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Do college professors need to be *Superman*? An in-depth discussion of the current college teaching environment in Taiwan

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ABSTRACT: In this research, three necessary relations were evaluated, taking into account the needs of 15 students (WHATs) and 12 technical measures (HOWs) through complete application of the House of Quality (HOQ) model of Quality Function Development (QFD), according to the methodology of Multiple Criteria Decision Making (MCDM). The Analytic Network Process (ANP) model and entropy methods, similar measure and TOPSIS method are used to discuss the contemporary college environment in Taiwan. It was found that professors not only have to be attractive, humorous, and show zeal, they must be less demanding, have a consultant's personality and apply their efforts to teaching and/or research. They also should devote themselves to supporting the recruiting of students and consulting programmes, as well as implement university administrative projects. This means the name, *Superman*, matches the reality of college professors in the complex condition of Taiwan's present university environment.

INTRODUCTION

The rapidly growing number of college students in Taiwan is due to the Taiwanese educational revolution that began approximately in 1995. In the past, the college acceptance rate from the joint boards of the college recruitment commission (JBCRC) and the college entrance examination centre (CEEC) has always been under or around 25%. To lessen public concern about low college acceptance rates, Taiwan's Ministry of Education, from a political perspective, started not only to upgrade all higher education units (from, e.g. vocational schools to junior colleges, junior colleges to 4-year colleges, and 4-year colleges to comprehensive universities) but also to encourage companies to build various new private junior colleges, 4-year colleges and comprehensive universities.

This rapid growth in the quantity of educational institutions caused the total number to increase, from 145 in 1995 to 251 in 2009, an increase of 73%. Accordingly, the total number of registered students from all colleges and universities has also rapidly increased, from 814,279 students in 1995 to 1,409,092 in 2009 with the number of students in Bachelor degree programmes increasing, from 772,182 to 1,191,877 (54.4%), in Masters degree programmes, from 33,200 to 183,401 (452.4%), and in doctorate degree programmes, from 8,897 to 33,751 (279.4%).

However, the total number of professors has only modestly increased, from 59,388 in 1995 to 68,731 in 2009, an increase of 15.7 %. Consequently, the student-professor ratio has increased, from 13.71:1 to 20.5:1. However, some private colleges and universities in Taiwan are beginning to struggle, partially due to the lower pool of college students as a result of the decline of Taiwan's birth rate and the increase in the number of colleges and universities.

To stay competitive and to attract new students, these private colleges and universities increasingly have focused on school rankings, which have led professors to focus not only on the quality of teaching but also to devote time to publishing articles in international journals. This results in better listings in Science Citation Index (SCI) and Social Sciences Citation Index (SSCI), since the number of articles published is considered a critical ranking factor.

Further, to improve the quality of the higher educational system, the Taiwanese Ministry of Education commenced an annual evaluation of departments at all colleges and universities. This is exercised through the control of various educational grants, which has resulted in professors taking additional responsibilities in administrative matters. These include admission administration, evaluation administration, students' guidance and assistance in campus life (e.g. by visiting students).

Specifically, this condition has been aggravated in private colleges and universities. Hence, given the trend of the Taiwanese educational revolution, the issue …*do college professors need to be Superman?* has become a popular topic in Taiwanese society [1-3]. Therefore, this article attempts to utilise a systematic approach using Multiple Criteria

Decision Making (MCDM) through the evaluated concepts and measured processes of Quality Function Development (QFD) [4][5]. The complete house of quality (HOQ) model links the relationship between customer needs (WHATs), competitors and technical measures (HOWs), and *goals* through the analytic network process (ANP) [6]. The entropy method, similar measure and order performance are used for similarity to an ideal solution called (TOPSIS) [7][8]. It positively matches WHATs and HOWs with *goals*. In order to concentrate on this topic, the inner dependence between customer needs and product technical requirements are considered in the measured model.

QUALITY FUNCTION DEVELIOPMENT

Quality Function Development (QFD) has been popularly utilised in the product design process since the 1960s. It focuses on product originality and can be applied in any managerial fields due to the development of the concepts of total quality control and total quality management [9].

The principal function of QFD is to employ a systematic method to efficiently design innovative products using limited resources and time, and to effectively understand the exact needs of customers. Further, customers' responses influence the product design systematically through QFD implementation cycles. This amends the development of products to fulfil highly changeable customers' desires. The two empirically well-known applications are Toyota and Texas Instruments [10].

In the early 1980s, Toyota started to utilise QFD to improve their initial car manufacture procedures to establish an effective and efficient supply chain. This was done with the assistance of the QFD research for the Japan Society for Quality Control (QFDRJS) [11][12]. Further, to upgrade the level of manufacturing and stabilise the high quality of their products, Texas Instruments began to introduce and implement QFD. This enabled them to improve manufacturing technology, and research and development (R&D) for products and, hence, to enter high-tech niche markets.

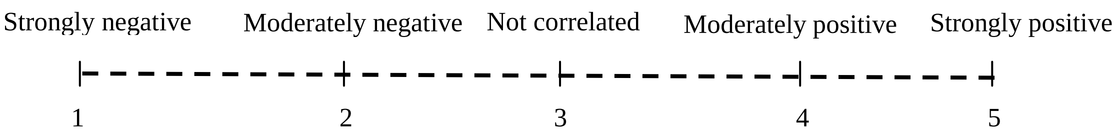
After the 1980s, more than 100 large enterprises started to use QFD for production and R&D. This allowed them to create extraordinary profits and benefits. Companies included 3M and Hewlett-Packard (HP). Cheng and Lin opined that enterprises can reduce manufacture and R&D costs by 60% and save 40% of the time of the production cycle [13]. This was based on the research and fieldwork of 25 companies using the entropy method [13].

Recently, QFD was used in discussing the relationship between customers' satisfaction and the quality of service. Bevilacqua inductively established the concept of the HOQ model after surveying essential research, journals and practical cases [12]. The relevant literature reviews were used to establish correctly and effectively the measured HOQ model in this article. The definition of the QFD elements is a critical necessity.

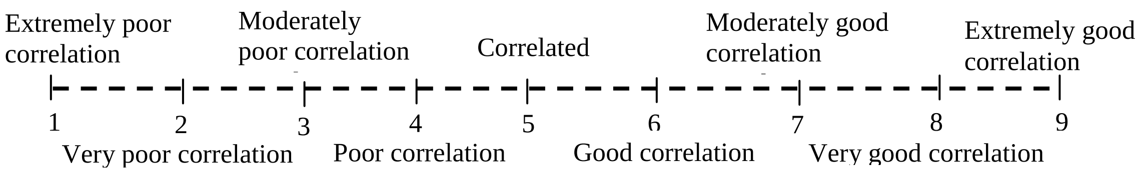
DEFINING QFD MEASURED ELEMENTS IN HOQ MODEL

The definition of classic HOQ of QFD used in this article consists of the following:

1. *Company (college or universities):* the companies are described as colleges or universities in Taiwan.
2. *Customers (students):* customers are defined as registered students in the Taiwanese educational system of college and universities.
3. *Products (services):* products are presented as services from professors of the Taiwanese colleges and universities, and include four aspects: teaching, researching, administrating and consulting.
4. *Customer needs (WHATs):* the needs of customers are represented as the requirements and expectation of students. They are expressed in general languages and are categorised into hierarchies to aid comprehension and analysis.
5. *Correlation matrix of customer needs (WHATs):* the correlation matrix consists of the pair wise connection between WHATs, using comparative analysis and empirical experience. It also allows the identification of decision-making niche key points. The level of correlation is evaluated by a five-point scale, from 1 to 5, indicating the interdependence and importance, from equal importance 1 to extreme importance 5, as follows:



6. *Related importance ratings for customer needs (WHATs):* the importance ratings of WHATs are assessed by the customers with a 5-point scale, but there is research using a 9-point scale as well:



7. *Sale-point:* the company's business position is represented as a sale-point. Usually, the important WHATs are rated *great* which is, in turn, defined as a *strong* sale-point; a *moderate* sale-point represents an importance rating (or competitive opportunity) of not so great, and no business opportunity is expressed as a *no* sale-point.
8. *Final related importance ratings of customer needs (WHATs):* the final importance ratings of WHATs are computed by the following function:

$$\text{Final related importance rating of the WHATs} = \sum (\text{relative importance*ameliorating* sale-point}) \quad (1)$$

where the summation is overall WHATs.

9. *Competitors:* competitors are defined as people, who have a doctoral degree.
10. *Competitors' assessment:* related performances of the product competitors' assessment are evaluated by the customers through comparing products of a company from a competitor's perspective. The measurement scale is the same as the importance rating of WHATs.
11. *Technical competitive assessment:* assessment of competitors' techniques is by evaluation of the performance of a company's products compared with similar products from competitors using a pair wise method for the HOW.
12. *Goals for customer needs (WHATs):* goals for customer needs are determined from practical customer needs to meet customers' desires. The assessment scale is similar to the related importance ratings of WHATs.
13. *Technical measurements (HOWs):* measurement of the university requirements for professors associated with design, specifications, qualitative characteristics, manufactures' attributes or methods of products are definitely interrelated with WHATs.
14. *Correlation matrix of technical measurements (HOWs):* the correlation matrix not only consists of pair wise relationships between HOWs by comparative analysis and empirical experience, it also provides the approach by which to identify the trend of product development to compete. The evaluated scale is the same as the correlation matrix of WHATs.
15. *Goals for technical measurements (HOWs):* goals for technical measurements are established to meet the performance goal of each HOW in order to compete.
16. *Related importance ratings of technical measurements (HOWs):* the importance ratings of the university requirements for professors are evaluated by the customers and, it is the principal output of the HOQ model of QFD. The measurement function is usually expressed as:

$$\begin{aligned}&\text{Related importance ratings of technical measurements (HOWs)} \quad (2)\\ &= \sum (\text{final importance rating of WHATs} \times \text{relationship value between WHATs and HOWs}),\end{aligned}$$

where the summation is overall WHATs and HOWs.

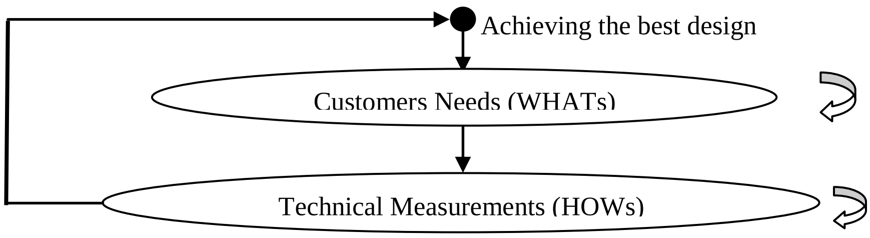
17. *Ameliorating directions of HOWs:* the customers' satisfaction can increase by identifying improvements of the HOWs after measuring the HOQ model of QFD. Essentially, there are three types of ameliorating direction: maximising (or increasing); meeting targets (or guidelines, standards and so on); minimising (or decreasing).
18. *Relationship matrix between WHATs and HOWs:* the pair wise matrix of relations between WHATs and HOWs is used to differentiate the correlation level between each WHAT and HOW and the measured scale is the same as the importance ratings of WHATs.
19. *Probability factors:* the probability factors indicate for each HOW the achievement of the performance goal. The measurement 5-point scale is:

Very low probability	Low probability	Moderate probability	High probability	Very high probability
1	2	3	4	5

CONSTRUCTING THE HOQ MODEL

After defining the necessary elements of QFD, the HOQ model was completely structured step-by-step to measure the evaluated matrices: WHATs, related importance ratings of WHATs; the HOWs, related importance ratings of HOWs; and relationship matrix between WHATs and HOWs through the comparison of the MCDM. To acquire the exact WHATs, the ANP is utilised to classify the weights of WHATs and HOWs based on a series of comprehensive surveyed reports regarding the improvement of quality education in private colleges and universities in Taiwan from the Association of Private Colleges and Universities of Technology, Taiwan (APUCT).

The next step, in terms of consistency of research and application of the HOQ model, was the delicate measurement of the 7-step HOQ model in Figure 2, to facilitate assessment of the overall matrices in this article. However, to concentrate on the relationship among WHATs, HOWs and the goals of WHATs and HOWs, the two correlation matrices of functional interactions of WHATs and HOWs were included in the evaluated processes. The two sessions are elaborated in the conclusions to reflect the super-matrix of integrity of the HOQ model of QFD as shown in Figure 2, and it is based on the literature from various fields that integrated the ANP, Fuzzy and QFD models to increase research feasibility and linguistic exactitude [14][15].



W=	Goal (G)	Customer Needs (WHATs)	Technical Measurements (HOWs)
Goal (G)	0	0	0
Customer Needs (WHATs)	***W1***	***W3***	**W5**
Technical Measurements (HOWs)	0	***W2***	***W4***

Resource: E.E. Karsak et al/Computers & Industrial Engineering 44 (2002) 171-190

Figure 1: The super matrix of integrity of HOQ model of QFD.

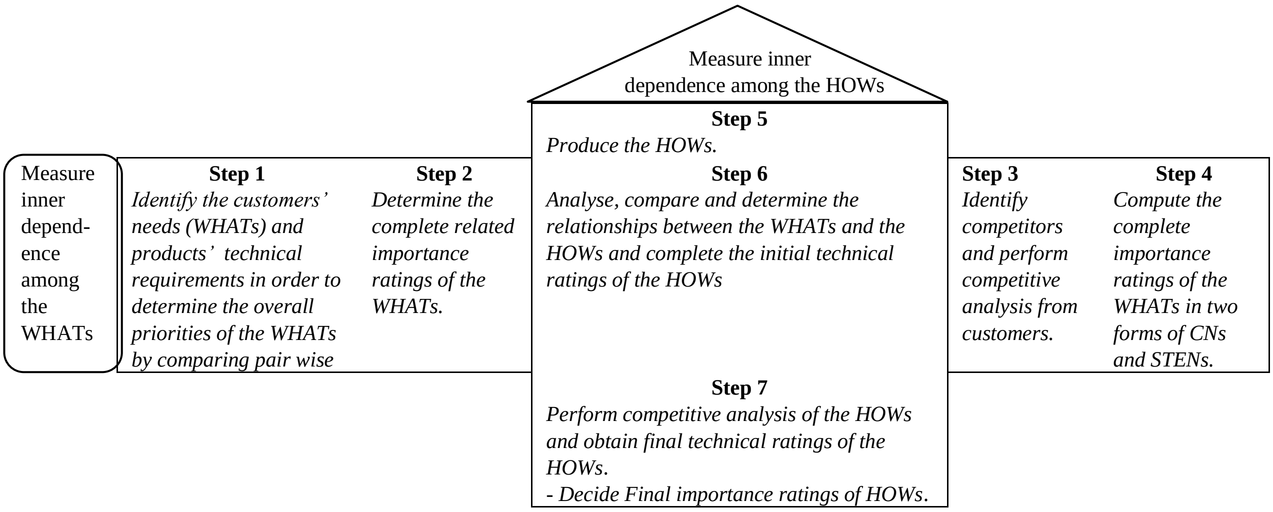
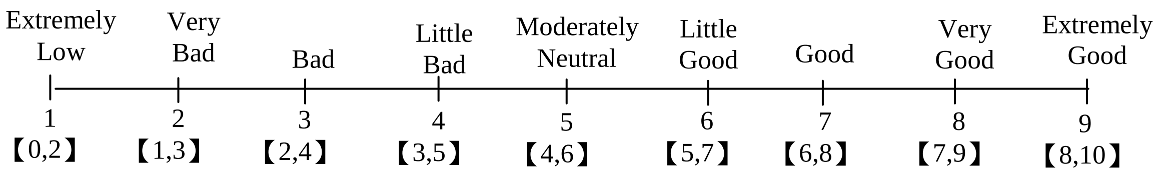
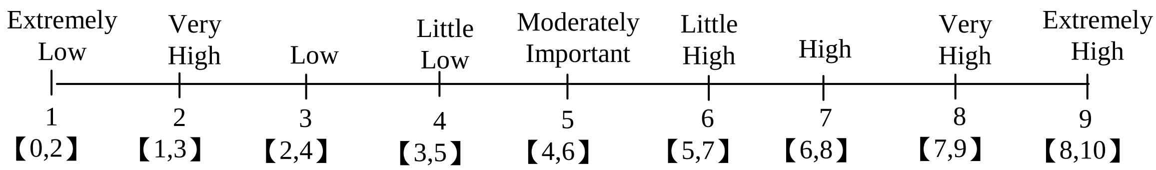
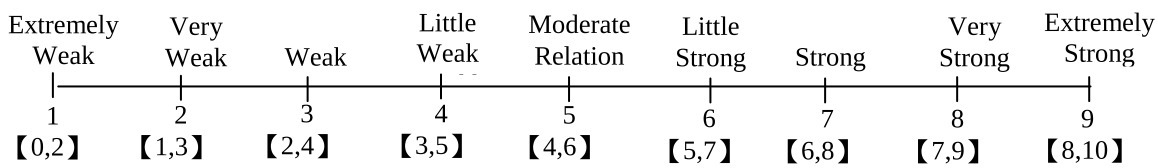


Figure 2: House of quality (HOQ) seven-step model.

In Figure 1, *W1* represents a vector, which expresses the impact of the goal and represents the satisfaction of the WHATs. From the customer needs aspect, *W2* is a measured matrix that indicates the impact of the WHATs on each HOW. *W3* and *W4* individually represent the measured matrices of the inner dependence of the WHATs and HOWs. To avoid the linguistic amphiboly of surveyed questionnaires, fuzzy theory was used in the linguistic assessments to avoid linguistic vagueness [16][17]. Based on the defuzzification concept of fuzzy theory, the initial overall five-point and nine-point scale were converted to a nine-point scale with symmetrical triangular fuzzy numbers (STFNs), such as【0.5, 1, 1.5】and【1.5, 2, 2.5】for linguistic evaluation, to improve the surveyed indefiniteness. Hence, a STEN is a specific fuzzy set expressing a fuzzy concept *uncertain b* or *approximately b*, based on the vector of【a, b】and, where $b=(a+b)/2$ through the three kinds of measurement scales:







DESCRIPTION OF HANDLING HOQ MODEL

Based on the fundamental concept of the HOQ model of QFD, the seven-step HOQ model, with reference to the qualitative and quantitative analyses proposed in this study, is as follows.

Step one: *Identify the customers' needs (WHATs) and product technical requirements to determine the overall priorities of the WHATs by pair wise comparison.* First, the enterprise has to recognise who are the key customers. There are five selected students (S_1, S_2, S_3, S_4, S_5) all of whom have taken courses from four surveyed professors (T_1, T_2, T_3, T_4) to further understand products critical for the enterprise. Information regarding the WHATs was gathered by individual interviews, brainstorm surveys and customer feedback. Specifically, after the first hierarchical discussion, the 15 WHATs ($D_1, D_2, ..., D_{10}$) were selected by two more systematic methods. The second hierarchical discussion contained affinity diagram and cluster analysis. In this step, the pair wise comparison between each WHAT (W_{DC_D} , D means WHATs and C_D means the number category of the WHATs) were also performed, utilising the ANP approach.

Step two: *Determine the complete related importance ratings of the customers' needs (WHATs).* Therefore, through surveying the customers regarding the 15 related importance ratings of the WHATs, the relative performance of the enterprise was determined for each WHAT. The comprehensive information was obtained by aggregating the related importance ratings of the 15 WHATs in two types of crisp number (CNs) ($\mathrm{D}g_m$) and STENs ($\tilde{\mathrm{D}g}_m$) to avoid linguistic amphiboly:

$$\mathrm{D}g_m = \frac{(\mathrm{D}g_{m1} + \mathrm{D}g_{m2} + ... + \mathrm{D}g_{ms})}{S} * W_{DC_D} = \sum_{s=1}^{s} \frac{\mathrm{D}g_{mk}}{S} * W_{DC_D} \quad \text{(CNs)} \tag{3}$$

$$\tilde{\mathrm{D}g}_m = \frac{(\tilde{\mathrm{D}g}_{m1} + \tilde{\mathrm{D}g}_{m2} + ... + \tilde{\mathrm{D}g}_{ms})}{S} * W_{DC_D} = \sum_{s=1}^{s} \frac{\tilde{\mathrm{D}g}_{mk}}{S} * W_{DC_D} \quad \text{(STENs)} \tag{4}$$

where W_{1r} , $m = 1, 2, ..., M$; M=a number of customers' needs.

Step three: *Identify competitors and perform competitive analysis from customers.* The strengths and weaknesses, and the development and constraints regarding designed new products, were identified by competitive analysis of similar products by asking the customers to rate the related performance of the enterprises and its competitors on each WHAT. Hence, the performance ratings of enterprises on each WHAT can be computed by a comparison matrix ($M \times L$) [18], as follows:

$$X = \begin{matrix} \\ D_1 \\ D_2 \\ \cdots \\ D_M \end{matrix} \begin{matrix} C_1 & C_2 & \cdots & C_L \\ \left(\begin{matrix} X_{11} & X_{12} & \cdots & X_{1L} \\ \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots \\ X_{M1} & X_{M2} & \cdots & X_{ML} \end{matrix} \right)_{M \times L} \end{matrix}$$

In accordance with the comparison matrix ($M \times L$), the competitive priority ratings from the customer on each WHAT for the producing company C_1 was determined as $E = (E_1, E_2, ..., E_m)$ where E_m is the current performance on customers' needs D_m . Further, according to the current performance of the enterprise C_1 compared with its competitors' performance, the performance goals on the WHATs can be established for the enterprise. These goals should comprehensively and realistically be captured from the academic organisations by considering the relevant literature. Thus, in terms of customer needs, the goal performance can be expressed as $A = (A_1, A_2, ..., A_m)$ from the customer-needs perspective. Further, the improvement ratio for D_m can be computed as $U_m = A_m / X_{mL}$ which means the higher the improvement ratio, the greater the work on the WHATs. In addition, in terms of the measurement of the probability distribution, the entropy method was applied to calculate the entropy number De_m . The entropy method can be used to deal with the amount of uncertainty by the discrete probability distribution $DE(p_1, p_2, ..., p_L)$ as

$DE(p_1, p_2, ..., p_L) = -\varnothing_L \sum_{l=1}^{L} p_l In(p_l)$, where $\varnothing_L = 1/ In(L)$ is a normalisation constant to make sure $0 \le E(p_1, p_2, ..., p_L) \le 1$.

For the row of m of the comparison matrix X for the customer corresponding to the customer needs D_m , the total score with reference to D_m can be computed as $X_m = \sum_{l=1}^{L} X_{ml}$ ($X = (X_1, X_2, ...X_{mL})$. The *probability distribution* of D_m on the L companies with entropy was calculated as:

$$E(D_m) = -\varnothing_L \sum_{l=1}^{L} P_{ml} In(p_{ml}) = -\varnothing_L \sum_{l=1}^{L} (\frac{X_{ml}}{X_m}) In(\frac{X_{ml}}{X_m}) \tag{5}$$

where D_m has zero variation and $E(D_m)$ reaches its maximum of 1 if all the performance ratings of enterprises on D_m are the same. Therefore, $E(D_m)$ reflects on the relative competitive advantage in accordance with the customer need D_m and, thus, after normalisation, all these e_m can be measured as:

$$De_m = E(D_m) / \sum_{m=1}^{M} E(D_m), \quad m = 1, 2, ..., M \tag{6}$$

Step four: *Compute the complete importance ratings of the customer's needs (WHATs) in two forms of CNs and STENs.* The higher related importance ratings, higher competitive priorities and improvement ratios from customers on the WHATs were considered. Therefore, in accordance with Equation (2), the complete importance ratings of customer needs (Df_m) is commonly computed by its related importance ratings Dg_m , competitive priorities De_m and improvement ratios DU_m as:

$$f_m = W_{DC} \times W1 \times W3 = DU_m \times Dg_m \times De_m \text{ , where } W_{DC} \times W1 = Dg_m \text{, } W3 = DU_m \times De_m \tag{7}$$

It is obvious that the complete importance ratings of customer needs are higher, which results in potential profits and benefits for the enterprise. Hence, the complete importance ratings of customer needs in empirical cases can be expressed as vector in two forms of CNs ($Df = (Df_1, Df_2, ..., Df_m)$) and STENs ($D\tilde{f} = (D\tilde{f}_1, D\tilde{f}_2, ..., D\tilde{f}_m)$). Based on the defuzzification from the effective order aspect, the similarity measure (S【A,】) is utilised by conducting the measurement of STENs between two measured vectors ($A_1 = (c_1, a_1, b_1)$ and $A_2 = (c_2, a_2, b_2)$) [19]:

$$S[V_1, V_2] = \begin{cases} 1 \\ \exp(-d^2/\alpha), \text{ if } V_1 \neq V_2 \end{cases} \tag{8}$$

where $d^2(A_1, A_2) = (a_1 - a_2)^2 = \left[\frac{((c_1 + a_1) - (c_2 + a_2))^2}{4}\right] + \left[\frac{((b_1 + a_1) - (b_2 + a_2))^2}{4}\right]$

$$\alpha = \frac{(D^* + D_*)}{2} + \frac{(|c_1 - c_2| + |b_1 - b_2|)}{8}, \; D^* = \frac{|(a_1 + b_1) - (a_2 + b_2)|}{2}, \; D_* = \frac{|(a_1 + c_1) - (a_2 + c_2)|}{2}$$

In order to minimise the linguistic amphiboly, Hwang and Yoon initially expressed the TOPSIS for dealing with problem of MCDM [20]. The selected alternatives are supposed not only to have the shortest distance from the fuzzy positive ideal reference point (FPIRP, A^+), but also have the longest distance form the fuzzy negative ideal reference point (FNIRP, A^-). Further, the distance of each initial WHATs from FPIRP and FNIRP is able to be individually denoted as:

$$d_i^+ = \sum_{k=1}^{n} d(\tilde{v}_{ij}, \tilde{v}^+_j) = \sqrt{\frac{\left[(a_1 - 1)^2 + (b_1 - 1)^2 + (c_1 - 1)^2\right]}{3}}, \; i = 1, 2, ..., m \; ; \; j = 1, 2, ..., n$$

$$d_i^- = \sum_{k=1}^{n} d(\tilde{v}_{ij}, \tilde{v}^-_j) = \sqrt{\frac{\left[(a_1 - 0)^2 + (b_1 - 0)^2 + (c_1 - 0)^2\right]}{3}}, \; i = 1, 2, ..., m \; ; \; j = 1, 2, ..., n$$

where $\tilde{v}^+_j = (1,1,1)$ and $\tilde{v}^-_j = (0,0,0)$, $j = 1, 2, ..., n$. The selected coefficient of each alternative ("$CC_{w_m}(V_1, V_2)$") is computed as: $CC_{w_m}(V_1, V_2) = d_i^- / d_i^+ + d_i^-$ (9)

Step five: *Produce the technical measurements (HOWs).* The staff and technicians in the R&D department have to expand the HOWs to satisfy the WHATs in measurable and operable technical terms after obtaining feedback of the WHATs. Further, the number *N* of the HOWs were determined using the affinity diagram method, cause-effect analysis and competitive analysis from technicians and customers. These HOWs can be categorised into some manageable group. In this step, the pair wise comparison between each HOW ($W4 = W_{HC_H}$, *H* means HOWs and C_H means the number of category of the WHATs) were performed using the ANP approach.

Step six: *Analyse, compare and determine the relationships between WHATs and HOWs and complete the initial technical ratings of HOWs.* This step is the critical one in the QFD of HOQ model because the analysis compares and determines the extent to which each HOW can impact on and be associated with the WHAT through the measurement of the following relationship comparison-matrix ($M \times \mathrm{N}$). The definitions of each WHAT and HOW are based on a nine-point scale:

$$
R = \begin{matrix} \\ D_1 \\ D_2 \\ \dots \\ D_M \end{matrix} \begin{matrix} H_1 & H_2 & \dots & H_N \\ X_{11} & X_{12} & \dots & X_{1L} \\ \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots \\ X_{M1} & X_{M2} & \dots & X_{ML} \end{matrix}_{M \times N}
$$

The comprehensive information was obtained by aggregating the initial technical ratings of the 12 HOWs on the 15 WHATs in two kinds of form of CNs (HI_N) and STENs ($\tilde{HI}_N$). This utilised the sample additive weighting (SAW) approach of Equation (7), according to the fundamental concepts of fuzzy theory to avoid the linguistic amphiboly.

$$
W2 = W4 \times HI_N = \sum_{N=1}^{15} Df_m \times H_N / 15 \text{ (CNs)} \tag{10}
$$

$$
W2 = W4 \times H\tilde{I}_N = \sum_{N=1}^{15} D\tilde{f}_m \times H_N / 15 \text{ (STENs)} \tag{11}
$$

To defuzzify the STENs of the initial technical ratings of the 12 HOWs, Equation (8) of the *S*【*A*,*B*】 and Equation (9) of the TOPSIS are utilised to measure the rank of the final importance ratings of the 12 HOWs in STENs.

Step seven: *Perform competitive analysis of the technical measurements (HOWs) and obtain the final technical ratings of the technical measurements (HOWs).* The information about the know-how and parameters of competitors on each HOW is a key point in this step because this information not only expresses the technical performance of the competitors' products but also the difficulty in obtaining any related competitive data from competitors. Therefore, the collection methods in this step are usually from comprehensive marketing analysis and customers' feedback. Through further analysis of this information, the performance ratings of enterprises on each HOW can be computed by a comparison matrix ($M \times N$) for customers as:

$$
Y = \begin{matrix} \\ H_1 \\ H_2 \\ \dots \\ \dots \\ H_N \end{matrix} \begin{matrix} C_1 & C_2 & \dots & C_L \\ Y_{11} & Y_{12} & |\dots & Y_{1L} \\ \\ \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots \\ Y_{M1} & Y_{M2} & \dots & Y_{ML} \end{matrix}_{M \times N}
$$

The measurement of the probability distribution of H_N on the N technical measures with entropy is calculated as:

$$
E(H_m) = -\varnothing_L \sum_{l=1}^{N} P_{Nl} In(p_{Nl}) = -\varnothing_N \sum_{l=1}^{N} (\frac{Y_{Nl}}{Y_N}) In(\frac{Y_{Nl}}{Y_N}) \tag{12}
$$

where H_N has zero variation and $E(H_N)$ reaches its maximum of 1 if all performance ratings of enterprises on H_N are the same. Therefore, $E(H_N)$ is able to reflect the relative competitive advantage H_N in accordance with customer needs. After normalisation, He_m can be measured as:

$$
He_m = E(H_N) / \sum_{m=1}^{N} E(H_N), \quad m = 1, 2, \dots, N \tag{13}
$$

Further, to calculate the complete importance ratings of technical measures (HOWs) in two forms of the CNs and the STENs, the higher related importance ratings, higher competitive priorities and improvement ratios from customers on each HOW should be considered. Therefore, in accordance with Equation (2), the complete importance ratings of technical measures (Hf_m) is commonly computed by its related importance ratings Hg_m, competitive priorities He_m and improvement ratios HU_m as:

$$
Hf_m = W_{HC} \times W3 \times W4 = HU_m \times Hg_m \times He_m, \quad \text{where } W_{HC} \times W3 = Hg_m, \ W4 = HU_m \times He_m \tag{14}
$$

Further, to avoid the linguistic vagueness regarding the competitive priorities He_m of the 12 HOWs, the Equation (8) of the *S*【*A*, *B*】[21] and Equation (9) [22] of the TOPSIS [23] are utilised to defuzzy the rank of the final importance ratings of the 12 HOWs in STENs.

INTACT ILLUSTRATIVE EXAMPLE

After cross-relating the collected questionnaires using the equations, the calculations of the CN of four professors were measured by the entropy method through competitive analysis. Therefore, the improved goal for HOWs (B_m) was established by the United Colleges Entrance Examination Organisation and the Taiwanese Government's annual education reports, which resulted from the satisfaction of students' needs. After complex measurements and considerations, the entropy numbers of the probability distribution of four professors for each of the 12 HOWs, utilising the entropy method was calculated as:

$$(E(H_1), E(H_2), ..., E(H_{12})) = (0.0836, 0.0837, 0.0838, 0.0828, 0.083, 0.0831, 0.0814, 0.0822, 0.0819, 0.085, 0.0842, 0.0853)$$

where $He_1 = E(H_1) / \sum_{m=1}^{15} E(H_m) = 1.0073 / 12.0536 = 0.0836$

Consequently, according to the related importance ratings and comparing priority ratings of technical and competitive analyses of each of the HOWs, the complete final related importance ratings are expressed as the CNs below:

$$Hf = (Hf_1, Hf_2, ..., Hf_{10}) = (0.0862, 0.0954, 0.0904, 0.1911, 0.2189, 0.1585, 0.1653, 0.1258, 0.1145, 0.1862, 0.1794, 0.1756)$$

Eventually, the rank of final importance ratings of the 12 HOWs was:

$$H_5 \succ H_4 \succ H_{10} \succ H_{11} \succ H_{12} \succ H_7 \succ H_6 \succ H_8 \succ H_9 \succ H_2 \succ H_3 \succ H_1$$

where $\succ$ means *more critical then…*

The complete final related importance ratings were expressed as the STEN numbers:

$$\begin{aligned} H\tilde{f} &= (H\tilde{f}_1, H\tilde{f}_2, ..., H\tilde{f}_{10}) \\ &= ([0.0608, 0.1115], [0.0689, 0.1219], [0.678, 0.113], [0.1496, 0.2327], [0.1713, 0.2664], [0.1168, 0.2002], \\ &\quad [0.1194, 0.2113], [0.0839, 0.1678], [0.0763, 0.1526], [0.158, 0.2144], [0.1505, 0.2083], [0.1473, 0.2039]) \end{aligned}$$

According to concept of performance assessment of the S【A, B】, the complete final importance ratings are expressed as the STEN numbers:

$$HS[V_1, V_2] = (0.7839, 0.7924, 0.7866, 0.8938, 0.929, 0.8585, 0.8674, 0.826, 0.8138, 0.8826, 0.8755, 0.8712).$$

Consequently, in terms of similar measure, the rank of related importance ratings of the 12 HOWs in STEN form is in the order below:

$$H_5 \succ H_4 \succ H_{10} \succ H_{11} \succ H_{12} \succ H_7 \succ H_6 \succ H_8 \succ H_9 \succ H_2 \succ H_3 \succ H_1$$

where $\succ$ means *more critical then…*

Further, based on evaluation of TOPSIS ("$CC_{w_m}(V_1, V_2)$"), the complete final related importance ratings are expressed as the STEN numbers:

$$CC_{w_m}(V_1, V_2) = d_1^- / (d_1^+ + d_1^-) = (0.0818, 0.0899, 0.0841, 0.1768, 0.2029, 0.1489, 0.1564, 0.1216, 0.1106, 0.1676, 0.162, 0.1585)$$

Consequently, in terms of TOPSIS, the rank of the related importance ratings of the 12 HOWs in STEN form is in the following order:

$$H_5 \succ H_4 \succ H_{10} \succ H_{11} \succ H_{12} \succ H_7 \succ H_6 \succ H_8 \succ H_9 \succ H_2 \succ H_3 \succ H_{18}$$

where $\succ$ means *more critical then…*

Most distinctly, the top highest measured scale-ratings results for CNs were the academic papers, patent applications and professional technical reports (*APT*) H_5 (0.2189), the numbers of published journals (*NPJ*) H_4 (0.1911) and evaluation from students (*CES*) H_{10} (0.1862), and, for STEN, they were the academic papers, patent applications and professional technical reports (*APT*) H_5 ($S[V_1, V_2] = (0.929); CC_{w_m}(V_1, V_2) = (0.2029)$), the numbers of published journals (*NPJ*) H_4 ($S[V_1, V_2] = (0.8938); CC_{w_m}(V_1, V_2) = (0.1768)$), and the evaluation from students (*CES*) H_{10} ($S[V_1, V_2] = (0.8826); CC_{w_m}(V_1, V_2) = (0.1676)$); as well, two evaluation methods (similar measures and TOPSIS) were used. These results reflect that academic research and consulting are still the main considerations for universities' recruitment.

CONCLUSIONS AND RECOMMENDATIONS

The effective systematic measurements and evaluated approaches with a series of assessed scales and analytical elements regarding the QFD theory and HOQ models are established by much recent research but there are few comprehensively successful QFD applications beyond reviewing a great deal of literature.

First, the comprehensive methodology and associated evaluation steps of the HOQ model are determined with the related evaluated elements and the various nine-point scales in order to avoid research arbitrariness, operational uncertainty and evaluation comparability because of the complicated theoretical concepts, data-collecting processes and computed procedures involved in the HOQ models of QFD in this study.

Specifically, not only the use of the CNs but also the utilisation of the STENs are both interlaced to minimise the indistinctness of the linguistic exactitude and to diminish the subjective concepts of the five selected students by employing the quantitative entropy methods, similar measure and the TOPSIS. To completely demonstrate the HOQ model of QFD, the professors in the university were examined by implementing competitive analysis and technical analysis with the five selected students (customers), the four professors, the 15 WHATs and the 12 HOWs.

Consequently, in terms of CNs and STENs of the 15 WHATs, it is the most pellucid that the top highest measured scale-ratings results are humour and zeal (H&Z), attractive and fit (A&F) and less demanding (LD). Thus humour, zeal, attractiveness and easygoingness, etc, all promote acceptance. However, in opposition, regarding the CNs and STENs of the 12 HOWs, the highest measured scale-ratings are for academic papers; patent applications and professional technical reports (APT); numbers of published journals (NPJ) and evaluation by students (CES); academic research awards from significant organisations around the world (ARA) and the administrative functions of education evaluation within the Taiwanese Government (AJEV). These lead to more academic, administrative and consulting positions; hence, it is more probable that employment will be obtained.

Further, through comparisons and evaluations of the WHATs and the HOWs, the highest weights are still focusing on academic research awards from significant organisations around the world (ARA), and the administrative functions of education evaluation from the Taiwanese Government (AJEV), as well as the academic papers, patent applications and professional technical reports (APT). The reason is that all universities and colleges have to carry out the complicated comprehensive performance evaluation system, which is the primary basis used to determine the distribution of the Government's education budget and the tuition of students.

In order to survive, private universities in Taiwan have to increase their rankings and, by doing so, attain a greater portion of the education budget and improve their ability to attract more new students. The management of lower-ranking colleges and universities has established innovative rigorous recruitment and evaluation performance systems for new professors based on four perspectives: teaching, research, administration and consulting.

Therefore, professors of colleges and universities not only have to be attractive and fit, but also humorous, demonstrate zeal and be less demanding in personality. They apply their efforts to teaching and/or researching (traditionally one or the other) and devote themselves to supporting the recruitment of students and consultancy programmes. As well, they implement the university's administrative projects (innovatively various perspectives).

Finally, do the college professors need to be *Superman*? The inductive answer in this article is that *Superman* is the name that matches the reality of college professors in the complex condition of Taiwan's current university environment, as demonstrated through the complete application of the HOQ model of QFD.

REFERENCES

1. Adamopoulos, G.I. and Pappis, C.P., A fuzzy-linguistic approach to multicriteria sequencing problem. *European J. of Operational Research*, 92, 628-636 (1996).
2. Akao, Y., QFD: Past, present, and future. *Proc. International Symposium on QFD'97*, Linkoping (1997).
3. Barbarosoglu, G. and Yazgac, T., An application of the analytic network process to the supplier selection problem. *Production and Inventory Management J.*, 38, **1**, 14-21 (1997).
4. Saaty, T.L., *Decision Making with Dependence and Feedback: The Analytic Network Process*. Pittsburgh, PA: RWS Publications, 1444-1458 (1996).
5. Karsak, E.E., Sozer, S. and Alptekin, S.E., Product planning in quality function deployment using combined analytic network process and goal programming approach. *Computers & Industrial Engng.*, 44, 171-190 (2002).
6. Mesey, G., A practical prioritization by multi-level group decision support. *Central European J. of Operations Researc*h, 16, 1-15 (2008).
7. Dangling, H, Zhiyong, Z. and Shiai, L., TOPSIS Analysis in Multi-target Decision-making Method and its application. *Computer and Agriculture*, **4**, 27-28 (1999).

8. Shujing, H. and Xiaomei, Z., Evaluation study on third-party reverse logistics enterprise based on RBF network improvement calculation. *Logistics Technology*, 2, **26**, 83-84 (2007).
9. Chan, L.K. and Wu, M.L., Quality function deployment: A literature review. *European J. of Operational Research*, 143, 463-497 (2002).
10. Al-Najjar, B. and Alsyouf, I., Selecting the most efficient maintenance approach using fuzzy multiple criteria decision making. *Inter. J. of Production Economics*, 84, **1**, 85-100 (2003).
11. Ayag, Z. and Ozdemir, R.G., A hybrid approach to concept selection through fuzzy analytic network process. *Computers and Industrial Engng*., 56, **1**, 368-379 (2009).
12. Bevilacqua, M., Ciarapicab, F.E. and Giacchettab, G., A fuzzy-QFD approach to supplier selection. *J. of Purchasing & Supply Management*, 12, 14-27 (2006).
13. Cheng, C.H. and Lin. Y., Evaluating the best main battle tank using fuzzy decision theory with linguistic criteria evaluation. *European J. of Operational Research*, 142, **1**, 174-186 (2002).
14. Hong, T.P., Yu, K.M. and Huang, C.M., LPT Scheduling on fuzzy tasks with triangular membership functions. *Proc. Second Conference on Knowledge-Based Intelligent Electronic Systems*, 21-23 (1998).
15. McCahon, C.S. and Lee, E.S., Job sequencing with fuzzy processing times. *Computers and Mathematics with Applications*. 19, **7**, 31-41 (1990).
16. Asan, U., Bozdag, E.C. and Polat, S., A fuzzy approach to qualitative cross impact analysis. *Omega - Inter. J. of Management Science*, 32, **6**, 443-458 (2004).
17. Driva H., Pawar K.S. and Menon, U., Measuring product development performance in manufacturing organizations. *Inter. J. of Production Economic*, 66, 147-159 (2001).
18. McCahon, C.S. and Lee, E.S., Job sequencing with fuzzy processing times. *Computers and Mathematics with Applications*, 19, **7**, 31-41 (1990).
19. Yang, M.S., Hung, W.L. and Chang-Chien, S. J., On a similarity measure between LR-type fuzzy numbers and its application to database acquisition. *Inter. J. of Intelligent Systems*, 20, 1001-16 (2005).
20. Hwang, C.L. and Yoon, K., *Multiple Attribute Decision Making Methods and Applications*. Berlin, Heidelberg, New York: Springer-Verlag,1-7 (1981).
21. Auerswald, P. and Branscomb, L.M., Research and Innovation in a Networked World. School of Public Policy, George Mason University, VA, USA (2008).
22. Saaty, T.L., *Multi-Criteria Decision Making: The Analytic Network Process*. Pittsburgh, PA: RWS Publications (1998).
23. Wang, X., Grey Analysis of the factors of industry production. *J. of Grey System*, 4, 173-180 (1992).