行政院國家科學委員會專題研究計畫 成果報告

利用多重屬性效用理論評等與選擇聯合品牌伙伴
研究成果報告(精簡版)

計 畫 類 別 ： 個別型
計 畫 編 號 ： NSC 97-2410-H-032-033-
執 行 期 間 ： 97 年 08 月 01 日至 98 年 07 月 31 日
執 行 單 位 ： 淡江大學企業管理學系

計畫主持人： 張瑋倫

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報 告 附 件 ： 出席國際會議研究心得報告及發表論文

處 理 方 式 ： 本計畫可公開查詢

中 華 民 國 98 年 09 月 02 日

行政院國家科學委員會補助專題研究計畫 ■成 果 報 告 □期中進度報告

利用多重屬性效用理論評等與選擇聯合品牌伙伴

計畫類別：■ 個別型計畫　　□ 整合型計畫
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成果報告類型(依經費核定清單規定繳交)：■精簡報告　□完整報告

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中　華　民　國　98　年　8　月　31　日

出席國際學術會議心得報告

計畫編號	NSC　97－2410－H－032－03
計畫名稱	利用多重屬性效用理論評等與選擇聯合品牌伙伴
出國人員姓名 服務機關及職稱	張瑋倫（淡江大學企業管理學系 助理教授）
會議時間地點	Kaohsiung, Taiwan, November 26-28, 2008
會議名稱	IEEE 8th International Conference on Intelligent System and Applications (ISDA 08)
發表論文題目	Using Multi-attribute Utility Theory to Rank and Select Co-branding Partners

一、參加會議經過

本次研討會以資訊應用為主題，包含服務導向技術以及未來相關應用，與會學者來自各國資訊技術方面專家，此研討會除資訊技術核心探討外，亦有許多主題與管理相關，因此，除了能夠聽取新技術的文章發表外，也看到許多資訊技術未來可能的應用領域。

二、與會心得

本次論文發表場次為技術應用相關主題，同場次的論文發表多為相關新的技術探討，因此許多學者對於本篇論文在行銷上的應用頗感興趣，亦有許多學者對於本研究有濃厚興趣，並且在會中與會後給予許多意見指導，此外，亦有學者分享類似研究結果與未來可投稿期刊方向，並給予高度評價與肯定。

Using Multi-attribute Utility Theory to Rank and Select Co-branding Partners

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***Abstract* - As many companies seek growth through the extension of new markets, co-branding strategy provides an avenue to provide signals of quality and image as successful brands. In the last decade, co-branding and other cooperative brand activities have seen a 40% annual growth. The present study utilizes big five model of brand personality concept to explore the potential co-branding partners by employing multi-attribute utility theory (MAUT) to estimate and rank utilities for possible partners from big five model. This work attempts to demonstrate the proof-of-concept of our approach for a company in determining a beneficial and supportive co-branding partner.**

***Index Terms* - Multi-attribute utility theory; big five model; brand personality; co-branding strategy.**

I. INTRODUCTION

As many companies seek growth through the extension of new markets, co-branding strategy provides an avenue to provide signals of quality and image as successful brands. Co-branding is a special case of brand extension in which two brands are extended to a new product. In a co-branding alliance, the participating companies should have a relationship that has potential to be commercially beneficial to both parties. A successful co-brand has the potential to achieve excellent synergy that capitalizes on the unique strengths of each contributing brand. In the last decade, co-branding and other cooperative brand activities have seen a 40% annual growth [1].

Grossman (1997) broadly defined co-branding as "any pairing of two brands in a marketing context, such as advertisements, products, product placements, and distribution outlets" [27]. More narrowly defined, co-branding stands for the combination of two brands to create a single, unique product [1][3][14]. Companies form co-branding alliances to fulfil several goals, including: (1) Increasing sales revenue, (2) exploring new markets, (3) sharing of risk, (4) improving product image and credibility, and (5) increasing customer confidence. One industry in which co-branding is frequently practised is the fashion and apparel industry [12].

The basic principle behind co-branding strategies is that the constituent brands assist each other to achieve their objectives. Utilizing two or more brand names in the process of introducing new products offers competitive advantages. The purpose of the double appeal is to capitalize on the reputation of the partner brands in an attempt to achieve immediate recognition and a positive evaluation from potential buyers. The presence of a second brand on a product reinforces the reception of high product quality, leading to higher product evaluations and greater market share.

Nevertheless, co-branding may also affect the partner brands negatively. James (2005) showed that combining two brands may cause brand meaning to transfer in ways that were never intended [4]. The potential benefits and risks associates with co-branding strategies must be explored and carefully examined. Several failed examples demonstrate incorrect co-branding partner selection, such as BenQ/Siemens, Hp/Compaq, and BMW/Range rover. Consequently, the pre-estimation and selection of co-branding partners is extremely significant for a successful company.

The present study utilizes big five model of brand personality concept to explore the potential co-branding partners. Big five model is the most well-known theory to measure brand personality in brand management. Aaker (1997) initially relates the traits of human to brand based on big five model [16]. Furthermore, we employ multi-attribute utility theory (MAUT) to estimate and rank utilities for possible partners from big five model (e.g., five factors). This work attempts to provide a feasible approach to a company in determining a beneficial and supportive co-branding partner.

Several advantages are identified from the present work: (1) providing clues for ranking and selection of co-branding partners, (2) exploring the brand personality of the potential partners primitively, (3) utilizing MAUT approach to estimate utilities of the partners and (4) furnishing a roadmap for brand alliance research. The rest of the paper are organized as follows, section 2 briefly defines the brand personality and MAUT from the literature, section 3 demonstrates the research framework and a proposed algorithm , section 4 provides evaluated results, , section 5 investigates the managerial implication, and a conclusion is furnished in section 6.

II. THEORETICAL BACKGROUND

Brand Personality

Big five model, proposed by Galton (1884), is the most well-known theory to measure personality in psychology which employs lexical hypothesis to describe human personalities [10]. Initially, Allport and Odbert (1936) extend Galton's theory to 17953 adjectives for describing human personalities [13]. Owing to the complicated measurement, Cattell (1943) reduces the number of adjectives from 17953 to 171 [27]. Next, Fiske (1947) utilizes factor analysis to extract 171 adjectives to five factors for human personality [9]. Finally, Norman (1963) summarizes certain literature and redoes factor analysis to develop the big five model [31].

The most used version of big five model is modified by McCrae et al. (1986) and Goldberg (1990) with five factors: surgency, agreeableness, dependability, emotional stability, and culture [27][19]. Hough and Schneider (1996) verify that big five model is a good classification framework to measure human personality [20]. Borkeanau (1992) and Peabody (1987) conduct the empirical research for big five model, and confirm to the research of MaCrae and Goldberg [23][7].

Kolter (2000) considers brand can deliver six levels of meaning to customers, for example, attribute, benefit, value, culture, personality, and users [25]. Brand personality is "the human personalities related to a brand" [4]. That is, the difference between brand and human is the source [17]. The human personality came from a person's behavior, appearance, attitude and belief [19] and the brand personality is the sum of messages such as experience, word of mouth, advertisement, and service. A strong brand personality may affect the customers, strength the purchase intension, and build the relationship with customers.

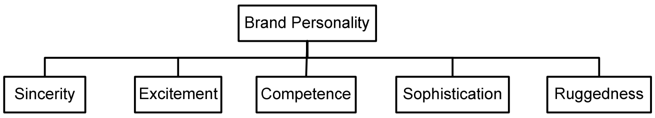

Figure 1 Brand personality framework

According to the explanation of Keller (1993), brand is not only the characteristic but the ability of self-expression [18]. Aaker (1997) constructs a brand personality framework which derives from big five model and enfolds 42 characteristics in 5 dimensions [22]. The five dimensions can mostly explain the brand personality from sampling 1000 US citizens and utilizing 60 brands from 42 questions in the survey. These characteristics/ dimensions and their facets as defined as: (1) sincerity (down-to-earth, honest, wholesome, cheerful), (2) excitement (daring, spirited, imaginative, up-to-date), (3) competence (reliable, intelligent, successful), (4) sophistication (upper class, charming), and (5) ruggedness (outdoorsy, tough).

Conversely, Fames et al. (2006) identify and verify the branding elements that consumers use when evaluating brand alliances [6]. The study looks at abstract personality issues and considers how consumer-rated brand personality traits fit and transfer. The findings reveal that managers should focus on discovering similarity between brand alliance partners in terms of brand personality. Meanwhile, the likelihood of the consumers to purchase the new product is improved where two brands do fit together.

Aaker et al. (1994) propose a conceptual model to verify whether brand personality and transgression affect partner quality, and partner quality further influences the relationship strength [14]. The effects of personality on the relationship are also conducted. The findings suggest a dynamic construal of brand personality, greater attention to interrupt events, and consideration of the relationship contracts formed at the hands of various brands. The aforementioned works demonstrate the interaction between brand personality and brand alliance; in particular, indicate the significance of these two issues for future research.

Multi-Attribute Utility Theory

The field of traditional decision theory [8] provides tools for rational decision making. Optimality is defined in terms of preference statements made by the decision maker. Specifying economic preferences between alternatives provides simple means for capturing goals and is well understood by decision makers. All decision alternatives are identified along with their respective consequences. The desirability of each consequence is determined using statements of preference from the decision maker. Probability is used to measure the likelihood of a consequence and a utility function is used to measure desirability of an alternative/consequence pair. Using this formulation, the alternative that provides the highest expected utility is chosen.

As for the decision-making related research, Shachaf and Hara (2007) propose a behavioral complexity theory (nonlinear) for media selection in global virtual teams which captures multiple contingencies into one holistic approach to media selection [26]. Hayward and Preston (1999) employ chaos theory to analyze the rationality and uncertainty [31]. Chaos theory allows for the possibility of an awareness of a range of future states; meanwhile, suggests that the past is not an accurate guide to the future.

Multi-Attribute Utility Theory (MAUT), proposed by Fishburn (1970), provides means to evaluate the desirability of multi-attribute consequences and facilitates multi-attribute decision making based on a decision theoretic approach [24]. For mutually preferentially independent attributes, the multi-attribute utility function is expressed as a weighted summation of attribute utility functions. However, all feasible alternatives must be enumerated and evaluated in order to specify the utility function which is also a major limitation for utility function.

According to MAUT, the overall evaluation v(x) of an object x is defined as a weighted addition of its evaluation with respect to its relevant value dimensions. The overall evaluation is defined by the following overall value function: $v(x)=\sum_{i=1}^{n} w_i v_i(x)$.

Here, $v_i(x)$ is the evaluation of the object on the i-th value dimension d_i and w_i the weight determining the impact of the i-th value dimension on the overall evaluation (also called the relative importance of a dimension), n is the number of different value dimensions, and $\sum_{i=1}^{n} w_i = 1$.

For each value dimension d_i the evaluation $v_i(x)$ is defined as the evaluation of the relevant attributes: $v_i(x)=\sum_{a\in A_i} w_{ai} v_{ai}(l(a))$. Here, i A is the set of all attributes relevant for d_i , $v_{ai}(l(a))$ is the evaluation of the actual level l(a) of attribute a on d_i .w_{ai} is the weight determining the impact of the evaluation of attribute a on value dimension d_i .w_{ai} is also called relative importance of attribute a for d_i. For all d_i (i=1,...,n) holds $\sum_{a\in A_i} w_{ai} = 1$. In order to evaluate the attributes, it is necessary to construct a scale representing the properties of the levels of an attribute.

MAUT enables the decision maker to structure a complex problem in the form of a simple hierarchy. Additionally, subjectively evaluate a large number of quantitative and qualitative factors in the presence of risk and uncertainty. The major strength of MAUT is the ability to deal with both deterministic and stochastic decision environment [30]. The systematic nature of MAUT in tacking complex problems under conflicted multiple criteria makes MAUT especially suitable for selecting the most appropriate brand alliance partner.

III. RESEARCH METHOD

Research framework

The selection of co-branding partners around the world is not a process to be taken slightly owing to its significant and long-lasting impact on successful co-branding strategies. If the selection is wrong, it may result in reducing the sales, shoddy product quality, and negative brand image; that is, a few of the problems the firm can encounter. As such, the co-branding partner selection decision is not trivial since it involves a large number of closely interrelated decisions for a brand personality.

Owing to the large number of factors affecting the decision, the decision should be made based on an orderly sequence steps. Most decision makers cannot simultaneously handle more than seven to nine factors when making a decision [11]. Thus, it is necessary to break down the complex problem into more manageable sub-problems through the multi-leveled decision hierarchy.

Figure 2 shows the structuring of the co-branding partner selection problem into a hierarchy of four levels. The top level of the hierarchy represents the goal of the problem (e.g., selecting the best partner). The second level of the hierarchy enfolds the general criteria which are usually considered significant in selecting the best co-branding partner.

These criteria include sincerity, excitement, competence, sophistication, and ruggedness based on the dimensions of Aaker's brand personality. At the third level, these criteria are decomposed into various attributes. Finally, the bottom level of the hierarchy is represented by certain alternatives (e.g., mobile phone companies such as MOKIA, Motorola, etc.). The main multiple criteria and attributes relevant to co-branding partner selection are described as follows.

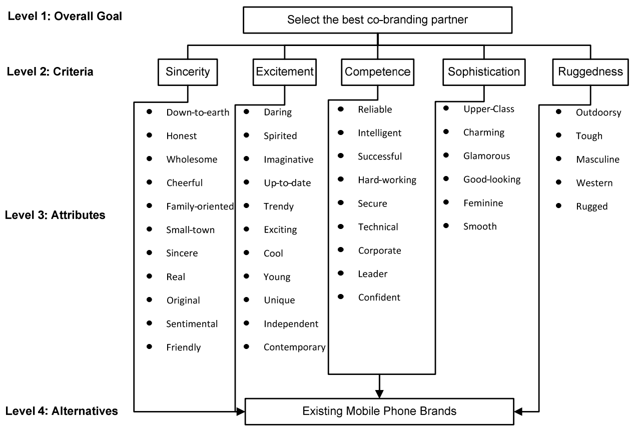

Figure 2 Research framework

- **Sincerity**

Sincerity represents if the brand is openness and trueness. Down-to-earth indicates the realistic of a brand, for example, whether the functions are useful for the consumers. Honest and sincere specify if the brand demonstrates correct information when delivering the product to the consumers. Wholesome stands for if the product of the brand is healthful (e.g., low specific absorption rate (SAR)). Real and original show if the brand is close to the real-world needs (e.g., calculator and time-zone changing). Furthermore, cheerful and friendly means if the brand is easygoing for the customers. Finally, sentimental specifies emotional factor of a brand, for instance, red and black represent different kinds of emotions in mind.

- **Excitement**

Excitement represents if the brand is exciting for the consumers. Daring and spirited indicates the brand is brave in attempting to demonstrate unique, imaginative, trendy, up-to-date, cool, and contemporary products. Young stands for the target market of the brand, in particular, young people market (e.g., NOKIA targets different niche market in various series of mobile phones). Finally, independent specifies if the product of the brand assists the customer to be independent (e.g., many mobile phones have overcome living problems, such as NOKIA utilizes GPS to solve navigating problem and dictionary to solve reading problem).

- **Competence**

Competence indicates if the brand has competitive advantages for a decision maker. For example, the products of the brand are reliable and successful will increase the reputation and competition. Intelligent, confident, secure, and technical represent the brand's image as useful and trustable. Hard-working and leader show the brand has the leading edge for a positive image.

- **Sophistication**

Sophistication stands for if the brand is attractive for consumers (e.g., charming, glamorous and good-looking). Furthermore, upper-class means if the brand is perceived as the upper-level quality for the customers. Smooth stands for stability of a brand; for instance, the frequency and possibility to be broken of a brand. Finally, feminine represents if the brand targets in female market (e.g., some brands target women as the niche market).

- **Ruggedness**

Ruggedness indicates if the brand is wild and extroversion. For example, several mobile phone brands are outdoorsy (e.g., NOKIA 5-series) and western (e.g., Motorola). Additionally, tough and rugged represent if the brand is strong and robust for its brand image. Ultimately, masculine shows if the brand targets in men market; for example, blackberry is further business and man oriented in mobile phone market.

Research Process

This study aims to rank utility values of all partners and advance the quality of partner selection. Moreover, we attempt to provide more clues fro decision makers by furnishing perceived values from user perspective. Based on research framework, four research processes are identified as follows (as shown in figure 3):

(1) Gather average scores of attributes

This work gathers average scores for all attributes from online users in order to attain objectivity. Online users give weight scores of all attributes for a mobile phone company that they perceived. In addition, they give decision scores for all attributes (if they want to find a co-branding partner) from their preferences.

(2) Estimate weight for each attribute

After gathering the required information, we estimate the weight for each attribute. Values of weights are generated by transforming average scores of all attributes to relative percentages. Hence, each value of weight is clearly identified and represented.

(3) Calculate utility values

Owing to values of weights are generated, we can multiply users' average decision scores (which are gathered from step 1) by their weights accordingly to estimate all utility values.

(4) Rank utility values

Finally, the estimated utility values will be ranked in terms of all criteria. The results not only provide orders of utility values of all mobile phone companies but detail the comparison of differences among them for each criterion.

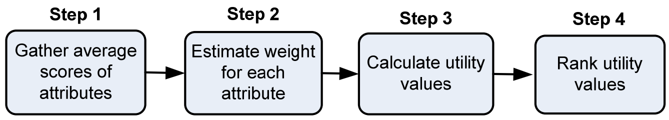

Figure 3 Research process

IV. EVALUATION AND DISCUSSION

Simulation Results

For illustrative purpose, the base-line scenario involves selecting the most appropriate global brand that sells the mobile phones. The base-line scenario considered eleven potential brands from different countries: NOKIA, Motorola, Sony-Ericsson, Sharp, Samsung, BenQ-Siemens, Panasonic, Toshiba, Asus, LG, and Gplus.

Under this scenario, we collected required information such as weight scores and decision scores from online users. This study provides an online questionnaire to all users who may contribute their perceptions. The results empower the collective intelligence from consumer perspective. The questionnaire is separated into two parts; first part inquires user perception of significance for a mobile phone company in terms of all attributes. Second part of the questionnaire inquires user decision in behavioral perspective; for example, users can assume they are decision makers and give decision score for each attribute respectively (e.g., the range is from 0 to 10 for each attribute of the perceived degree).

We collected 43 responses from the experiment excluding incomplete answers. The reason for low response is that the number of attributes is large and online users may not pay attention to completing it. However, this work is the first attempt to combine these two concepts (MAUT and brand personality). We still can utilize limited responses to prove our concept. Hence, the relative weights of attributes were determined from the collected data.

The weights were determined by calculating the scaling constant for each attribute based on the assumption. That is, an overall utility for each alternative can be expressed as an additive multi-attribute utility function shown in equation (1). This work estimates the average weight for each attribute and approximates the relative weights for all attributes.

$$U(x) = w_1 U_1(x) + w_2 U_2(x) + ... + w_n U_n(x) \quad (1)$$

Where

$U(x)$ = the overall utility for alternative x

w_i = the weight for attribute i; also called scaling constant w for attribute i.

Based on the weights, the attribute of up-to-date is most important, followed by young, trendy, corporate, cool, unique, and so on. The results reveal that the decision maker prefers a brand with newly, trendy, and unique characteristics. Hence, the estimated weights can establish the utility function and compute the overall utility score for each alternative and rank them accordingly.

Discussion

In the dimension of sincerity (Figure 4), SonyEircsson (1.9518075) and NOKIA (1.926734) are two brands in the leading group. However, LG (1.4367335) and GPlus (1.3229348) are worst two brands in sincerity dimension. NOKIA and SonyEricsson have positive brand image in sincerity dimension; furthermore, they dedicate in telecommunication industry for research and development. The result confirms these two brands lead the competitive advantages in an openness and trueness way. Consequently, NOKIA and SonyEricsson will be excellent collaborators in sincerity dimension if a company wants to select a superior co-branding partner.

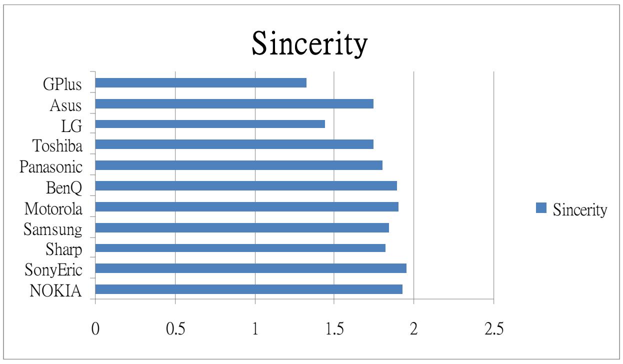

Figure 4 Utilities in sincerity dimension

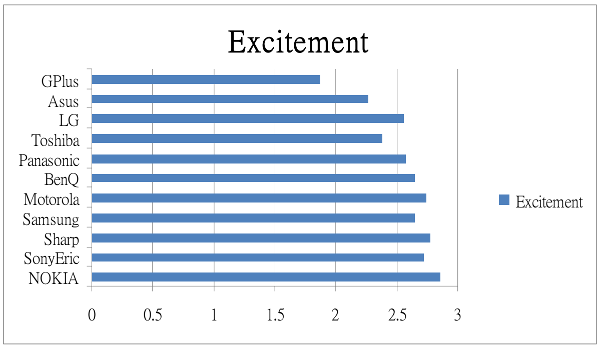

Figure 5 Utilities in excitement dimension

In the dimension of excitement (Figure 5), NOKIA (2.85445266) and Sharp (2.76935332) are the two brands in the leading group. Nevertheless, they are two different countries which have various background and culture. In other words, NOKIA and Sharp devote into innovated concept of mobile phone development. For example, NOKIA launched several mobile phones that embedded GPS or PDA functions. In the development of Japanese mobile phone industry, the life-style concept is employed and combined with mobile phone to solve real-time needs (e.g., Keitai for NTT DoCoMo). Conversely, LG (1.4367335) and GPlus (1.3229348) cannot surprise the consumers as a result of insufficient innovated design.

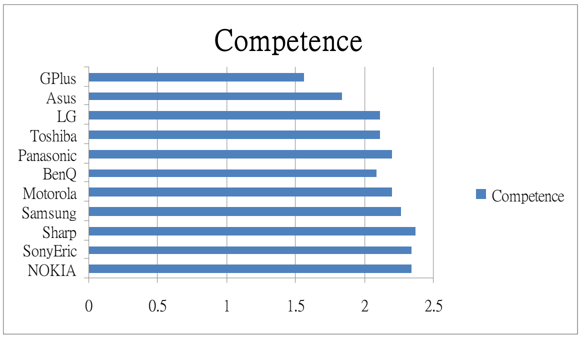

Figure 6 Utilities in competence dimension

In the dimension of competence (Figure 6), Sharp (2.366896595), NOKIA (2.339901019), and SonyEricsson (2.337595149) are three brands in the leading group. In particular, Sharp indicates the different design philosophy of typical Japanese companies. For example, people in Japan utilize cellular phone to do micro-payment, play games and watch video on demand, transact over the Internet, and so on. NOKIA and SonyEricsson typically increase innovative functions in their mobile phone design. Conversely, GPlus (1.560100539) and Asus (1.836336498) present low perceived utility as a result of the sufficient experience in telecommunication industry.

In the sophistication dimension (Figure 7), LG (1.440572801) and Samsung (1.347167689) are two brands in the leading group. LG launched many fashion styles of mobile phones with new technology such as tough-sensitive keys. For example, LG PRADA and LG Shine are two upper-class exemplars. Meanwhile, Samsung also delivered mobile phones with tough-sensitive keys function recently. Followed by LAG and Samsung, Sharp and Panasonic are the second group in this dimension. Particularly, Motorola (1.003957713) has negative brand image in sophistication dimension as the result of cultural reason. In other words, the US companies always emphasize on rugged factor for mobile phone design.

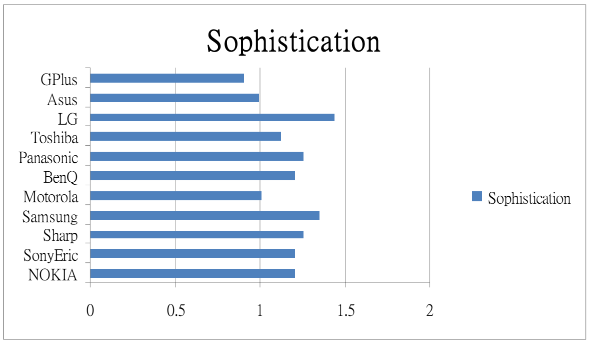

Figure 7 Utilities in sophistication dimension

In the ruggedness dimension (Figure 8), SonyEricsson (0.425566811) and BenQ (0.421387145) are two leading brands and followed by NOKIA (0.409184005) and Motorola (0.41100577). These four brands show consolidated image of the phones from consumer perspective and masculine. Conversely, most of Korea and Japanese brands are slender and slight.

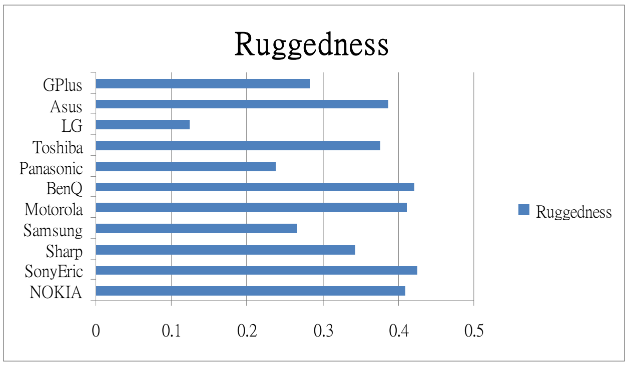

Figure 8 Utilities in ruggedness dimension

CONCLUSION

The decision maker sometimes faces the dilemma in selecting a good co-branding partner. The wrong decision will result in failing operation and increase the negative brand image. The present paper proposes a novel approach to rank the existing partners and assist the decision maker to select one. We utilize multi-attribute utility theory to estimate the perceived value from five dimensions of brand personality. The concept of brand personality is based on big five model from human personalities. MAUT can estimate the perceived value and rank them by scores and provide clues for decision making.

The experiment results confirm that NOKIA, sharp, and SonyEricsson are leading brands in the market. Moreover, they have competitive advantages in all dimensions. This study also recommends two possible strategies; for instance, the first one is to select a partner to complement and the second one is to select a similar partner. Several advantages are identified from the present work: (1) providing clues for ranking and selection of co-branding partners, (2) exploring the brand personality of the potential partners primitively, (3) utilizing MAUT approach to estimate utilities of the partners and (4) furnishing a roadmap for brand alliance research.

Finally, this study has certain limitations for future research. The result of this work only provides a preliminary attempt to strategic alliance in co-branding and demonstrates the proof-of-concept by utilizing MAUT. Furthermore, other alternative methodologies such as AHP or Delphi method can be compared to show differences and shortcomings for future research.

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計畫成果自評

本研究探討資訊技術理論結合品牌管理的概念，將多重準則效用理論的概念應用於選擇聯合品牌的伙伴上，透過品牌個性的面向，讓管理者能夠在挑選聯合品牌伙伴時，有不同的思考方向。本研究在研討會中有許多相關學者給予高度肯定評價，並且在期刊的投稿過程中，審閱者亦給予本研究價值肯定，本研究將管理與技術兩者概念結合，充分結合不同學門的理論，在管理上提供新的研究方向。本研究亦被SCI期刊Kybernetes (Impact Factor: 0.235)所接受刊登於2009年第38期第6卷中，亦對於本研究方向與價值給予肯定。

行政院國家科學委員會補助國內專家學者出席國際學術會議報告

98 年 5 月 5 日

報告人姓名	**張瑋倫 (Wei-Lun Chang)**	服務機關及職稱	**淡江大學企業管理系助理教授**
會議時間地點	**2009/4/24~2009/5/1 Les Vegas, Nevada**	本會核定補助文號	**NSC-97-2410-H-032-033**
會議名稱	（中文） （英文）**IEEE 6th International Conference on Information Technology : New Generations (ITNG 09)**		
發表論文題目	（中文） （英文）**A Heuristic Model of Network-Based Group Decision Making for E-Services**		

告內容應包括下列各項：

一、參加會議經過

本次研討會以資訊應用為主題，包含服務導向技術以及未來相關應用，與會學者來自各國資訊技術方面專家，此研討會除資訊技術核心探討外，亦有許多主題與管理相關，因此，除了能夠聽取新技術的文章發表外，也看到許多資訊技術未來可能的應用領域。

二、與會心得

由於本人亦為該研討會 Track Chair，該場次為服務導向技術應用論文發表，許多學者對於本研究有濃厚興趣，並且在會中與會後給予許多意見指導，此外，亦有學者分享類似研究結果與未來可投稿期刊方向。

三、考察參觀活動(無是項活動者省略)

四、建議

由於該研討會為技術導向，對於管理相關議題的 Track 較缺乏，因此許多管理相關的研究學者並不多，未來可走向技術與管理並行的雙管主題，讓各領域的專家學者能夠參與，並且能夠從不同觀點給予論文正向的意見。

五、攜回資料名稱及內容

1.研討會論文集(光碟)。

2.研討會提袋

3.研討會議程

六、其他

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A Heuristic Model of Network-Based Group Decision Making for E-Services

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RDT08

Abstract

Decision making in groups can ease personal biases which enables the participants discuss, argue and coordinate the ideas of coalitions. The final outcome of a group decision making process reaches a consensus decision. However, using one particular model should not preclude the consideration of other models or other means of assessing group decision making. This study aims to provide a Delphi-based group decision model of collective intelligence. Many research mainly focus on how to attain the consensus; however, rarely further investigate the expert selection process. Hence, this work (1) furnishes a group decision process that takes into account the people from social network, (2) empowers the collective intelligence from social network, and (3) leverages the decision effort of experts.

Key Words: Social network, collective intelligence, Delphi method, group decision making

1. Introduction

Decision making is a cognitive mental process with the selection of certain actions among several alternatives. The output of a decision making process should be an action or an option. However, a person's decision making style may cause cognitive or personal biases. For example, people always face the dilemma of finding a sweat lover or a clever wife/husband. Therefore, biases can creep into our decision making process.

Decision making in groups can ease personal biases which enables the participants discuss, argue and coordinate the ideas of coalitions. The final outcome of a group decision making process reaches a consensus decision. The outcome follows the rules such as majority, range voting, gathering, and plurality. Since the resources involved in the group decision-making process as well as the impact of these decisions affect organizational performance, it is crucial to make the group decision-making process as efficient and effective as possible.

In order to determine the appropriate use of a group decision-making model, the advantages and disadvantages of using a model should be discussed. The advantage of using a model is that it helps to enhance understanding (Burke, 1994; Winch, 1995). The potential disadvantage or pitfall to be aware of when using a model is that of being trapped by it (Burke, 1994). Matsatsinis et al. (2005) combines two well-known multi-criteria methods, based on the notion of aggregation of preferences to construct a consensus seeking methodology for collective decision-making. However, using one particular model should not preclude the consideration of other models or other means of assessing group decision making.

This study aims to provide a Delphi-based group decision model of collective intelligence. Delphi Method is a systematic interactive forecasting method for obtaining forecasts from a panel of independent experts. Many research mainly focus on how to attain the consensus; however, rarely further investigate the expert selection process. Hence, this work (1) furnishes a group decision process that takes into account the people from social network, (2) empowers the collective intelligence from social network, and (3) leverages the decision effort of experts. The remainder of this paper is organized as follows. Section 2 presents brief discussion of theoretical background for Delphi method. Section 3 outlines the proposed Delphi-based decision model. Section 4 evaluates the proposed decision model. Finally, Section 5 presents a brief discussion and concluding remarks.

2. Theoretical Background

The Delphi method was developed, over a period of years, at the Rand Corporation at the beginning of the cold war to forecast the impact of technology on warfare. The Delphi technique is a method of obtaining what could be considered an intuitive consensus of group expert opinions. Different approaches were tried, but the shortcomings of traditional forecasting methods, such as theoretical approach, quantitative models or trend extrapolation, in areas where precise scientific laws have not been established yet, quickly became apparent. To combat these shortcomings, the Delphi method was developed in RAND Corporation by Helmer and Rescher (1959).

The objective of most Delphi applications is the reliable and creative exploration of ideas or the production of suitable information for decision making. The Delphi Method is based on a structured process for collecting and distilling knowledge from a group of experts by means of a series of questionnaires interspersed with controlled opinion feedback (Adler and Ziglio, 1996). According to the study of Helmer (1977), Delphi Method represents a useful communication device among a group of experts and facilitates the formation of a group judgment. Baldwin (1982) asserts that lacking full scientific knowledge, decision-makers have to rely on their own intuition or on expert opinion. The Delphi method has been widely used to generate forecasts in technology, education, and other fields (Cornish, 1977).

As for the detailed process, firstly, the problem should be well identified and formulated as simple questions. Next, the carefully selected experts will response in two or more rounds. After each round, a facilitator provides an anonymous summary of the experts' forecasts from the previous round as well as the reasons they provided for their judgments. Thus, participants are encouraged to revise their earlier answers in light of the replies of other members of the group. The range of the answers will decrease and the group and converge towards a consensus answer. Finally, the process is stopped after a pre-defined stop criterion (e.g. number of rounds) and the mean or median scores of the final rounds determine the results.

3. Model Formulation

In this section, we propose a novel group decision making model which takes into account the power of collective intelligence. Collective intelligence is a form of intelligence that emerges from the collaboration and competition of many individuals. Collective Intelligence considered as a specific computational process is providing a straightforward explanation of several social phenomena. Szuba (2001) attempts to propose a mathematical model for the phenomenon of collective intelligence. It is assumed to be an unconscious, random, parallel, and distributed computational process, run in mathematical logic by the social structure.

This study takes into account the power of collective intelligence from social network. In the conventional Delphi method, expert selection is rarely be further investigation. Most of the existing literature merely focuses on group decision process in terms of how to attain the consensus. However, the selecting process of experts is significant and the selected experts affect the quality of the decision. Hence, we consider people from a person's social network are valuable and will provide in-depth suggestions close to the person.

Consequently, this paper proposes a heuristic model for expert selection and group decision making based on Delphi method. We assume GDs is the decisions for a specific problem, Es is the selected experts from a person's social network, DP function to represent Delphi method process, SN is function to signify the expert selection process, and TR is the function of solution threshold. The model is formulated in equation (1). We also assume this model is triggered by a person and the social network of the person is pre-defined already.

$$GDs = DP(SN(Es), TR(Es)) \qquad \textbf{(1)}$$

In Eq. (1), Es are the experts through our proposed selecting model. Meanwhile, SN function provides social network searching based on a person. DP function furnishes traditional concept of Delphi method in terms of anonymity, group decision making, and systematic forecasting. TR function estimates the required number of solutions (ideas) as the threshold to ensure the width of solutions. Finally, couples of decisions are the final outputs from this model.

3.2 Expert Selection from Social Network

We assume the person has a pre-defined social network with a specific level as shown in Figure 1(a). Supposedly, a person has a social network including friends, relatives, and families. The people of first level are the most familiar peers for the person and considered as strong ties. The people of second level are familiar with the ones from first level and considered as weak ties. The same concept will be expanded to the following levels. The number of level will be generated by the given number of experts from our model. The selected process should avoid a strong tie situation (Fig. 1(b)); for example, selecting peer A in the first level but un-selecting peer A's friends in the second level. The reason is to attain the heterogeneity of selected experts and good quality of the decisions.

In order to propose a model for expert selection, we assume N is the selected experts, L is the required levels of the social network, K is the actual numbers of friends for each level, n is the number of peers of each social network level, n' is the modified number of experts of each social network level, and i and p represents the current level. N is greater than three which ensures the minimum number of experts in group decision. That is, $N \geq 3, i \geq 2, p, i \geq 1$.

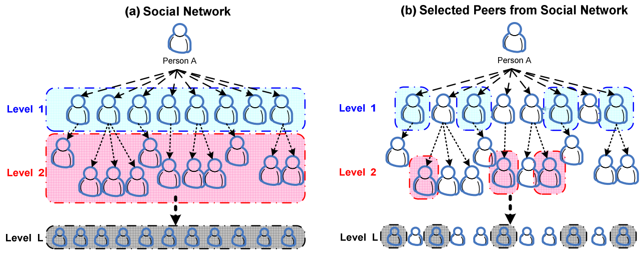

Figure 1 (a) A pre-defined social network, (b) concept of the expert selection

$$L = \left\lceil \frac{N}{3} \right\rceil \qquad \textbf{(2)}$$

In Eq. (2), we set the total number of level is the ceiling of N that is divided by three. The reason is to ensure the minimum number of level (L=1) if the number of experts is given to three (N=3). For example, if the person prefers to five experts (N=5) then the number of level will be two (L=2). Additionally, another reason is to increase the heterogeneity of experts if the number of level rises. We also separated two situations for selecting experts from each level: (1) the required number of experts is always equal or lower than actual number of friends for all levels and (2) the required number of experts is greater than the actual number of friends for an unknown level. However, only when the given number of experts is three (N=3) might be an exception for the following two situations. That is, all three experts will be selected from first level.

(a) if $n_i \leq K_i$ (assume all n_i is less than K_i)

In Eq. (3), the number of selected experts for first level is the floor of N that is divided by three. The reason is to ensure the minimum number of experts for first level (n_1=1) if the number of experts is given to four (N=4). For example, if the person prefers to seven experts (N=7), then the number of experts for first level will be one (n_1=2).

$$n_1 = \left\lfloor \frac{N}{3} \right\rfloor \qquad \textbf{(3)}$$

In Eq. (4), it represents the number of experts for each level except the first level. n_i is equal to the ceiling of the difference between given number of experts and number of experts for the previous levels ($N - \sum_{z=1}^{i-1} n_z$) that is divided by the rest number of levels ($L-(i-1)$). For example, if the person prefers to seven experts (N=7), then the number of experts for first level will be two (n_1=2) and the total number of level is three (L=3). Conversely, the rest number for other levels (except the first level) are three and two (i.e., n_2=3, n_3=2). Meanwhile, Eq. (5) represents that the actual number of peers for each level (N_i) should be lower than the required number of experts (n_i).

$$n_i = \left\lceil \frac{N - \sum_{z=1}^{i-1} n_z}{L - (i-1)} \right\rceil \qquad (4)$$

$$N_i \geq n_i \qquad (5)$$

(b) if $n_p > K_p$ (assume one level of n_p is greater than K_p)

In the second condition, we assume it exists a level with insufficient number of peers for selection. In Eq. (6), K_p is the actual number of peers and n_p is the required number of experts for a specific level p. Once the required number is greater than the actual number ($n_p > K_p$), a new level to select the expert will be needed (p+1). The required number of expert for new level is the difference between required number of experts and actual number of peers for the previous level (i.e., $n_p - K_p$).

$$n'_{p+1} = (n_p - K_p) \qquad (6)$$

We utilize the same example in the aforementioned section. The required number of experts for third level is two (n_3=2) but we assume the actual number is one (K_p=1). That is, one expert will be selected from level four (n_4=1) owing to the minus of n_3 and K_p. Moreover, Eq. (6) is the iterative process while the actual number of peers is lower than the required number of experts for any level. The iterative process will be terminated until all the required experts are selected from required levels.

3.3 Solution Threshold for Delphi Method

After selecting the required experts, we set an idea number as a threshold in the model. The threshold signifies the number of solutions should be large enough when the number of experts increases. In conventional Delphi method, experts attempt to propose their ideas as possible as they can. However, insufficient number of ideas may result in low quality of decisions. Hence, we propose a solution threshold in the group decision model in order to attain better quality of decisions.

We assume α is the number of required solutions, and N is the given number of selected experts ($N \geq 3$). In Eq. (7), if the required number of experts is greater to the floor of average number of experts, α should be at least greater than two-third of M. Otherwise, α should be at least greater than a half of M. The rationale is that the ideas should be increased if the number of required experts rises.

$$\text{If } N > \left\lfloor \frac{3+N}{2} \right\rfloor \text{ then } \alpha \geq \left\lfloor \frac{2N}{3} \right\rfloor \text{; otherwise } \alpha \geq \left\lfloor \frac{N}{2} \right\rfloor \qquad (7)$$

Let's continue using the same example. If we set the given number of experts is seven (N=7), the number of solutions should be at least greater than four ($\alpha \geq 4$). Similarly, if we replace the given number of experts by four (N=4), the number of solutions should be at least greater than two ($\alpha \geq 2$). In other words, the number of solutions (α) is subject to the given number of experts (N).

3.4 Decision Ranking Mechanism

Theoretically, Delphi method enables the experts proposing and revising the ideas iterative for two rounds. In the proposed model, this work un-limits the number of rounds in order to gain more feasible ideas for group decision making. Additionally, we propose a decision ranking mechanism to ensure the consensus of selected decisions. The traditional group decision making approach utilizes the questionnaires to attain the consensus. However, a facilitator should be existed to gather the questionnaires and summarize the information manually. The proposed mathematical model not only enhances the efficiency (i.e., select the solutions quickly) but attains the effectiveness (i.e., select the right solutions).

We assume W is the weight, I is the weight interval for each level, X is the total number of proposed solutions (ideas), E_y represents a specific expert y, q stands for the level of expert y, S is the solution (idea) set, $\bar{s}$ mean a specific solution, and r is the ranking of a solution from the expert. In Eq. (8), the weight interval of each level is estimated by the reverse of total number of levels plus one. The reason is to ensure the weights of top three solutions are not equal to zero. The estimated weight interval is used to set different decision weights of varied level of experts in Eq. (9). Supposedly, the decision weight decreases if the level of the expert increases. The reason is to distinguish the differences among different levels of experts. The first level of experts should have higher decision weight than experts in the second level.

For example, if the total number of levels is three (L=3), the weight interval will be a quarter ($I = \frac{1}{4}$). The decision weight for the experts of first level is three-quarter ($W_1 = \frac{3}{4}$) and the second level is one-second ($W_2 = \frac{1}{2}$).

$$I = \left\lfloor \frac{1}{L+1} \right\rfloor \quad \textbf{(8)}$$

$$W_q = 1 - (q * I) \quad \textbf{(9)}$$

In Eq. (10), we take into account the top three as the priority for the solutions from each expert's ranking list. If the solution is prioritized as first (r=1), the score of the solution will be 2X. The reason is to distinguish the different scores of different solutions at various priorities. Hence, the final score of a solution ($\bar{s}_r$) is estimated by multiplying the score ($\left\lfloor \frac{2X}{r} \right\rfloor$) and weight ($W_q^{E_y}$) of the solution. Finally, we sum and rank the scores of the solution appeared in each expert's list in Eq. (11).

$$\bar{s}_r = \left\lfloor \frac{2X}{r} \right\rfloor W_q^{E_y} \quad \textbf{(10)}$$

$$Rank_{\bar{s}_r} = \sum_{r \in S} \bar{s}_r \quad \textbf{(11)}$$

We utilize the aforementioned example to explain the rationale of the proposed model. We assume the required number of experts is seven (N=7), the total number of levels is three (L=3), and the total number of solutions is seven (X=7). The first solution of expert 1 is S_3 and the decision score and weight are fourteen (score=14) and three-quarter ($W_1 = \frac{3}{4}$). Meanwhile, expert 3 and expert 4 also prioritize S_3 in the list. The decision score and weight of S_3 for expert 3 are three (score=3) and one-second ($W_2 = \frac{1}{2}$). The decision score and weight of S_3 for expert 4 is seven (score=7) and one-second ($W_2 = \frac{1}{2}$). The decision score and weight of S_3 for expert 5 is seven (score=7) and one-second ($W_2 = \frac{1}{2}$). Although expert 3 and expert 4 are in the same level; however, they give different priorities for S_3. Thus, the decision score are different.

Finally, the decision score and weight of S_3 for expert 7 is seven (score=7) and a quarter ($W_3 = \frac{1}{4}$). We can estimate the final score of S_3 by summing the aforementioned scores for each expert; in other words, $Rank_{\bar{s}_3}$ is equal to 20.75. Similarly, the final scores of other solutions can be estimated at the same time. The top three score of the solutions will be the possible recommendations.

4. Evaluation

In this section, we provide three evaluating metrics to demonstrate the performance of the proposed decision model: average decision effort, ratio of required solutions, and decision difference. Average decision effort (ADE) stands for the average percentage of effort for experts from each level. Ratio of required solutions (RRS) means the percentage of proposed solutions based on the required number of N. Ratio of decision difference (RDD) measures the differences of recommended solutions between the proposed model and traditional Delphi method based on different numbers of N.

4.1 Average Decision Effort

In the proposed model, we assume people from the social network might familiar with the problem generator (a person). That is, the decision effort can be distributed to different levels of people based on our model. In the traditional Delphi method, the experts are not really familiar with the problem generator. We assume each expert has same contribution and effort in group decision making process. Hence, average decision effort for each level of experts can be formulated in Eq. (12).

$$ADE_{n_i} = \frac{n_i}{N} \quad \textbf{(12)}$$

The range of ADE for the experts from first level change slightly from 20% (N=5) to 33.33% (N=6,9,12,15) except the number of N is three. The range of ADE for experts from second level change dramatically from 20% (N=15) to 80 (N=5); meanwhile, the vales diminish according the decrease of N. That is, the proposed model successfully decreases the loading of experts from second level. The range of ADE for experts from third level vary from 20% (N=15) to 37.5% (N=8). The result of ADE for experts of third level also reveals the decrease of decision effort according to the increase of N. Moreover, the range of ADE for experts from the fourth level changes slightly from 10% (N=10) to 23% (N=13). Finally, the values of ADE for the experts from fifth level are small since the familiarity is diminished much and distributed in the previous levels. The results also demonstrated n2 dominate the majority of decision effort when N is from four to seven (N=4 to 7). The values of ADE for experts from each level become equally distributed when N is from eight to fifteen (N=8 to 15). The simulated result confirms the concept of our model which emphasizes distributing the effort and empowers the advantage of collective intelligence from social network.

4.2 Ratio of Required Solutions

Theoretically, group decision making provides more complete information, alternatives, consensus behind the group, and legality for final decisions. In our proposed model, we furnish an indicator to present the feasibility in accordance with the identified advantages. The ratio of required solutions can be formulated in Eq. (13) based on different number of N.

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$$RRS = \frac{\alpha}{N} \quad \textbf{(13)}$$

The result reveal that the average RRS is around 60 percent when N is greater than four (N>4). The lowest RRS is 33.33% when the number of N is three (N=3). The highest RRS is 66.67% when the number of N is six, nine, twelve, and fifteen (N=6,9,12,15). In our model, we asure the minimum number of proposed solutions; meanwhile, increase the RRS slightly in accordance with the increase of N. The increase of RRS also attains the advantage of the diverse strengths and sufficient expertise. Hence, it is possible that the group can generate a greater number of alternatives that are of higher quality than the individual. If a greater number of higher quality alternatives are generated, then it is likely that the group will eventually reach a superior problem solution than the individual.

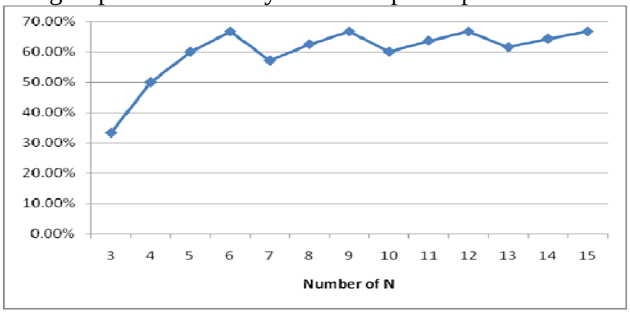

Figure 2 Comparison of different RSS

4.3 Ratio of Decision Difference

Supposedly, we assume the proposed decision model closes to reasonable real-world ranking mechanism. The weight for different experts from different levels should be various. This study provides an indicator to measure the difference between our model and conventional Delphi method. The ratio of decision difference presents the percentage of difference between two methods; meanwhile, can be formulated in Eq. (14). β means the number of different ranking solutions and π stands for the total number of solutions based on N.

$$RDD = \frac{\beta}{\pi} \quad \textbf{(14)}$$

We randomize the ranking of solutions to all experts for ten times in order to attain the average RDD of top three ranking solutions. We also assume the maximum number of solutions and required experts are both fifteen (X=15 and N=15). Conversely, this work estimates the average RDD for all solutions based on different number of N. The results reveal that RDD is the lowest when the number of N is eleven (N=11). That is, the recommended solutions from our model are closer to the results derived from traditional Delphi method.

The trend of two curves reveals the values of RDD (for either top three ranking or all ranking solutions) reduce when the value of N is down to nine (N=9). In particular, the values of RDD of top three ranking solutions are higher than RDD of all ranking solutions when the N is from eight to ten, fourteen and fifteen (N=8 to 10, 14,15). This means the proposed model provides similar results compared to traditional Delphi method for all ranking solutions.

Moreover, the result reveals our model has large differences compared to Delphi method when the values of N is from twelve to fifteen (N=12 to 15). The differences increase when the number of N increases. The increased numbers of solutions and levels may result in clear differences. The values of RDD reveal our model at least has one or two different recommended solution(s) from traditional Delphi method if the number of N is large enough (i.e., N=14 or 15). Otherwise, our model at least has one different recommended solution in average if the number of N from five to thirteen (N=5 to 13).

5. Concluding Remarks

In this study, we propose a mathematical model for group decision making which is a type of modified Delphi method. The anonymity is the major strength of our model; meanwhile, the proposed model considers the power of collective intelligence from social network. Additionally, the mathematical scoring approach of decision making mechanism also provides a way to prioritize and summarize the ideas timely and efficiently.

Comparing with the traditional group decision making methods (e.g., Delphi, brainstorming, and nominal group technique), our model combines the characteristics of these methods. For example, brainstorming enables a large number of ideas, nominal group technique asserts the ideas can be prioritized, and Delphi method states the anonymity of participants. This paper contributes to empower the collective intelligence from social network (i.e., collective decision making), leverage the decision effort of experts (i.e., each level has selected experts), ensure the heterogeneity of experts (i.e., assure different levels of experts), and diminish the domination (i.e., different weights and scores for different level of expert).

Furthermore, this work also has several research limitations which can be considered as the direction of future research. First, the expertise of the experts may totally different even we select the participants from the social network. Second, the separation of the levels may disperse the decision power. It still exists rooms to revise and adjust the proposed mathematical model. Finally, the proposed ideas (solutions) may cause biases if the level of expert increases. That is, the maximum number of level can be limited in the future research.

6. Acknowledgement

The authors would like to thank the Wen Foundation in Taiwan for financially supporting this research.

7. References

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