillment level of each DR and the total customer satisfaction degree (the objective function value) are calculated and shown in Table 6. Figure 3 indicates the membership functions of the total customer satisfaction degree of the QFD processes as levels in the feasible regions using originally unique perspective and three perspectives for CRs ranking. Obviously, the membership function of the total customer satisfaction degree from proposed method is better than the unique perspective one, i.e., importance to customer requirements perspective, although all of them meet the requirement in new product planning.

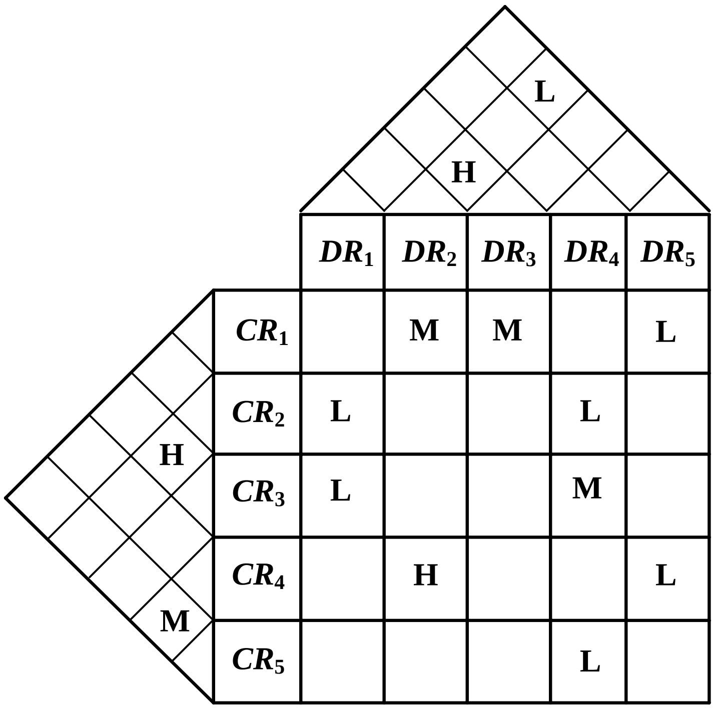

Figure 2. The HOQ for a T^2BGA product planning

Table 5. The lower and upper bounds of $\tilde{W}_j$ at different α levels

α	W_1^L	W_1^U	W_2^L	W_2^U	W_3^L	W_3^U	W_4^L	W_4^U	W_5^L	W_5^U
1	0.257	0.257	0.17	0.17	0.018	0.018	0.229	0.229	0.184	0.184
0.8	0.2	0.313	0.143	0.198	0.016	0.021	0.189	0.273	0.13	0.241
0.6	0.145	0.368	0.12	0.228	0.013	0.023	0.15	0.318	0.084	0.298
0.4	0.093	0.42	0.099	0.257	0.011	0.026	0.115	0.364	0.047	0.348
0.2	0.044	0.468	0.081	0.285	0.009	0.029	0.084	0.411	0.02	0.389
0	0	0.511	0.066	0.311	0.008	0.032	0.055	0.459	0	0.42

Table 6. Outcomes of the total customer satisfaction degree and fulfillment level of DRs

α	Z_1^L	Z_1^U	$x_1^{(L)}$	$x_1^{(U)}$	$x_2^{(L)}$	$x_2^{(U)}$	$x_3^{(L)}$	$x_3^{(U)}$	$x_4^{(L)}$	$x_4^{(U)}$	$x_5^{(L)}$	$x_5^{(U)}$
1	**0.656**	**0.656**	**0.881**	**0.881**	**0.1**	**0.1**	**0.1**	**0.1**	**0.989**	**0.989**	**1**	**1**
0.9	**0.552**	**0.764**	**0.733**	**1**	**0.112**	**0.1**	**0.1**	**0.1**	**1**	**0.979**	**1**	**1**
0.8	**0.459**	**0.854**	**0.604**	**1**	**0.125**	**0.127**	**0.1**	**0.1**	**1**	**1**	**1**	**1**
0.7	**0.38**	**0.943**	**0.496**	**1**	**0.133**	**0.164**	**0.1**	**0.1**	**1**	**1**	**1**	**1**
0.6	**0.311**	**1.032**	**0.408**	**1**	**0.136**	**0.202**	**0.1**	**0.1**	**1**	**1**	**1**	**1**
0.5	**0.252**	**1.121**	**0.334**	**1**	**0.135**	**0.241**	**0.1**	**0.1**	**1**	**1**	**1**	**1**

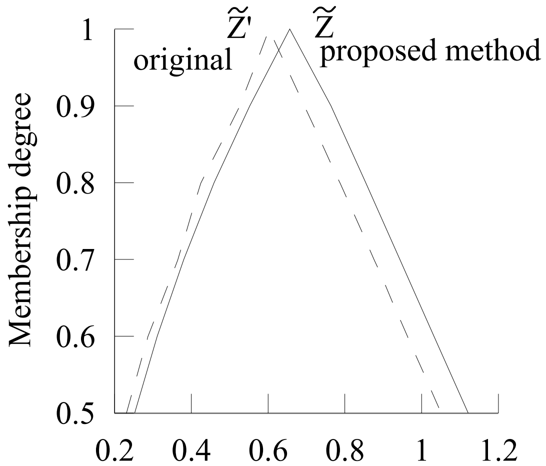

Figure 3. The membership functions of customer satisfaction with different approaches

5. CONCLUDING REMARKS

Determining the performance levels of DRs is an important decision problem in QFD applications, but recognizing and ranking the importance levels of customer requirements is more important issue for product planning. To improve the understanding of customer voice to obtain the better customer satisfaction, this study proposed a new method to aggregate the various assessment perspectives including, importance to customers, competition and value three perspectives to determine the importance scores of CRs. Moreover, determining the relationship between CRs and DRs and calculating the importance rating of DRs are further steps for a HOQ construction. This paper not only considered both relationship between DRs themselves but also take the relationship between CRs themselves into account to determine the relationship between CRs and DRs. A modified model is proposed to determine the relationship between CRs and DRs to improve the reasonability of the existing normalization model. Through the modification of the importance score of CRs and the the relationship between CRs and DRs, the importance rating DRs can be determine. The illustration of the proposed methods with a numerical example indicates that the total customer satisfaction degree is greater than that from the existing perspective of CRs evaluation while using the same fuzzy linear model. To enhance the customer satisfaction, the other considerations, such as the concept of theory of constraints or the group decision-making approaches could be modeled to improve the understanding of the voice of customer in the future study.

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無研發成果推廣資料

國科會補助專題研究計畫成果報告自評表

請就研究內容與原計畫相符程度、達成預期目標情況、研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）、是否適合在學術期刊發表或申請專利、主要發現或其他有關價值等，作一綜合評估。

1. 請就研究內容與原計畫相符程度、達成預期目標情況作一綜合評估 ■達成目標 □未達成目標（請說明，以 100 字為限） 　　□實驗失敗 　　□因故實驗中斷 　　□其他原因 說明：
2. 研究成果在學術期刊發表或申請專利等情形： 論文：□已發表 ■未發表之文稿 □撰寫中 □無 專利：□已獲得 □申請中 ■無 技轉：□已技轉 □洽談中 ■無 其他：（以 100 字為限） 本計劃之研究成果預計在 2010/9/30 以前投稿國際期刊。
3. 請依學術成就、技術創新、社會影響等方面，評估研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）（以 500 字為限） 本研究利用模糊理論提出一個結合顧客、競爭與價值等三項觀點的評估模式以獲得客戶需求的重要性評比，對於新產品在設計規劃階段，有助於提升對客戶需求的了解。此外本研究將顧客需求的交互影響及設計需求的交互影響，納入 QFD 之關係矩陣，對於 QFD 各項設計需求的重要性評比可獲得較正確的結果。由案例模擬，本研究所提出之方法較傳統的 QFD 建構模式可獲的較佳的客戶滿意度。在產品生命週期愈來愈短的時代，本研究成果，有助於減少設計變更，加速新產品開發的速度，並獲的較佳的客戶滿意度。本研究未來可結合二元模糊語意的方法，考慮設計規劃風險，更進一步提升對客戶需求的了解，以獲得更佳的客戶滿意度。