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A NOVEL DECISION APPROACH: INTUITIONISTIC FUZZY IMPORTANCE PERFORMANCE ANALYSIS

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Abstract:
Importance performance analysis (IPA) is a technique used for conducting a relative-position comparison of specific evaluation items by using “importance” (the degree of importance as perceived by customers) and “performance” (the degree of customer satisfaction regarding the performance of an enterprise). Moreover, it is an approach for incorporating the voice of the customer into product development and the evaluation of management performance. Because of numerous factors of uncertainty and linguistic vagueness during the information collection process for product design, the traditional IPA is not appropriate for conducting performance analysis. Therefore, this study proposes a novel intuitionistic fuzzy sets (IFSs) IPA performance evaluation model. In addition, analytical network processing was combined with the model and benchmarking enterprise competitiveness was considered. This model can solve the ambiguity and decision-making problems that currently exist in questionnaires. Thus, it directs the focus on the objective features emphasized by customers, and provides enterprises with a practical evaluation model for relative product design or decision evaluation.

Keywords: intuitionistic fuzzy sets, importance performance analysis, analytical network process, decision analysis

1. INTRODUCTION

The IPA is an analytic tool used for analyzing consumers' emphasis on quality attributes and their evaluation of enterprise performance level; subsequently, it can also be used to prioritize the importance degree of attributes and its correlation with performance levels (Sampson and Showalter (1999), Hansen and Bush (1999), Chu and Choi (2000)). The analysis results can be provided to enterprises for the evaluation of attribute performance, and can be used as a reference for the future operation and development of an enterprise and the improvement of the current status of customer relations.

The IPA was first proposed by Martilla and James (1977), who used the IPA to analyze product attributes in the automobile industry. The primary concept was to compute the mean values of the importance degree and performance level in a two-dimensional matrix, which was adopted to identify the relative positions of attributes possessing various mean values. Martilla and James (1977) subsequently suggested practical recommendations and strategic applications for specific quality attributes. However, Hollenhorst et al. (1992) observed that the analysis results produced by Martilla and James (1977), who used the median of the two-dimensional matrix to evaluate enterprise service attributes, did not correspond to the actual situation. Thus, Hollenhorst et al. (1992) proposed using the overall means of the importance degree and performance level as the dividing points for the axes of the IPA two-dimensional matrix. Therefore, the distribution of the quality attributes in the matrix featured high determination ability. For enterprise managers, analyzing market competition is necessary for enterprises to obtain competitive advantage. By adopting customer evaluation scores of enterprise performance levels as the basis for the comparison between the case enterprise and the optimal competitor, and by employing the performance ratio (PR) analysis method, an understanding of the gap between the market competitiveness of two enterprises and their positions in the market can be achieved. This study proposes a modified IPA model, which was incorporated with the concept of enterprise benchmarking and combined with the PR concept proposed by Garver (2003). Furthermore, the analysis method of PR was adopted to calculate the market competitiveness gap between two enterprises, and the calculation results were used to replace the *y*-axis in the traditional IPA diagram (satisfaction degree). The standardized measurement was expected not only to effectively avoid the drawbacks of traditional IPA assumptions, but also to be used in the quantitative competitiveness analysis of the case enterprise and its outstanding competitors.

The meanings of the four IPA quadrants are as follows (Martilla and James (1977), Zhang and Chow (2004)): (a) *Quadrant I (Keep Up the Good Work):* This area is emphasized by the customers and currently perceived by the consumers as exhibiting a satisfactory performance level; thus, it is the primary source of enterprise competitive advantage, which enterprises should endeavor to maintain. (b) *Quadrant II (Possible Overkill):* This area exhibits a superior performance level, which is not focused on by the customers but is currently perceived by the consumers. This is the second source of enterprise advantage; the enterprise should not overly invest resources in this area. (c) *Quadrant III (Low Priority):* This area is not emphasized by customers and perceived by consumers as featuring a low performance level. This is the second source of enterprise disadvantage, which must be improved after Quadrant IV has been improved. (4) *Quadrant IV (Concentrate Here):* Customers pay attention to this area, but the performance perceived by consumers does not achieve the expected level. Attributes located in Quadrant IV are the key factors determining the future development of enterprises. Therefore, an enterprise must invest more resources to improve this area, which is the primary source of enterprise disadvantage, also called "Critical Quality Attributes.

To fulfill an optimal alternative, reaching a consensus through expert group decision-making is vital. In this study, one of the aims was to understand the problem of expressing uncertainties, namely, "agree," "disagree," and "neutral," during the decision-making process. Although Deng (2008) and Wang and Tseng (2011) have proposed applying the integration of fuzzy theory and IPA to the performance evaluation of various service attributes. However, compared with fuzzy theory, IFSs theory exhibits a superior capacity for conforming to the logical thinking of people in the form of linguistic expression. Scholars have not applied IFSs to IPA. Therefore, this study constructed an IFSs-IPA model that was applied to the design of green products.

2. BACKGROUND THEORIES

2.1 Intuitionistic fuzzy sets (IFSs)

Zadeh (1965) proposed fuzzy theory as a solution for the subjective consciousness and uncertainty that exist in the thinking modes of people. Fuzzy sets were adopted to describe objects, and fuzzy linguistic variables were quantified into values through the membership function to denote the degree of membership between “agree” and “disagree.” However, the “neutral” state was excluded. Thus, the IFSs theory proposed Atanassov (1986) developed a method for solving the problem of neutrality. The values used for representing the degree of membership in the traditional fuzzy theory was changed to ratios, which can express not only “agree” and “disagree” but also “neutral.” In other words, the linguistic expression derived from the IFSs can accord with the logical thinking of people.

According to Atanassov (1986) and Gau and Buehrer (1993), the definition of IFSs is as follows:
Definition 1: Let *X* be a universe, then the IFSs *A* in *X* is presented as $A=\{x,\langle\mu_A(x),v_A(x)\rangle|x\in X\}$, where $\mu_A(x):X\rightarrow[0,1]$ denotes the membership of ”agree”, and $v_A(x):X\rightarrow[0,1]$ denotes the membership of “disagree.” Because $\mu_A(x)+v_A(x)\le 1$, $1-\mu_A(x)-v_A(x)$ signifies the membership of “neutral”. For example, if $A=\{x,\langle 0.6,0.3\rangle|x\in X\}$ is explained using election poll ratings, then 60% of the people support something, 30% of the people oppose something, and 10% of the people are neutral.
Definition 2: $A=\{x,\langle\mu_A(x),v_A(x)\rangle|x\in X\}$ and $B=\{x,\langle\mu_B(x),v_B(x)\rangle|x\in X\}$ are IFSs in *X*. The addition and multiplication formulas for sets *A* and *B* are as follows:

$$A+B=\{x,(\mu_A(x)+\mu_B(x)-\mu_A(x)\cdot\mu_B(x),v_A(x)\cdot v_B(x))\} \quad (1)$$

$$A\times B=\{x,(\mu_A(x)\cdot\mu_B(x),v_A(x)+v_B(x)-v_A(x)\cdot v_B(x))\} \quad (2)$$

2.2 Analytical network process (ANP)

The ANP was proposed by Saaty (1996) to solve the problem of possible interdependence among aspects or criteria and the feedback effect, which exists in the framework of the traditional analytic hierarchy process (AHP). In the traditional analysis of AHP, a hierarchy attribute is assumed to be mutually independent of other hierarchy attributes and possible alternatives. Thus, the decision-making problems only feature hierarchical relationships. However, in an actual decision-making environment, numerous decision problems cannot be constructed based simply on hierarchical relationships, because the problems may involve the interaction relationships among the AS in the same hierarchy or the effect of interdependence among various hierarchies. Moreover, Meade and Presley (2002) and Saaty (2006) contended that the subordinate relationships between hierarchies are difficult to clearly identify in some problem structures. A hierarchy may simultaneously dominate and be dominated by other hierarchies, which is the feedback effect problem. In other words, hierarchical structures that feature a top-down linear pattern cannot effectively solve complex decision problems. The development of ANPs involved the adoption of the network process concept to improve the limitation of independence derived from the hierarchical structure.

To solve the interdependency relationships among the elements in a problem structure, a supermatrix was adopted in the ANP method to calculate the relative weight of each element. The supermatrix comprises numerous submatrices, in which a blank space or 0 denotes the independence among the groups or criteria. A major advantage of ANP is that it can be used to evaluate the inner and outer interdependence of criteria. Outer interdependence refers to the relationships in which the groups are mutually influenced, and inner interdependence refers to the interdependency relationships between each criteria in the same group. A supermatrix consists of several submatrices, which comprise eigenvectors produced by the mutual comparison between each criteria. The variable *M′* denotes the unweighted elementary matrix. The column values may not correspond to the column-stochastic principle (for example, the sum of column values is not equal to 1) and thus need to be converted using a specific procedure to obtain the weighted supermatrix *M*. Through the conversion procedure and the process of limiting, *M* and *M′* were multiplied to the power of 2*k*+1 (*k* was decided subjectively); subsequently, a converged limit value was obtained. The limit value was fixed and was the relative weight among the elements (Saaty, 1996).

Wei (2008) combined fuzzy Delphi with ANP and applied them to the green design of products to ensure that the development of new products enabled the continuous growth of company operation. Furthermore, Lu and Lin (2010) contended that establishing an optimal evaluation alternative for environmental strategic orientations for green innovation is a crucial step for enterprises' development of green innovation in the current stage. Thus, Lu and Lin 11 integrated the decision making trial and evaluation laboratory (DEMATEL) method with ANP to obtain crucial influencing factors and weights for the green environmental strategic orientations, which enterprises can reference when developing green innovation strategies.

3. RESEARCH METHOD

In this study, an IFSs-IPA model was constructed considering complex human thinking and behavior modes and the ambiguity of people's preferences. The evaluation scores provided by experts for each aspects (AS) and criteria (C) were converted to the intuitionistic fuzzy interval values; the score standard was based on the intuitionistic fuzzy linguistic conversion scale developed by Li (2011); in the scale, μ denotes "agree," and v denotes "disagree." (Atanassov, 1986) The intuitionistic fuzzy linguistic scale is displayed in Table 1.

Table 1: The intuitionistic fuzzy linguistic conversion scale

Linguistic variables	Very important	Important	Neutral	Slightly important	Not important at all
$\mathrm{IFS}(\mu,\nu)$	(0.95, 0.05)	(0.70, 0.25)	(0.50, 0.40)	(0.25, 0.70)	(0.05, 0.95)

In this study, the modified IPA evaluation model was adopted. Based on the concept of IFSs, the overall means of the importance degree and performance level were used as the dividing points to divide the two-dimensional matrix into four quadrants. In addition, the voices of the customers and experts were collected based on the concept of IFSs; the ANP expert questionnaire was produced by using IFSs as proposed by Atanassov (1986). The experts in the decision-making group were asked to determine the relative importance degrees among C. Subsequently, the relative weights for the customer requirements for products were calculated and displayed on the *x*-axis. The customer-provided evaluation scores for the enterprise performance level were adopted as the baseline for the case enterprise to compare with the optimal competitor; the market competitiveness gap between the two enterprises was calculated using PR and subsequently displayed on the *y*-axis. The four quadrants were employed as the analysis tool for measuring the customer-perceived importance and satisfaction degree regarding the quality attributes of green product innovation. The four quadrants can also be referenced by enterprises to improve service quality and decide marketing strategies. The operation procedure used in this study is as follows:

Step 1: The development of AS for the goal hierarchy in green product innovation. The decision goal was first confirmed. Relevant information regarding green innovation was collected by conducting a literature review and gathering expert opinions. The evaluation aspect (AS_i) and criteria (C_{ij}) were extracted, where *i* =1, …,*m* and *j* =1, …,*n*.

Step 2: The performance degree (*S*) and PR exhibited by the case enterprise and the competitor in the development of AS and C for green product innovation were computed as the *y*-axis in the modified IPA matrix.

Based on the intuitionistic fuzzy linguistic scale in Table 1, the expert group provided performance scores for the AS_i and C_{ij} of green product innovation developed by the case enterprise and the competitor. Referencing the approach adopted by Klir and Yuan (1995), the geometric mean was used to converge the intuitionistic fuzzy scores provided by the expert group into a single intuitionistic fuzzy score, as displayed in Equations (3) and (4). Furthermore, the intuitionistic fuzzy set scores derived from the expert group were converged, the results of which were then defuzzified using the approach adopted by Hung et al. (2008), as shown in Equation (5). Thus, the crisp performance values (*S*) between each AS_i and C_{ij} for the products developed by the case enterprise and the competitor were obtained.

$$\tilde{S}(\mu)_{ij} = \sqrt[\frac{1}{k}]{(S^1(\mu)_{ij} \cdot ... \cdot S^k(\mu)_{ij})}; i = 1,...,m; j = 1,...,n; k = 1,...,c \quad (3)$$

$$\tilde{S}(v)_{ij} = \sqrt[\frac{1}{k}]{(S^1(v)_{ij} \cdot ... \cdot S^k(v)_{ij})}; i = 1,...,m; j = 1,...,n; k = 1,...,c \quad (4)$$

$$S_{ij} = \frac{\mu_{ij}(x)}{\mu_{ij}(x) + v_{ij}(x)}; i = 1,\ldots,m; j = 1,...,n \quad (5)$$

This study adopted the modified IPA model. The customer-provided evaluation scores for the enterprise performance level were adopted as the baseline to compare the case enterprise with the optimal competitor and identify the position of the enterprise in the market. Additionally, the concept of PR can facilitate the understanding of the market competitiveness gap between the two enterprises. Therefore, the PR of the average satisfaction value of every service item of the case enterprise to that of the competitor's was calculated by using Equation (6). The traditional IPA performance value was replaced by the PR value (Y-axis).

$$\text{PR} = \frac{\theta}{\rho} \quad (6)$$

Where θ denotes the average satisfaction value of the service quality provided by the case enterprise. The ρ denotes the average satisfaction value of the service quality provided by the competitor.

Step 3: The importance degree (*I*) of the AS and C for green product innovation was computed as the *x*-axis in the IPA matrix.

Step 3.1: Based on the intuitionistic fuzzy linguistic scale in Table 1, the expert group provided importance degree (*I*) scores for the AS_i and C_{ij} of green product innovation. The obtained scores were defuzzified using the approach provided by Hung et al. (2008), as shown in Equation (5). Subsequently, the crisp values of the relative weights (I_{ij}) for each AS_i and C_{ij} were obtained and normalized using Equation (7) to be the weights (I_{ij}^{normal}).

$$I_{ij}^{normal} = \frac{I_{ij}}{\sum_{i=1}^{m}\sum_{j=1}^{n} I_{ij}}; i = 1,\ldots,m; j = 1,\ldots,n \quad (7)$$

Step 3.2: The normalized weights of the AS_i and C_{ij} for the submatrices, which were obtained in Step 3.1, were integrated to obtain the unweighted supermatrix *M'*. Because the column values in the unweighted supermatrix may not correspond to the column-stochastic principle, *M'* was converted to be a weighted supermatrix *M*. *M* was then multiplied to the power of *k* using Equation (8) to yield a limiting supermatrix *M**, through which the importance degree *I* for the AS_i and C_{ij} of green product innovation were obtained.

$$M^* = \lim_{k \to \infty} M^k; k \in power \quad (8)$$

Subsequently, a pairwise comparison between the matrices for AS_i and C_{ij} was conducted followed by consistency testing. According to Saaty (1980), for matrices of the same hierarchy, the consistency ratio (*CR*) is required for consistency testing, which is the ratio of the consistency index (*CI*) to the random index (*RI*), as shown in Equations (9) and (10). The degree of consistency for matrices is achieved when the CR value is smaller than 0.1.

$$CI = (\lambda_{\max} - n)/(n-1) \quad (9)$$

$$CR = CI/RI \quad (10)$$

where $\lambda_{\max}$ denotes the maximum eigenvalue, and *n* denotes the number of hierarchies for the given matrix.

Step 4: The PR values acquired in Step 2 for the AS_i and C_{ij} of green product innovation were adopted as the vertical axis (the *y*-axis) in the IFSs-IPA model. The values of importance degree (*I*) acquired in Step 3 for the AS_i and C_{ij} of green product innovation were adopted as the horizontal axis (the *x*-axis) in the IFSs-IPA model. The evaluation results of AS_i and C_{ij} were incorporated in the IFSs-IPA performance evaluation matrix. Therefore, The IFSs-PA performance evaluation matrix has been produced.

Step 5: The IFSs-IPA performance evaluation matrix obtained in Step 4 for the development of green product innovation was used in analyses on strengths and weaknesses and evaluation of management implication regarding the strategies of green product innovation. Thus, enterprises can use it as a reference for effective operations. Thus analyses on strengths and weaknesses were conducted.

4. CASE VERIFICATION

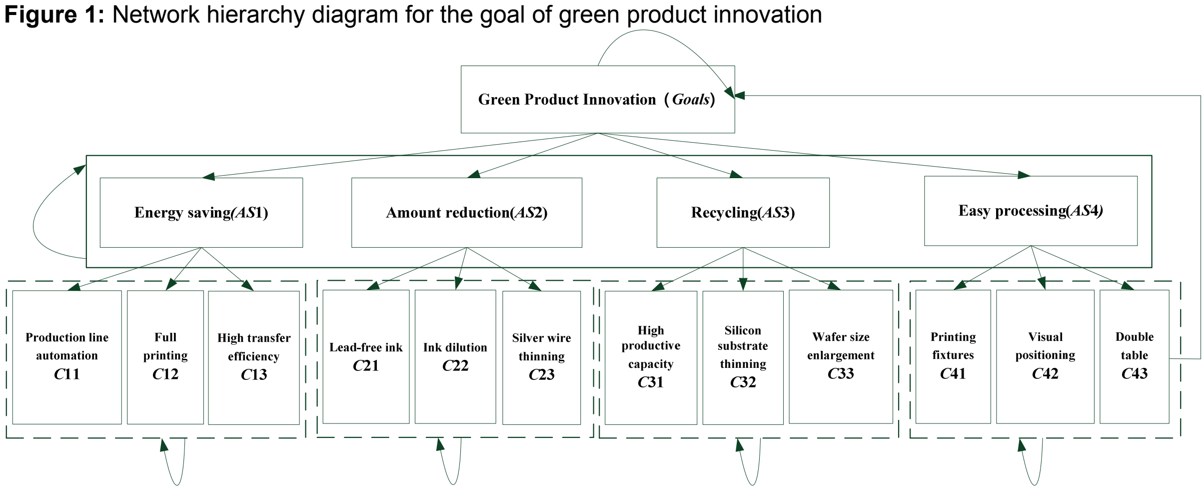
Due the surging popularity of environmental consciousness and the concept of a sustainable earth, green product innovation has become an essential topic for modern enterprise operation and management. In response to the need of technique development regarding the modularization of new-generation fuel cells, the case enterprise implemented green product development and innovation to fulfill the environmental protection requirements of customers. Thus, this study adopted a Taiwanese fuel cell-producing enterprise as the case study example. This enterprise was analyzed by following the five steps stated in Section 3 shown as the following,

Step 1: Four aspects and twelve criteria regarding green innovation requirements were proposed to evaluate the innovative design requirements for the new-generation fuel cell module, as shown in Table 2. The criteria were obtained by interviewing experts. Moreover and the ANP was adopted to construct an evaluation model to investigate the interdependency relationships between the criteria and the alternatives as well as the interdependency relationships among the criteria. The results can be provided as a reference for enterprises in the development of green products. Figure 1 displays the interdependency and feedback relationships among the aspects and criteria.

Table 2: The AS of the requirement hierarchy in green product innovation

Aspect *(*AS)	Criterion (C)		
Energy saving *(AS*1)	Production line automation (*C*11)	Full printing (*C*12)	High transfer efficiency (*C*13)
Amount reduction (*AS*2)	Lead-free ink (*C*21)	Ink dilution (*C*22)	Silver wire thinning (*C*23)
Recycling (*AS*3)	High productive capacity (*C*31)	Silicon substrate thinning (*C*32)	Wafer size enlargement (*C*33)
Easy processing (*AS*4)	Printing fixtures (*C*41)	Visual positioning (*C*42)	Double table (*C*43)

Figure 1: Network hierarchy diagram for the goal of green product innovation



Step 2: Targeting the performance degrees of the goals, AS, and C of green product innovation implemented by the case enterprise and the competitor, the expert group conducted an intuitionistic fuzzy linguistic evaluation. Using Equations (3) and (4), the collected expert-group IFSs scores were converged, the results of which were used in Equation (5) to obtain the crisp performance values. Then using the Equation (6) computes the PR values shown in Table 3.

Table 3: PR values for the implementation of green product innovation AS obtained by the case enterprise and the benchmarking competitor

Items	PR values for the implementation of green product innovation AS															
	Goals	*AS*1	*AS*2	*AS*3	*AS*4	*C*11	*C*12	*C*13	*C*21	*C*22	*C*23	*C*31	*C*32	*C*33	*C*41	*C*42	*C*43
Case enterprise	0.80	0.73	0.73	0.73	0.73	0.73	0.67	0.80	0.67	0.87	0.80	0.55	0.94	0.80	0.87	0.61	0.55
competitor	0.61	0.61	0.67	0.80	0.61	0.95	0.61	0.67	0.80	0.61	0.47	0.95	0.61	0.67	0.55	0.55	0.87
***PR* values**	**1.3129**	**1.20**	**1.09**	**0.91**	**1.20**	**0.77**	**1.09**	**1.19**	**0.83**	**1.42**	**1.68**	**0.58**	**1.54**	**1.19**	**1.57**	**1.10**	**0.63**

Step 3: Based on the intuitionistic fuzzy linguistic scale in Table 1, the expert group provided intuitionistic fuzzy scores for the importance degrees of the green product innovation aspects and criteria. Furthermore, the expert-group IFSs scores were converged, and the results were used in Equations (3) and (4) to acquire the crisp values of relative weights. The relative positions of the submatrices in relation to the supermatrix were established. Using the weighted supermatrix *M* was limited to obtain the limiting supermatrix *M**. Thus, importance degree (*I*) weights of the aspects and criteria of green product development were achieved, as shown in Table 4.

Table 4: Limiting supermatrix *M**

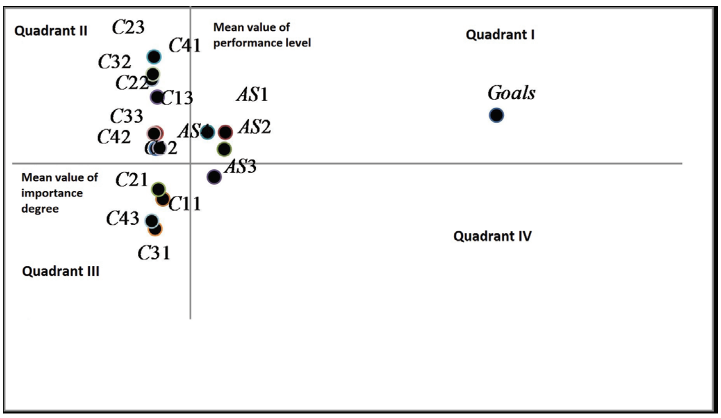
	Goals	*AS*1	*AS*2	*AS*3	*AS*4	*C*11	*C*12	*C*13	*C*21	*C*22	*C*23	*C*31	*C*32	*C*33	*C*41	*C*42	*C*43
Goals	0.333	0.090	0.089	0.080	0.074	0.034	0.028	0.028	0.03	0.029	0.026	0.027	0.024	0.026	0.025	0.031	0.024

Step 4: The performance and importance degrees obtained in Steps 2 and 3 were collated in Table 5. The data were then incorporated in the IFSs-IPA evaluation matrix proposed in this study to analyze the competition strategies for green industry innovation.

Table 5: The case enterprise's current implementation status regarding green product innovation

	The implementation of each AS for green product innovation																
	Goals	*AS*1	*AS*2	*AS*3	*AS*4	*C*11	*C*12	*C*13	*C*21	*C*22	*C*23	*C*31	*C*32	*C*33	*C*41	*C*42	*C*43	Overall mean
Importance degree	0.333	0.09	0.089	0.08	0.074	0.034	0.028	0.028	0.03	0.029	0.026	0.027	0.024	0.026	0.025	0.031	0.024	**0.0587**
PR	1.3129	1.2027	1.0946	0.9167	1.2037	0.7756	1.0989	1.1969	0.8369	1.4291	1.6867	0.5848	1.5424	1.1948	1.5760	1.1027	0.6345	**1.0000**

Figure 2: IFSs-IPA analysis diagram derived from case verification.



Step 5: Based on Table 5, the IFSs-IPA performance evaluation matrix (Figure 2) was established for the aspects and criteria of green product innovation, and analyses of strengths and weaknesses were subsequently conducted.

This study integrated the concept of IFSs with IPA, and applied the IFSs-IPA model to the product design and development of the modularization process of green fuel cells. Based on the concepts of "agree," "disagree," and "neutral," the performance scores were converted to intuitionistic fuzzy linguistic values. Thus, the case study verified that the IFSs-IPA model exhibited a superior performance capacity for processing uncertain information and solving multiattribute decision-making problems. Additionally, the customer requirements and the AS importance degree scores can be acquired using objective thinking.

5. DISCUSSION AND ANALYSIS

The Figure 2 displays the data of AS and C required in green innovation distributed in the four quadrants of the matrix, representing four types of resource distribution exhibited by the enterprise. The meanings of the quadrants were as follows:

1. The research results show that the evaluation items located in Quadrant I (Keep Up the Good Work) were the foundations for the enterprise to develop green product innovation. The items involved green industry innovation (*Goals*), energy-saving (*AS*1), amount reduction (*AS*2), and easy processing (*AS*4), suggesting that the effort made by the case enterprise on these items in green product innovation was consistent with the expectations of the customers. Moreover, the customer satisfaction degree acquired by the case enterprise was higher than that acquired by the major competitor. Thus, the enterprise competitive advantage lies in Quadrant I. The key factors for the enterprise to maintain its competitiveness in the industry and its sustainable development are maintaining its service standards and constantly sparing no efforts to innovate and develop green products.
2. The evaluation items located in Quadrant II (Possible Overkill) comprised full printing (*C*12), high transfer efficiency (*C*13), ink dilution (*C*22), silver wire thinning (*C*23), silicon substrate thinning (C32), wafer size enlargement (*C*33), printing fixtures (*C*41), and visual positioning (*C*42). The majority of items were located in Quadrant II, suggesting that although the items provided by the enterprise were superior to those provided by the competitor, the enterprise possesses considerable experience in the photoelectricity and solar energy industries and thus has invested too much resources in these items. Thus, the customer satisfaction degree regarding the service quality pertaining to green product innovation by far exceeded their expectations of the enterprise performance degree. Thus, the enterprise should rearrange the overall resource distribution and invest resources in items located in Quadrant IV, which feature high importance degrees but low satisfaction.
3. The items located in Quadrant III (Low Priority) involved production line automation (*C*11), lead-free ink (*C*21), high productive capacity (*C*31), and double table (*C*43). Compared with the other service attributes of green industry innovation, the customers perceived the importance degrees of these items as low. Additionally, the performance degrees of these the provided by the enterprise were inferior to those provided by the competitors. Consequently, the enterprise should integrate and employ more resources (such as resources from the government, research institutions, and schools) in this area to surpass its competitors. Thereby, the customer satisfaction degree can be improved, and the enterprise's competitive advantage in green product innovation can be enhanced.
4. Only one item was located in Quadrant IV (Concentrate Here), which was recycling (AS3). This suggests that customers perceived this item as highly important, and that the satisfaction degree regarding the enterprise implementation was lower than that of its major competitor. In other words, the enterprise has not completely implemented this service item. The concept of recycling should be enhanced regarding the effective recycling designed for components related to machinery facilities. Failing to implement this item may not only influence the enterprise performance regarding the green product manufacturing process, but also cause the product design of this enterprise to fall far behind that of its competitors.

6. CONCLUSIONS

For the evaluation model constructed by this study, the intuitionistic fuzzy importance degree data were combined with the ANP to calculate the importance degree weights for the evaluation items, which served as the X-axis in the IFSs-IPA evaluation model, to solve the interdependency and feedback relationship among AS and C. In addition, the relative intuitionistic fuzzy satisfaction degrees for the competitiveness of the case enterprise and the benchmarking enterprise were adopted as the Y-axis in the IFSs-IPA evaluation model and can be used to evaluate the compared performance of the case enterprise and the optimal competitor. The IFSs-IPA evaluation model can provide green innovation designers with more complete information and facilitate decision-making. Thus, during the decision-making process for product design and development, customer requirements can be considered objectively, and the goal of increasing customer satisfaction can be achieved.

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