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Using Importance-Performance Analysis and Decision Making Trial and Evaluation Laboratory to Enhance Order-Winner Criteria ~ A Study of Computer Industry

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Abstract: This study proposes a new decision analysis methodology that identifies the core order-winner criteria problems. A modified Importance-Performance Analysis (IPA) and multiple regression analysis are applied to define the implicit importance of quality characteristics and overall satisfaction. Gap analysis is used to identify the performance of quality characteristics. Decision making trial and evaluation laboratory (DEMATEL) is used to correlate the interrelationship among the quality characteristics. This methodology better defines the importance and priority over quality characteristic improvements and solves the practically complicated, contradictory problems with the least resources. This study performs empirical research into the Taiwanese computer industry and explains the application and benefits of the modified IPA and DEMATEL.

Key words: Decision making trial and evaluation laboratory, gap analysis, importance-performance analysis, multiple regression analysis, Order-Winner Criteria

INTRODUCTION

After the rise of different quality management systems in the 80s, we tend to find Customer Satisfaction as the main assessment index for organizational performance in both theoretical and empirical studies. Thus, research on the importance and satisfaction of service quality characteristics has become popular. Generally speaking, the tool commonly used in this kind of research is Importance-Performance Analysis (IPA). This method directly analyzes the advantages and disadvantages of organizations from market surveys. Martilla and James (1977) initially developed market strategies using IPA, which have also been applied to varied industries for nearly 30 years. For example, in a recent study, Levenburg and Magal (2005) applied IPA to the construction of e-commerce strategies and resource distribution. Zhang and Chow (2004) applied IPA to improve tourism service quality. Matzler *et al.* (2003) applied IPA to bank service quality improvement and strategic development. Aigbedo and Parameswaran (2004) improved food service quality in schools using IPA. Matzler *et al.* (2004) used the automobile industry as an example and re-considered the application of IPA. Matzler *et al.* (2005) applied IPA to modern management and an orientation study of the tools. Huang *et al.* (2006) explored satisfactory service quality using intermediate and long trip passengers from high schools using IPA. Tonge and Moore (2007) assessed the perception quality of coastal Marine-Park visitors using IPA and Gap Analysis and managed environmental protection more effectively. Lee *et al.* (2008) used a modified IPA model to assess supplier quality performance. Martilla and James (1977) emphasized the advantages of IPA: low cost, useful application, better focus and strategic suggestions which were the main reason that the method was generally accepted and applied.

The basic concept of this method is to probe into the customers cognitive importance of quality characteristics through market research and the customers actual satisfaction with the quality characteristic after receiving the services. Using two-dimensional Importance and Performance matrix analysis, they allocated the quality characteristics into four categories according to importance and performance for the organizations market strategies. Of course, in the history of IPA development, many scholars tried to compare the effectiveness of different IPA models and its framework.

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For example, Oh (2001), who re-studied the concept and methods of the past IPA researches provided future research directions and also reorganized ten conclusions for effectively and reliably using IPA. Bacon (2003) compared several different IPA methods using 15 pieces of data to find the most effective one. Fontenot *et al.* (2005) compared four models that were commonly used for studying Customer Satisfaction and demonstrated that when constructing the action project, multi-variance sequence, technique was the priority.

Recently, many scholars tried to modify the traditional IPA model. Through a bank service quality empirical study, Matzler *et al.* (2003) indicated that Customer Satisfaction exhibited a linear quality characteristic structure and demonstrated that the traditional IPA model would lead to wrong organizational decision-making. Sampson and Showalter (1999) demonstrated the negative correlation between importance and performance. They suggested that importance should not be revealed using point estimation. Instead, it should be shown using a causal performance function. Yavas and Shemwell (2001) modified IPA by multiplying the gap between the company's performance and that of rivals using relative importance. They demonstrated the application using the medical industry as an example. In Customer Satisfaction results on the quality characteristics of outdoor recreational facilities, Tarrant and Smith (2002) modified IPA using means and standard deviation to supplement the disadvantage of point estimation in the traditional means.

The aforementioned scholars' researches on IPA made great contributions. However, traditional IPA presupposes that explicit customer response data is used for assessing the importance and performance of quality characteristics and that each quality characteristic is an independent variable. Under this supposition, when the quality characteristic has explicit data and causation, traditional IPA cannot correctly show the importance and priority of improvements. This study proposes a new methodology for decision analysis that identifies the core order-winner criteria problems using a modified IPA and multiple regression analysis applied to define the implicit importance of quality characteristics and overall satisfaction. Gap Analysis (GA) is used for the performance of quality characteristics. The decision making trial and evaluation laboratory (DEMATEL) is used to determine the correlation and interrelationship among the quality characteristics. This methodology better defines the importance and priority over quality characteristic improvements and solves the practically complicated, contradictory problems using the least resources. This study performs empirical research into the Taiwanese computer industry and explains the application and benefits of the modified IPA and DEMATEL.

IPA models review: IPA was proposed by Martilla and James (1977) and used to develop effective market strategies. The organizations probed into the customers' acceptance of specific quality characteristics using market research and they encountered two problems: (1) they only surveyed the acceptance of one aspect of the quality characteristics (importance or performance); (2) according to the research finding, they could not find the empirical importance and influence through the coefficient of determination in the statistical analysis. Thus, IPA revealed a perfect solution for the above problems. With such simple data, the organizations could analyze and study four different types of quality characteristics and develop a strategy and action plans with regard to the quality characteristic in each quadrant. The IPA questionnaire design tended to invite the respondents to answer the following two questions related to quality characteristics: (1) How important is the quality characteristic for you? (2) How is the organization's performance with regard to this quality characteristic?

IPA constructs a two-dimensional matrix by collecting the above two responses. With regard to the central tendency of importance and performance, it divides the quality characteristics into four quadrants by treating the median as the matrix split value. Some scholars replaced the median with the means, which becomes the main statistics in the IPA. The traditional IPA model reveals the states of the quality characteristics using a two-dimensional graph used to explain and judge the strategies. We can respectively define four matrix quadrants: (1) Concentrate here: the customers suggest that the importance of the product or service quality characteristic is high; however, the organizational performance is low. (2) Keep up the good work: the customers suggest that the importance of the product or service quality characteristic is high and the organizational performance is also high. (3) Low priority: organizational performance on the product service quality characteristic is low and the customers' cognitive importance is also low. (4) Possible overkill: organizational performance on the product or service quality characteristic is high; however, the customers' cognitive importance is low.

Although IPA is easy to use and explain there are still some latent problems. After Martilla and James (1977) proposed IPA, many well-known scholars proposed modified models. Yavas and Shemwell (2001) integrated the relative importance as a weighting index to replace the importance of the vertical axis and used the relative performance. In other words, they compared and calculated the difference between the performances of the organization and its' rivals and multiplied it by importance to replace performance in the original horizontal axis. In addition, they redefined four strategies of importance-performance into a two-dimensional matrix. Tarrant and Smith (2002) modified IPA using the standard deviation of the means of the quality characteristics. This method successfully assessed the dispersion of the average importance and performance. Martilla and James (1977) suggested that importance and performance were independent variables. However, the dynamic model proposed by Sampson and Showalter (1999) demonstrated that the change in organizational performance would further influence the customers' cognitive importance. The main reason was in that the correlation coefficient between importance and performance was not zero. Based on this argument, when the organizational performance was higher, the gap between importance and performance would be immediately reduced. Likewise, the study of Matzler *et al.* (2003) indicated that organizational overall satisfaction was the function of quality characteristic performance. The study of Matzler *et al.* (2004) indicated that importance of a quality characteristic was the function of quality characteristic performance. Matzler and Sauerwein (2002) regarded importance as the function of performance. Therefore, they regarded performance as independent variables and overall satisfaction as dependent variables for Multiple Regression Analysis. In the solution of regression formula, they treated regression factor as the importance of quality characteristics to reconstruct importance and performance to analyze matrix. Deng (2007) and Deng *et al.* (2008a, b) provided a revised IPA that integrated partial correlation analysis and natural logarithmic transformation for measuring the importance of attributes. Their papers provide a modified IPA and makes extended use of IPA in assessing a supplier's quality performance.

Although the above researches and findings contributed much to IPA theory and application, research on how the correlation between quality characteristics influence the conclusion has not been processed yet. To know such influence, this study takes the implicit importance from Matzler and Sauerwein (2002) as the satisfaction function of the quality characteristics and adopts gap analysis and IPA from Fontenot *et al.* (2005) to create a more reasonable IPA for analysis. This study takes into account of the correlation and interrelationship among quality characteristics to modify the importance and priority of improvements of quality characteristics, aiming to avoid wrong decisions, to improve quality characteristics and rationalize resource allocation.

PROPOSED MODEL

After the IPA literature review this study presents a more reasonable, modified IPA. As to the causation of quality characteristics that have not been analyzed, This research uses DEMATEL to identify the causation and interrelationship between the quality characteristics and adjusts their priority to determine the core problems and avoid the huge losses arising from wrong decisions. The proposed method also improves the quality characteristics and rationalizes resource allocation. The modified IPA and DEMATEL used in this study involve five subjects: (1) determining the gap between the importance and performance of each quality characteristic and estimating organizational performance; (2) multiple regression analysis is used to forge a functional relationship for the performance and overall satisfaction of each quality characteristic. The regression coefficient from this relationship is the estimate of importance for each quality characteristic; (3) implicit importance is shown on Y axis with the performance gap on the X axis of the IPA matrix; (4) DEMATEL is employed for the causation and interrelationship; (5) IPA and DEMATEL are combined for new decisions and improvements.

Modified IPA model: In customer satisfaction, the key is whether customers think what is important is recognized by the organization and the organization produces goods that customers want. Therefore, it is necessary to assess both the customers recognition and satisfaction for the goods and services. A common method for this assessment is the gap analysis developed by Parasuraman *et al.* (1985). Gap analysis is based on the difference between the customers recognition and perception. Traditional IPA lacks clear prioritization of improvements in quality characteristics, which can be complemented by the gap analysis for it can prioritize in a simpler and more reasonable way the improvements and resource allocation of quality characteristics of organizational goods and services (Fontenot *et al.*, 2005).

In researches by Matzler and Sauerwein (2002) and Matzler *et al.* (2004), the IPA model has two types of measurements for the importance of quality characteristics. The first is customers disclose how important they think a given quality characteristic is, called the explicit importance. The second is how important that quality characteristic is for customers using the multiple regression equation, called the implicit importance. With performance as the independent variable and overall satisfaction as the dependent variable in the multiple regression equation, Matzler and Sauerwein (2002) proved that it is the implicit importance, not the customers self presentation that serves as the satisfaction function of a quality characteristic. Therefore, the multiple regression equation is a better measurement of the customers' perception of the quality characteristics. The multiple regression equation with performance as the independent variable and overall satisfaction as the dependent variable is shown below:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + ... + \beta_k X_k \quad (1)$$

In this equation:

Y = Overall satisfaction
X_i = The performance of i of quality characteristics (i = 1, 2,..., k)

In Matzler and Sauerwein (2002) the regression coefficient β_i of the equation stands for the performance influence of the quality characteristic on overall satisfaction. Yet, this regression coefficient β_i in the empirical research is negative, so it is reasonable to make $|\beta_i|$ an estimate of the implicit importance. In the study by Hansen and Bush (1999), IPA was generally acknowledged a simple and effective tool for acquiring the greatest customer satisfaction using efficient allocation of limited resources. Hence, the traditional importance-performance matrix in this study was changed to one with the regression coefficient, not importance, as the Y axis and the gap analysis for quality characteristics, not performance, as the X axis. The modified IPA is shown in Fig. 1. The concentration trend in the form of an average is used to create four quadrants in the importance-performance matrix. The definition and strategy in those four quadrants are the same as those defined by Martilla and James (1977). Therefore, the new matrix is still easily explained and analyzed.

Quality characteristics are usually improved under the supposition that they are independent and can be improved according to IPA matrix shown in Fig. 1. However, when there is causation among the quality characteristics and one improved characteristic will definitely change the other relevant characteristics, quality characteristics with greater influence should be considered first. Knowing how such causation works on decision making and improvements is critical. The two sections below examine decision making and improvements based on a combination of the DEMATEL and IPA results.

Decision making trial and evaluation laboratory: The Decision Making Trial and Evaluation Laboratory (DEMATEL) was developed by Battelle Memorial Institute of the Geneva Research Center (Gabus and Fontela, 1973; Fontela and Gabus, 1976). DEMATEL was used to solve sophisticated problems such as race, famine, environmental protection, energy and others (Fontela and Gabus, 1976). Recently Japan, Korea and Taiwan use it comprehensively in other domains. Hajime *et al.* (2005) integrated QFD, TRIZ and DEMATEL to settle disputes over new product designs. Nanayo and Toshiaki (2002) adopted a modified DEMATEL in an integral evaluation of the medical system. Kenichi and Yoshihiro (2002) introduced DEMATEL into an analysis of the functions and ineffectiveness of a snow melting system. Kim (2006) integrated PCA, AHP and DEMATEL to evaluate the impacts on the livestock industry and agricultural information. Wu and Lee (2007) used Fuzzy DEMATEL to discuss questions about the core capability of a manager. Lin and Wu (2008) applied Fuzzy DEMATEL to group decisions. DEMATEL has been utilized in many circles. DEMATEL aims to present the direct/indirect causation and degree of influence of quality characteristics by comparing their interrelationships in the matrix. The causation and influence on the matrix are shown as a reference when one makes decisions. In other words, DEMATEL can turn a complicated system into clear cause and effect and quantify how one quality characteristic affects another in identifying core problems and improvements. Here is a brief explanation of the DEMATEL framework and arithmetic.

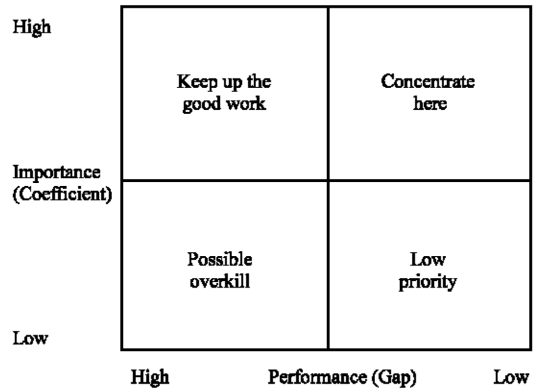

Fig. 1: Modified IPA map

Definition of quality characteristics and creation of scale of measurement: From the literature review brainstorming or specialists comments, this study lists and defines the quality characteristics of a certain complicated system and assumes that n number of quality characteristics exist. Next a scale of measurement for pair-wise comparison between the characteristics and their causation is created.

This scale has four measurement levels from 0, 1, 2, to 3, representing no influence low influence high influence and great influence (Lin and Wu, 2008). The measurement scale has six levels from 0, 1, 2, 3, 4 to 5, representing no influence extremely low influence low influence moderate influence high influence and great influence (Kim, 2006). In Huang *et al.* (2006, 2007) the scale has 11 levels from 0 to 10, representing no influence to great influence. Thus, the scale has no specific limitation or rules.

Direct-relation matrix: If the number of quality characteristics is n, when this study makes pair-wise comparison between the causation and quality characteristic influence, the result will be an n×n direct-relation matrix X, in which x_{ij} stands for how i quality characteristic influences j quality characteristic and quality characteristics x_{ii} at the corner are set to 0.

$$X = \begin{bmatrix} 0 & x_{12} & \cdots & x_{1n} \\ x_{21} & 0 & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{n1} & x_{n2} & \cdots & 0 \end{bmatrix}$$

A sign matrix S is created to show whether the influence is positive or negative, shown as + and -.

Normalized direct-relation matrix: The normalized direct-relation matrix has two types of arithmetic. In the studies of Wu and Lee (2007), Lin and Wu (2008), Kim (2006) and Seyed-Hosseini *et al.* (2006), the normalized standard is row vector and the maximum, whereas Tzeng *et al.* (2007) used the column/row vector and the maximum.
As:

$$\lambda = \frac{1}{\underset{1 \le i \le n}{\mathrm{Max}}\left(\sum_{j=1}^{n} x_{ij}\right)} \quad \text{or} \quad \lambda = \mathrm{Min}\left[\frac{1}{\underset{1 \le i \le n}{\mathrm{Max}}\left(\sum_{j=1}^{n} x_{ij}\right)}, \frac{1}{\underset{1 \le j \le n}{\mathrm{Max}}\left(\sum_{i=1}^{n} x_{ij}\right)}\right] \tag{2}$$

In formulas 2 and 3, when the direct-relation matrix X is multiplied by λ, the normalized direct-relation matrix is N.

$$N = \lambda X \tag{3}$$

Under the DEMATEL supposition, the sum of at least one i row must be in line with formula (4) and Lin and Wu (2008) concluded that nearly all cases can satisfy this formula.

$$\sum_{j=1}^{n} x_{ij} < \frac{1}{\lambda} \tag{4}$$

Hence, this study derives a sub-stochastic matrix from the normalized direct-relation matrix N and an absorbing-state Markov chain matrix. According to Papoulis and Pillai (2002):

$$\lim_{k\to\infty} N^k = O \text{ and } \lim_{k\to\infty}\left(I + N + N^2 + \cdots + N^k\right) = (I - N)^{-1} \tag{5}$$

In this, O is the null matrix and I is the identity matrix.

Direct/indirect relation matrix: Since the normalized direct-relation matrix N contains properties of formula (5), indirect/direct-relation matrix, or total-relation matrix, can be derived from formula (6) (Huang *et al.*, 2007). Further, the indirect relation matrix H, or total-indirect-relation matrix, can be derived from formula (7) (Lin and Wu, 2008).

$$T = \lim_{k\to\infty}\left(N + N^2 + \cdots + N^k\right) = N(I - N)^{-1} \tag{6}$$

$$H = \lim_{k\to\infty}\left(N^2 + N^3 + \cdots + N^k\right) = N^2(I - N)^{-1} \tag{7}$$

Suppose that t_{ij} is the quality characteristic for the total-relation matrix T and i, j = 1, 2,..., n, then formulas 8 and 9 can be used to determine the sum of values in the row and column of the total-relation matrix T. Also, D_i is the sum of i row, which means quality characteristic i can affect the sum of other quality characteristics; R_j is the sum of j row, which means quality characteristic i is affected by the sum of other quality characteristics. D_i and R_j of the total-relation matrix T include direct/indirect influences.

$$D_i = \sum_{j=1}^{n} t_{ij} \quad (i = 1, 2, \cdots, n) \tag{8}$$

$$R_j = \sum_{i=1}^{n} t_{ij} \quad (j = 1, 2, \cdots, n) \tag{9}$$

Causal diagram: when $D_k + R_k$ is prominent and k = i = j = 1, 2,..., n, this shows how the quality characteristic is influenced by or affects others and how prominent quality characteristic k is in all problems. When D_k-R_k is the relation, this shows the variation in the quality characteristic being influenced by or affecting others and whether quality characteristic k is more like a cause or a result. If the result is positive, the quality characteristic is more like a cause, otherwise it is a result. This causal diagram has (D + R) as x axis and (D - R) as y axis. This diagram is equal to 2D diagram of sing matrix s. With a causation diagram and the position of a quality characteristic, a decision maker can know if a quality characteristic is a cause or a result and how it is affected or affects others. According to the result, the decision maker can make plans to solve his/her problems.

This study determines the coordinate value ($D_k + R_k$, D_k-R_k) of each quality characteristic and marks the value on the causal diagram. When D_k-R_k is positive, quality characteristic k is a cause; when D_k-R_k is negative, quality characteristic k is a result. When the sum of $D_k + R_k$ is bigger, a quality characteristic affects or is affected by others more greatly. According to the causal diagram, when D_k-R_k is negative and $D_k + R_k$ is of small value, quality characteristic k is more independent, which means that k is influenced by only a few factors. When D_k-R_k is positive and $D_k + R_k$ has a small value, quality characteristic k is also independent, which means that k influences only a few quality characteristics. When D_k-R_k is positive and $D_k + R_k$ has a large value, quality characteristic k is a cause of a core problem and should be solved first. Therefore, the decision maker can know if a quality characteristic is a cause or a result and how it is affected or affects others by the causal diagram and make plans to solve his/her problems.

Combination of IPA and DEMATEL: Traditionally people use the IPA matrix in Fig. 1 to discern quality characteristics that should be improved one at a time. Yet, if causation lies among several quality characteristics, i.e., one quality characteristic can influence others, quality characteristics with great influence should be addressed first. To know the causation pattern of quality characteristics, it is good idea to use a 2D causal diagram charted in accordance with the DEMATEL result and with four quadrants that are demarcated by the average of each axis. Quadrant 1 has high prominence and high relation, showing the quality characteristics in this area are core problems and affect others. They should be addressed first. Quadrant 2 has low prominence and high relation, showing the quality characteristics in this area are highly independent and affect only a few quality characteristics. Quadrant 3 has low prominence and low relation, showing the quality characteristics in this area are highly independent and affected by only a few quality characteristics. Quadrant 4 has high prominence and low relation, showing the quality characteristics in this area are core problems and affected only by other quality characteristics. In all, the quality characteristics in quadrants 1, 2 and 4 of the causal diagram can sway the IPA matrix result. Quadrant 3 with low prominence and low relation already fulfills the IPA model supposition, so the quality characteristics in this area can be improved according to IPA strategies. The combination of IPA and DEMATEL has two categories and four policies, shown below:

Quality characteristic with high prominence and relation:

- If quality characteristics are in the keep up the good work quadrant and other positively influential quality characteristics are in concentrate here and low priority, these quality characteristics should be maintained in order to keep their advantages and enhance the performance of other quality characteristics. However, if the affected quality characteristics are in the possible overkill quadrant, their influences and countermeasures should be taken into account.
- If quality characteristics are in the Concentrate here quadrant and other positively influential quality characteristics are in keep up the good work and low priority, these quality characteristics should be improved immediately in order to increase their advantages and enhance the performance of other quality characteristics. However, if affected quality characteristics are in the possible overkill quadrant, their influences and countermeasures should be taken into account.
- If quality characteristics are in the low priority quadrant and other positively influential quality characteristics are in concentrate here, these quality characteristics should be improved immediately in order to increase their advantages and enhance the performance of other quality characteristics. However, if affected quality characteristics are in the possible overkill or keep up the good work quadrant, their influences and necessity for improvements should be taken into account.
- If quality characteristics are in the possible overkill quadrant, their influences and necessity for improvements should be taken into account no matter which quadrant other affected quality characteristics are in.

Quality characteristic with high prominence and low relation:

- If quality characteristics are in the keep up the good work quadrant and other positively influential quality characteristics are in concentrate here, these influential quality characteristics should be improved immediately in order to increase their advantages and enhance the performance.
- If quality characteristics are in the concentrate here quadrant and other positively influential quality characteristics are in keep up the good work and low priority, these quality characteristics should be improved immediately in order to increase their

advantages and enhance the performance of other quality characteristics. However, if the quality characteristics are in the possible overkill quadrant, their influences and countermeasures should be taken into account.

- If quality characteristics are in the low priority quadrant and other positively affected quality characteristics are in concentrate here, these quality characteristics should be improved immediately. However, if influential quality characteristics are in the possible overkill or keep up the good work quadrant, their influences and the necessity for improvements should be taken into account.
- If quality characteristics are in the possible overkill quadrant and other positively affected quality characteristics are in concentrate here, these influential quality characteristics should be improved immediately. The necessity for improvements in the rest of the influential quality characteristics should be evaluated.

In accordance with its management and analysis an organization can lower down influence to a certain extent below which all quality characteristics are not influential, i.e., of no causation. This is in favor of simpler management, analysis and decision.

RESULTS AND DISCUSSION

The research subjects of this study are Taiwanese computer companies. IPA and DEMATEL were used to analyze the order-winner criteria to improve customer satisfaction. The case here is a large 24-old Taiwanese computer company with 500 employees in 2008, 20% of the market share and ISO 9001 Quality Management System and ISO 14001 Environmental Management System accreditations. Its business has steadily expanded. This study applies the order-winner criteria to a questionnaire for collecting satisfaction information about the customer base of this company. The answers were analyzed by IPA and DEMATEL to define the core problems and countermeasures, making the company more competitive.

Creation of IPA and DEMATEL questionnaire and survey: In 2007 this study undertook a survey of order-winner criteria for industrial computer satisfaction. A scalogram with 9 satisfaction degrees by Slack (1994) was used as the IPA questionnaire. To really know customers perception of goods to understand this company's performance, this study put a satisfaction scale on each question and each scale was marked with 1-very unsatisfied to 9-very satisfied. In addition, the questionnaire is also designed with questions aiming to realize what customers value at and how they see the question. The scale for each question was marked with 1-very unimportant to 9-very important. This questionnaire has 14 order-winner criteria by Hill (2000) as quality characteristics and was approved its effectiveness by 20 customers and 15 senior officials. According to Griffin and Hauser (1993), interviews with 20-30 customers can help define 90-95% of the quality characteristics in homogeneous markets. Further, the last question asks customers to rank overall satisfaction at the company, with marks from 0 to 100. The customers surveyed are those who completed transactions. One hundred fifty six questionnaires were mailed to the executives of customer purchasing departments. Ninety-three effective questionnaires were collected, reaching a recovery rate of 59.61%.

Fourteen order-winner criteria by Hill (2000) were taken as the draft DEMATEL questionnaire, which, with comments from 15 senior officials, was developed into a sign and direct-relation matrix with 14 order-winner criteria. + shows a positive relation and - shows a negative relation between two order-winner criteria. The measurement scale for the direct-relation matrix is a scalogram with 11 degrees by Huang *et al.* (2006, 2007), ranging from 0 as no influence to 10 as great influence. The analysis software used for this study is SPSS R14 and EXCEL 2003. The company hopes to create an importance-satisfaction matrix based on questionnaire and a modified IPA and to know the direct/indirect relations among order-winner criteria by DEMATEL.

Analysis results: This study performed multiple regression analysis of the overall satisfaction using the order-winner criteria performance. In Table 1, the prominent (p-value<0.05) overall satisfaction values are price (OW1), delivery speed (OW3), quality conformance (OW4) and being an existing supplier (OW10). The absolute regression coefficient is the relative importance of the order-winner criteria. According to the modified IPA, the gap in prominent importance and performance is the X-axis and the absolute implicit importance and regression coefficient is Y-axis. This importance-performance matrix can demarcate order-winner criteria into four types, on which corporal manufacturing and market strategies are based. Table 2 shows figures derived from the modified IPA. In addition to the importance of regression coefficient and the gap analysis performance, Table 2 also shows the priority of improvements in the order-winner criteria with the gap as the first sequence standard and importance as the secondary standard.

Table 1: Multiple regression coefficients of performance and overall satisfaction

	Un-standardized coefficients			
Model (Order-Winner Criteria)	B	Std. error	t	Sig.
(Constant)	12.6506	5.5737	2.2697	0.0260*
Price (OW1)	1.7895	0.6455	2.7724	0.0070**
Delivery reliability (OW2)	-0.0878	1.0389	-0.0845	0.9329
Delivery speed (OW3)	2.2730	0.8732	2.6030	0.0111*
Quality conformance (OW4)	2.7788	0.8441	3.2920	0.0015**
Demand increases (OW5)	-0.6164	0.5042	-1.2224	0.2252
Product range (OW6)	0.3922	0.4943	0.7933	0.4300
Design (OW7)	-0.6186	0.7603	-0.8137	0.4183
Distribution (OW8)	0.5273	0.7633	0.6908	0.4917
Design leadership (OW9)	0.5358	0.5634	0.9511	0.3445
Being an existing supplier (OW10)	1.0767	0.5116	2.1045	0.0386*
Marketing and sales (OW11)	0.5421	0.7184	0.7547	0.4527
Brand name (OW12)	0.4383	0.5115	0.8569	0.3941
Technical liaison and support (OW13)	0.6705	0.6692	1.0020	0.3194
After-Sales support (OW14)	-0.3468	0.6355	-0.5457	0.5868

Adjusted R^2: 0.7923; *p-value<0.05; **p-value<0.01

Table 2: Modified IPA analysis table

Notation	Order-Winner Criteria	Importance (Implicit)	Gap	Strategy	Priority (Gap)
OW1	Price	1.7895	0.4839	C	2
OW2	Delivery reliability	0.0878	0.3548	L	4
OW3	Delivery speed	2.2730	0.1828	K	10
OW4	Quality conformance	2.7788	0.6667	C	1
OW5	Demand increases	0.6164	0.1935	P	9
OW6	Product range	0.3922	0.0108	P	13
OW7	Design	0.6186	0.3226	L	6
OW8	Distribution	0.5273	0.2258	P	8
OW9	Design leadership	0.5358	0.0000	P	14
OW10	Being an existing supplier	1.0767	0.1398	K	12
OW11	Marketing and sales	0.5421	0.1828	P	11
OW12	Brand name	0.4383	0.3548	L	3
OW13	Technical liaison and support	0.6705	0.2581	P	7
OW14	After-Sales support	0.3468	0.3226	L	5

C = Concentrate here; K = Keep up the good work; L = Low priority; P = Possible overkill

Figure 2 is an importance-performance matrix made by the absolute regression coefficient and gap analysis. According to Fig. 2, order-winner criteria in the concentrate here should be improved immediately and the sequence of this improvement is quality conformance (OW4) and Price (OW1). Order-winner criteria in keep up the good work are Delivery speed (OW3) and being an existing supplier (OW10); Order-winner criteria in Possible overkill are Technical liaison and support (OW13), Distribution (OW8), Demand increases (OW5), Marketing and sales (OW11), Product range (OW6) and Design leadership (OW9). Quality characteristics in Low priority are Brand name (OW12), Delivery reliability (OW2), After-Sales support (OW14) and Design (OW7).

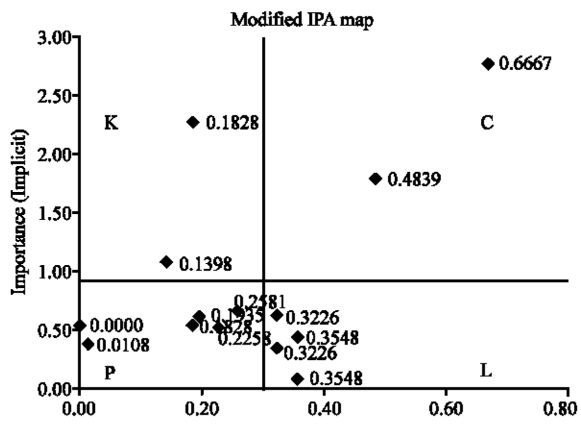

Fig. 2: Modified importance-performance matrix of Order-Winner Criteria

With DEMATEL, this study analyzes the order-winner criteria to know their causation. A direct/indirect relation matrix can be derived from formula (6); D_i, row value and R_i, column value, as well as prominence ($D_i + R_i$) and relation (D_i-R_i) can be derived from formulas 8 and 9. They are shown in Table 3.

The sum of prominence ($D_i + R_i$) and relation ($D_i - R_i$) divided by the 14 order-winner criteria is the average, which is also the estimate of the concentration trend of the causal matrix. This estimate can demarcate the causal diagram into four quadrants, shown in Fig. 3. According to Fig. 3, high prominence and high relation of these

Table 3: Coefficient table of prominence and relation of order-winner criteria

Notation	Order-Winner Criteria	D	R	D + R	D - R
OW1	Price	0.1250	1.3529	1.4779	-1.2279
OW2	Delivery reliability	0.2283	0.3113	0.5397	-0.0830
OW3	Delivery speed	1.0445	0.5914	1.6360	0.4531
OW4	Quality conformance	1.2723	0.8176	2.0900	0.4547
OW5	Demand increases	0.4795	0.0000	0.4795	0.4795
OW6	Product range	0.2000	0.3750	0.5750	-0.1750
OW7	Design	1.4045	0.0000	1.4045	1.4045
OW8	Distribution	0.2282	0.0000	0.2282	0.2282
OW9	Design leadership	1.0249	0.2000	1.2249	0.8249
OW10	Being an existing supplier	0.0000	1.2095	1.2095	-1.2095
OW11	Marketing and sales	0.0000	1.2403	1.2403	-1.2403
OW12	Brand name	0.2531	0.6181	0.8712	-0.3650
OW13	Technical liaison and support	0.1986	0.0550	0.2536	0.1436
OW14	After-Sales support	0.3122	0.0000	0.3122	0.3122

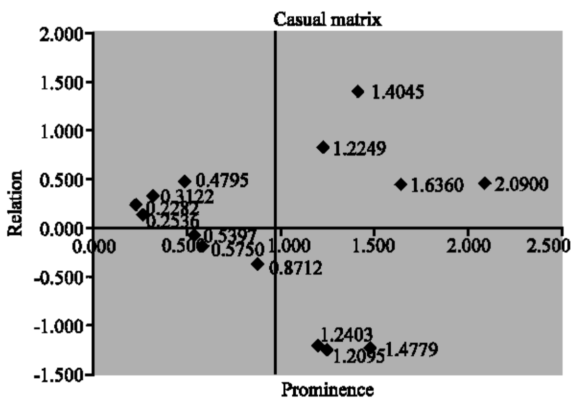

Fig. 3: Causal matrix of Order-Winner Criteria

order-winner criteria respectively are quality conformance (OW4), delivery speed (OW3), design (OW7) and design leadership (OW9); they can affect others. High prominence and low relation respectively are price (OW1), Marketing and sales (OW11) and Being an existing supplier (OW10); they will be affected others. As to other characteristics of order-winner criteria, they are independent for their prominence is below the average of 0.9673 and therefore they barely affect others.

Due to the complicated relations in the order-winner criteria, those with influence degree below 0.1 cannot affect or be affected by others. Further, a sign matrix can be used to simplify the causal diagram. In Fig. 4, + means positive influence (greater quality performance, higher the price); - means negative influence (higher price, less likely being an existing supplier). The arrow means influence direction: the arrow is the result and the other end is the cause. Additionally, those with a brim means they have high prominence and are different from others.

Decision: According to the IPA importance-performance matrix in Table 2 and Fig. 2 that is modified by regression coefficient and gap analysis, order-winner criteria in Concentrate here that must be improved immediately are quality performance (OW4) and price (OW1); order-winner criteria in low priority that must be improved in order are brand name (OW12), delivery reliability (OW2), after-sales support (OW14) and design (OW7). Roughly speaking, it is reasonable to make decisions in accordance with each gap and importance. An organization usually will make countermeasures accordingly, only when order-winner criteria are independent of one another. Yet, when the order-winner criteria is causal, decisions cannot reach their goal regardless how many resources are committed because these decisions are under a premise that the order-winner criteria are independent of one another. This study explains the combination of IPA and DEMATEL by improving quality performance (OW4) and Price (OW1) in Concentrate here quadrant.

According to Fig. 3 and Table 3, quality performance (OW4) is the order-winner criteria of high prominence and high relation. So what is the result when quality performance (OW4) is improved? First of all, a uses the quality performance tree (OW4) created in (Fig. 5). According to Fig. 4 and 5, improved quality performance (OW4) can also increase Price (OW1, coefficient of 0.3056) and marketing and sales (OW11, coefficient of 0.1710), decrease delivery speed (OW3, coefficient of 0.1865), enhance brand name (OW12, coefficient of 0.1807) and increase the opportunities of being an existing supplier (OW10, coefficient of 0.3183). Usually, improved quality means more quality costs. Further, when quality beats that of competitors, an organization often raises the price. However, Price (OW1) is also in the concentrate here quadrant, so if improved quality means unimproved Price (OW1) or Price (OW1) is beyond customers capacity, this will cause negative effects. Improved quality performance (OW4) leads to better Marketing and sales (OW11), excess resources and waste, since marketing and sales (OW11) is in possible overkill quadrant that means customers do not think the factors are very important, it is unnecessary to pour more resource to enhance performance. Better quality performance (OW4) leads to

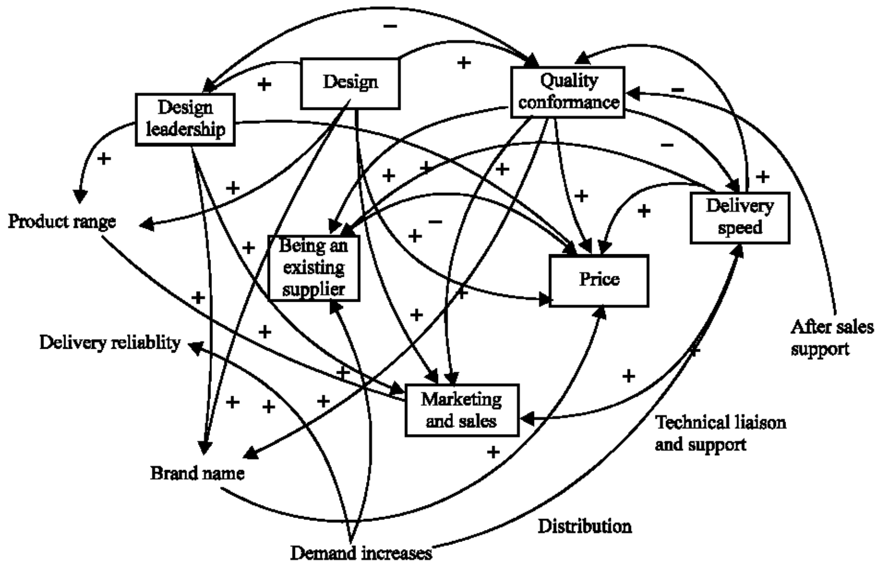

Fig. 4: Causal diagram of the order-winner criteria

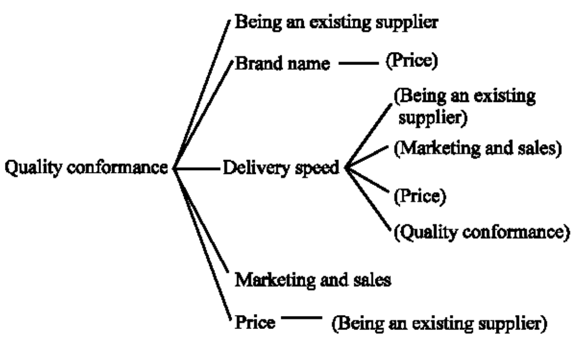

Fig. 5: Uses tree of quality conformance (OW4)

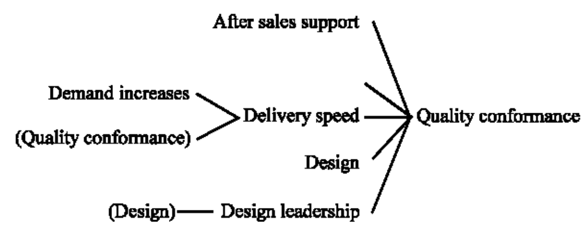

Fig. 6: Causes tree of quality conformance (OW4)

worse delivery speed (OW3) and poor competitiveness, since delivery speed (OW3) is in keep up the good work quadrant, better quality performance (OW4) will bring something good to brand name (OW12) and also indirectly increases price (OW1). Nevertheless, better quality performance (OW4) is prominent to the being an existing supplier (OW10) and will not affect other order-winner criteria. Overall, improving quality performance (OW4) cannot benefit an organization as expected.

According to the above situation, to improve quality performance (OW4) is to find order-winner criteria that affect it, so the causes tree (Fig. 6) should be created for the sake of analysis. According to Fig. 4 and 6, the order-winner criteria of quality performance (OW4) are design leadership (OW9, coefficient of 0.1826), design (OW7, coefficient of 0.1417), delivery speed (OW3, coefficient of 0.1807) and after-sales support (OW14, coefficient of 0.1291); design (OW7) and after-sales support (OW14) are in low priority quadrant; Design leadership (OW9) is in possible overkill quadrant; delivery speed (OW3) is in keep up the good work quadrant. Next step is to find order-winner criteria that improve quality performance (OW4) and will not influence on or lower down price (OW1). Thus, it is necessary to pour fewer resources for design leadership (OW9) in order to reduce the production cost, because customers think design leadership (OW9) is unimportant and that the organization's performance is overwhelming. Regression coefficient and IPA matrix can prove this situation. Meanwhile, according to Fig. 4, pouring fewer resources for design leadership (OW9) can enhance quality performance (OW4). This is because the corporate market strategy is design leadership (OW9) and the company's design does not take the crushing lead, plus a number of prototype-like products, so quality performance (OW4) is deteriorating. Judging from the survey, design leadership (OW9) does only somewhat good for customers, so it is necessary to pour fewer resources for design leadership (OW9) in order to enhance quality performance (OW4). Next to come is to better services of after-sales support (OW14). After-sales support (OW14) should be improved partly because customers find inferior performance but better after-sales support (OW14), according to Fig. 4, can enhance quality performance (OW4) and will not interfere with higher Price (OW1).

In the end, this study discusses the reaction chain and negative effects of improved design leadership (OW9) and after-sales support (OW14). According to Fig. 4, fewer resources for design leadership (OW9) will directly/indirectly lower price (OW1). The influence coefficient of such direct influence is 0.2078. As for indirect influence, poor brand name (OW12, coefficient of 0.1570) will lead to lower price (OW1, coefficient of 0.2250). Improved design leadership (OW9) will narrow the product range (OW6, coefficient of 0.1250) and deteriorate marketing and sales (OW11, coefficient of 0.2053). Yet, that product range (OW6) and marketing and sales (OW11) are in possible overkill quadrant means fewer resources for them and consequential lower costs. What is important is that although fewer resources for design leadership (OW9) will lead to poor brand name (OW12) with the influence coefficient of 0.1570, since better quality performance (OW4) can make brand name (OW12) more visible (the influence coefficient is 0.1807), so this improvement will cause negative effects. Likewise, after-sales support (OW14), according to DEMATEL, is independent, so only quality performance (OW4) can affect order-winner criteria and this improvement will incur negative effects.

In view of analyses of and discussion on quality performance (OW4) and Price (OW1), when a modified IPA is used to improve quality performance (OW4) and price (OW1), decisions will be correct only if the order-winner criteria are independent of one another. However, when the order-winner criteria are causal, decisions must be made in accordance with their causation. By combining IPA and DEMATEL, this study pinpoints design leadership (OW9) and after-sales support (OW14) are to be addressed and fixes the dilemma of quality performance (OW4) and Price (OW1) that higher performance (OW4) will be followed by higher Price (OW1).

CONCLUSION

Traditionally, the information about customer satisfaction is acquired using questionnaires and scales of measurement. After determining the average importance and performance of quality characteristics, an importance-performance matrix is created to know what quality characteristics should be scaled down, improved, or maintained to preserve the organization's competitiveness. Traditional IPA and subsequent researches contribute much to this analysis, but this analysis has potential problems to be further discussed and studied: (1) explicit importance is not taken into account in influence of performance and overall satisfaction with the quality characteristics; (2) implicit importance does not involve the performance gap analysis; (3) when quality characteristics are interrelated, the traditional hypothesis that the quality characteristics are independent will lead to wrong policies. With gap analysis and multiple regression analysis, this study created a modified IPA model with the importance and performance of quality characteristics. With DEMATEL this study presented a more reasonable importance-performance analysis. For corporate performance analysis, the gap analysis of importance and performance replaces the traditional explicit performance. The bigger the gap is, the higher the improvement priority. Multiple regression analysis is used to establish the implicit importance of the relations between performance and overall satisfaction in the quality characteristics and derives the factors for overall satisfaction. The absolute regression coefficient is implicit importance, so the bigger the absolute is, the greater the importance a quality characteristic has. This study used the gap analysis and implicit importance as the coordinate axis of the importance-satisfaction matrix. DEMATEL was applied to find the causation for the quality characteristics to create a causal diagram for the quality characteristics, in which IPA and DEMATEL were employed to identify the core problems and countermeasures.

This study presented a modified IPA model combined with DEMATEL methodology. This new method solves the potential problems arising in the traditional model and clears up the practically complicated, contradictory problems. This method helps define the quality characteristics to be improved and how they should be fixed with the least resources. By analyzing and discussing the industrial computer company in Taiwan, this study verified the modified IPA model composed of gap analysis and multiple regression combined with DEMATEL. A more reasonable importance and performance method that allows the least resources for solving causal sophisticated quality characteristic problems. This new methodology makes use of customer responses and effectively provides the decision maker with correct useful information.

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