



Exploring smart phone improvements based on a hybrid MCDM model



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ABSTRACT

In recent years, the smart phone equipped with advanced mobile applications such as convenient and easy access to the Internet has become an essential tool for the multitasking era, recently termed the M-era. How we can understand customers' needs and gaps and subsequently satisfy these needs and lessen these gaps by creating a high value-added product to enhance customer satisfaction and increase the benefits to, and the competitive advantage of, enterprises? This study proposes a smart phone improvement for promoting the product value to satisfy the customers' needs with a hybrid MCDM model, which combines the DANP (DEMATEL-based ANP) and VIKOR. The DANP can establish an influential network relation map (INRM) to analyze interrelationship among dimensions/criteria by using the DEMATEL technique and then can measure the influential weights by combining the basic concept of the ANP. Furthermore, the VIKOR combining the influential weights in each criterion can integrate into each dimensional and overall evaluation based on the INRM to improve the gaps for achieving aspiration level and can enhance their competitive advantage in the smart phone market by lessening the gaps related to mobile convenience, thus creating a high value-added mobile phone product.

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1. Introduction

Smart phones are electronic devices that combine the universal mobile phone and the personal computer. They integrate useful functionalities such as e-mail, web browsing, audiovisual amusement, word processing, mobile video, and a Global Positioning System (GPS). With the technological advancements of semiconductors, wireless communication, multiprocessors, real-time operating systems and high performance memory capacity, the performance and the size of smart phones have continually improved. Moreover, smart phones enable mobile conveniences, such as electronic payments, broadband internet access, high computing and communication performance, and multimedia platforms. According to investigation of the Gartner Group (Gartner), smart phones were considered the most desired consumption device by American consumers in 2011, thus surpassing mobile phones, e-book readers, media tablets and gaming machines. Gartner also predicts that the smart phone market will continue to expand and rapidly create significant business opportunities. Smart phones exemplify the multitasking era, or the M-era, by possessing the multiple features previously mentioned. Smart phone usage has continued to grow via the advancement in mobile marketing (Watson, McCarthy, & Rowley, 2013). Academic research

involving smart phones, however, is scarce. Hence, the issue of smart phone has become more significant.

The study uses a hybrid MCDM (Multiple Criteria Decision Making) model combining the DANP (DEMATEL-based ANP) with VIKOR (VlseKriterijumska Optimizacija I Kompromisno Resenje) to reduce the gaps corresponding to each dimension/criterion. This improvement model can provide useful information to enterprises regarding how to optimally satisfy customer needs. By adopting the realized improvement scheme, enterprises consequently attain a high enterprise competitive advantage. In this study, challenges to the interrelationship and influential weights among the dimensions/criteria of smart phones are resolved by MCDM, which Kleijnen (2005) explained as a method that can consider the methodology of multiple decision-attributes simultaneously with priority ranking and evaluation according to the feature/attribute of each alternative, thus helping decision-makers when faced with limited feasible alternatives. This study also uses DEMATEL (Decision Making Trial and Evaluation Laboratory), a technique developed by the Geneva Battelle Research Center in 1972 that is effective for understanding the causality structure by observing the degree of factor interactions (Tzeng, Cheng, & Huang, 2007; Tzeng, Chiang, & Li, 2007). Moreover, this study adopts the ANP (Analytic Network Process), which Saaty (1996) noted can address problems of interdependence and feedback among criteria. Hence, we use the inter-relational influence matrix of the DEMATEL technique with the basic concepts of the ANP to determine the

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influential weights of dimensions/criteria (called DANP). By using the DANP, individual weights and rankings can be used to determine the key factors for decision-making. Finally, the optimal decision-making alternative can be obtained with VIKOR, which probes enterprises' problems to suggest how to lessen the gaps in dimensions/criteria for achieving a specific aspiration level.

The traditional model (Büyüközkan, 2009; Büyüközkan, Feyzioğlu, & Nebol, 2008; Işıklar & Büyüközkan, 2007; Chen, Hu, Kuo, & Liang, 2010; Zavadskas & Turskis, 2011) assumes that the criteria are structured independently and hierarchically; however, in real world problems, the relationships between the criteria or dimensions are often interdependent and sometimes provide feedback-like effects. Büyüközkan et al. (2008) and Büyüközkan (2009) listed many MCDM methods, but assumed independent criteria in a hierarchical structure (such as additive model and weighting by AHP). In addition, the traditional model can only conduct the selection/ranking (achieving the relatively optimal result) without improvement for achieving the aspiration level. So this study attempts to achieve the aspiration level using an empirical case of an improvement plan for the smart phone and seeks to contribute to grasp the improvement strategies for promoting competitiveness of smart phones with a hybrid MCDM model based on an influential network relation map (INRM) and the degree of influence derived from the DEMATEL technique and the gaps derived from VIKOR method. Fig. 1 illustrates the basic concepts of problem-solving (Liou & Tzeng, 2012; Tzeng & Huang, 2011). Responses and social and personal attributes of the objectives may be represented as a data set (e.g., crisp, fuzzy set, and rough set) via investigation of the objectives. The data could be analyzed by using MCDM. MCDM could help decision-makers when faced with multiple-objective or multiple-attribute problems (Tzeng, Cheng, et al., 2007; Tzeng, Chiang, et al., 2007; Chiu, Tzeng, & Li, 2013; Lee, Tzeng, Yeih, Wang, & Yang, 2013; Liou, 2013; Liou & Tzeng, 2012).

The paper is organized in the following order: Section 2 describes the evaluation attributes of the smart phone; Section 3 illustrates the research methods; Section 4 provides an empirical case analysis for smart phones; and Section 5 presents the conclusion.

2. Evaluation attributions of the smart phone

Smart phones have become a system intimately associated with areas such as personal needs, commercial applications, and Internet access. Young people play games, listen to music, and watch YouTube videos with smart phones to stay abreast of the latest trends. Previously, a computer would have been required to perform these actions (Pooters, 2010). A smart phone combines a general mobile phone with a personal digital assistant (PDA), which includes more convenient and mobile commercial services such as electronic wallets and electronic payments, broadband Internet access and multimedia (Chang, Chen, & Zhou, 2009). In the current communication market, Internet access via mobile phones is becoming increasingly popular with the constant development of Internet networks and information science. Moreover, mobile communication is being popularized, thus gradually increasing consumers' desire to use smart phones (Watson et al., 2013). As smart phones become powerful mobile tools for wireless internet access by combining the advantages of mobile phones and Internet networks, an effective evaluation method of their services is important. In this regard, this paper explores the evaluation attributes with the existing literature and questionnaire responses and suggests that the three dimensions of customer equity, product function and mobile convenience can influence consumer willingness to purchase a smart phone.

Customer equity, as advanced by Rust, Zeithaml, and Lemon (2000), comprises value equity, brand equity and retention equity,

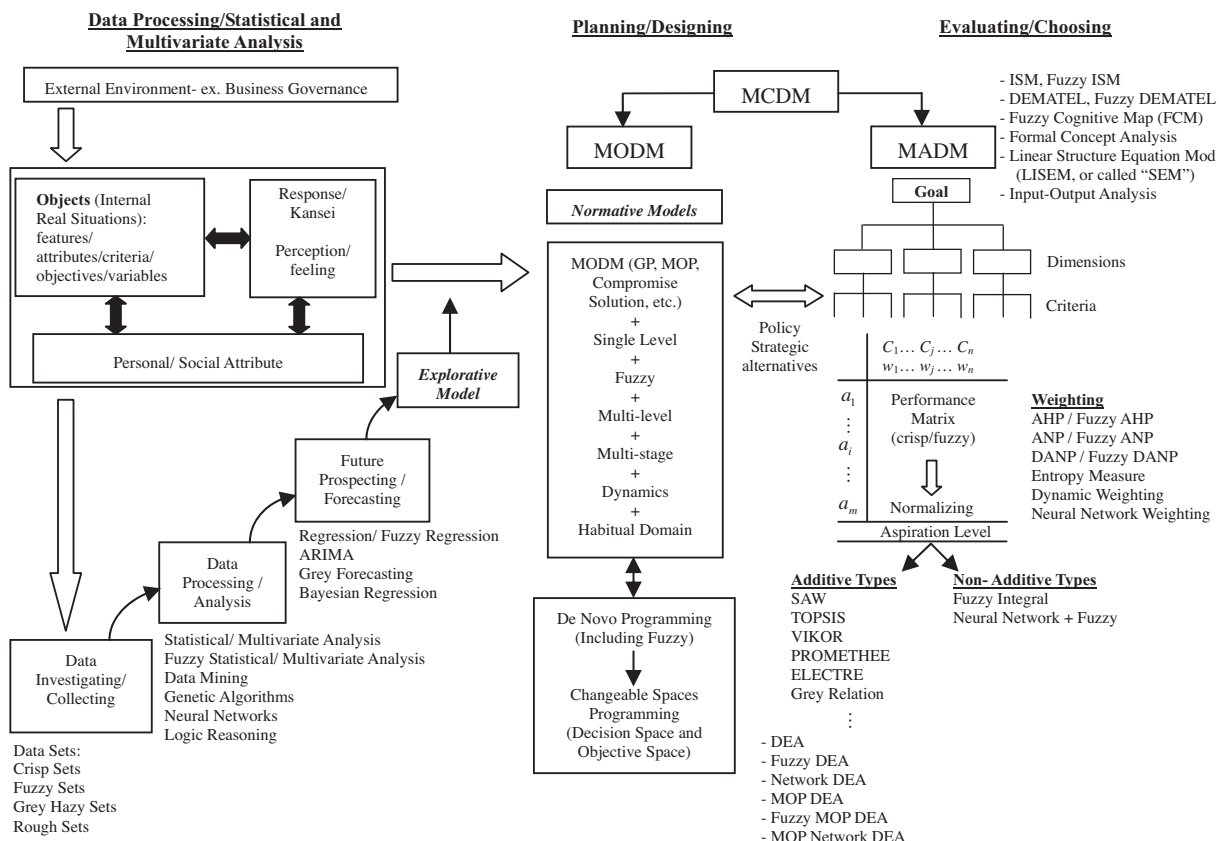


Fig. 1. The basic concepts and framework in research methods for problem-solving (Liou & Tzeng, 2012; Tzeng & Huang, 2011).

i.e., the total value of the lifetime value discount for sharing all of a company's customers. Customer equity can help enterprises to understand, manage and maintain existing customers while simultaneously valuing customers as important assets, with scrupulous ideas and attitudes. The goals, based on customer equity, are for the enterprise to derive the maximum gross profit value from its customers and to effectively discuss the formulation of marketing resource allocation and management decision-making. In this study, according to the framework of customer equity published by Rust, Lemon, and Zeithaml (2004) and Vogel, Evanschitzky, and Ramaseshan (2008), criteria based on value equity were used, in addition to brand equity and retention equity, to investigate the relationship of customer equity to smart phones.

Value equity is the goal evaluation of benefit derived from products and costs related to the customer. If products and services of enterprises focus only on brand strategy and marketing strategy, they will be unable to satisfy customers' needs and expectations. Factors affecting value equity relate to quality, price and convenience (Zhang, Doorn, & Leeflang, 2014). Quality refers to the level of products and services offered by the enterprise from an objective angle. Price influences consumers' choices and prompts consumers to conduct Internet searches for the enterprise offering the lowest price. Convenience relates to how enterprises enable fast inquiries and searches for product costs, thus resulting in cooperation. These indicate value equity's influence in ensuring that customer equity is strongest during the evaluation of products based on their differences and complexity.

Brand equity is a subjective and invisible evaluation of brand stemming from the brand awareness, the brand ethics and the brand attitude of the customer. The enterprise uses public relations, advertisements and other communication tools to influence these factors (Buil, De Chernatony, & Martínez, 2013). When a product has fewer differences and more mood factors, brand equity becomes relatively important. Uslu, Durmus, and Kolivar (2013) proposed a model to promote each enterprise's competitive advantage in the aviation market amid intense competition by making enterprises develop their own brand value and build high brand equity. Therefore, brand equity is crucial for enterprises to maintain a competitive advantage and to capture an important source of surplus. Aaker (1991) showed that customers are continuously willing to purchase the goods of such brands and are willing to purchase a high-priced good when its brand equity is highest among alternatives. Furthermore, Aaker (1991) observed the importance of brand awareness, i.e., a famous brand easily becomes a purchase alternative and a candidate for customer evaluation, and brand equity in reducing customers' perceived purchase decision risks.

Retention equity relates to how customers insist on a brand. It stems from loyalty programs, special recognition and treatment, affinity programs and knowledge-building programs. Given the constant changes in the economy, the enterprise must improve the intimacy of its relations with consumers, except when good brand equity and value equity preexist. Such an intimate relationship is called retention equity, i.e., the customers' brand insistence exceeds their subjective/objective brand evaluation. Loyalty programs refer to rewarding a specific customer behavior, whereas special recognition and treatment offer a distinct preference to customers by confirming their behavior, thus providing reciprocal benefits. Affinity programs establish a fictitious community to promote the relationship between the enterprise and the customer. The enterprise becomes incorporated into the consumer's daily life to consolidate a relationship with the customer. Finally, knowledge-building programs seek to determine the consumer's needs, thus maintaining a relationship with customers (Boss & Maas, 2013; Ramaseshan, Rabbanee, & Hui, 2013). This outcome promotes the retention equity of enterprises and customers, who thus

become unwilling to seek other enterprises. Retention equity is relatively important when the customer continues to conduct business with a supplier based on favorable personal relations and habits.

In terms of the product functions of smart phones, this study explores four components: (1) the memory, (2) the processor, (3) the touch panel, and (4) the operating system. The memory is an electronic device manufactured with semiconductor technology and stores data when a smart phone is being used. The embedded memory of smart phones enables high-speed access, high capacity and low power consumption. The mobile memory device in mobile phones increases memory capacity and constantly reduces volume; NAND flash memory is widely used for data storage applications in mobile phones. Mobile memory has entered an era of high performance, high capacity and low electric consumption (Vihmalo & Lipponen, 2005). Flash memory can be electrically erased and reprogrammed, its advantages being its small size, low electricity consumption, and absence of machine components. Therefore, more mobile embedded systems such as digital cameras, MP3 players and mobile phones have replaced magnetic disc devices (Yuhui & Jipeng, 2011). The processor, or the central processing unit (CPU), is a programmable integrated circuit whose major function is sharing tasks for communication and applications with two or more processors. The baseband processor handles the conversion of digital and analog signals during communication, and the application processor handles the operation tasks of the operating system and other programs. Multi-core processors can enhance operation speed and thus length the waiting time for the mobile phone battery. Typical high-order smart phones include a mobile application processor, a graphics processor, a baseband processor and a flexible processor for sharing tasks related to applications and communication (Swanson & Taylor, 2011). Hence, different types of processors can effectively address different types of work such as data processing, gaming, mobile communication, camera, GPS, and Wi-Fi. A touch panel, also called a touch screen, is a reaction-type liquid crystal device. When touching the on-screen figure button, the on-screen feedback system drives various types of connecting devices according to the compiled programs. Touch panels have extensive applications, from PDAs to automated teller machines (ATMs) and industrial touching computers, and provide a lifelike human-machine interface. Its application in computers and smart phones has become a basic interface because a touch panel requires simple, intuitive touch. The touch panel of smart phones can reduce the device weight, can adapt to user preferences, and can display functions of scientific and technological products (Kim, Jung, & Im, 2014). The operating system manages the software and hardware resources for the computer and thus is the foundation of the computer system. An operating system can complete basic tasks such as managing internal memory, determining the preferential order for the use of system resources, controlling input and output devices, and networking and managing file system operations. In addition, the operating system offers an interaction interface between the user and the system. An operating system should be capable of easily upgrading machines, managing all resources and the security of the computer system, thus offering unusual services as an application (Jiang et al., 2010). Some mobile devices generate high electricity consumption by using high-performance processors. Thus, mobile devices must possess an efficient operating system that can operate with a minimum execution time (Seo, Park, Kim, & Lee, 2008). Overall, an operating system can improve the performance of smart phones because of its effective management and distribution of resources.

This study also explores four components in terms of mobile convenience: (1) Remote Control Services (RCS), (2) Location Based Services (LBS), (3) Mobile Wallet Services (MWS), and (4) Mobile Multimedia Services (MMS). Remote control services can use

online networking to control a computer remotely from a distance. For a home surveillance system, integrated services are offered by combining surveillance, a door control system, a sensor, and a remote control through digital and network development. A remote control in smart phones has been gradually accepted by consumers because it offers better portable convenience than does a computer. Therefore, a mobile phone's remote control system is simpler and cheaper than the traditional method and provides greater convenience in daily life (Erdal & Nihat, 2005). LBS refer to an information service for mobile users that can accurately obtain the location of mobile users via wireless communication networks (e.g., GSM) and an outer positioning mode (e.g., GPS) (Kühn, 2004). With LBS, mobile users can obtain private services such as weather information, advertisements, and games (Shin, Vaidya, & Atluri, 2010). In recent years, mobile network providers have applied LBS to several purposes, such as navigation, instant communication, emergency rescue and other safety services (Ardagna, Cremonini, & Gianini, 2009). The electronic wallet is a function that can be used for a group of account numbers and to store cash via a network bank. It allows users to control the network service of online shopping (Chang et al., 2009). MWS offer an application for mobile payment that replaces the physical wallet and includes a membership card, a loyalty card and a travel card and can be used to store personal and sensitive information, such as data from passports, credit cards, PIN cards, shopping bills, and insurance policies, online. MWS represent a growing component of the digital economy and indicate index commerce growth through commercial mobile services (Shin, 2009). These services can enable information storage for mobile users and simultaneously perform various types of financial transactions. MMS are composed of spread media and a dynamic information exchange between two media types that are mobile services for comprehensive electronic information technology. MMS require a high-performance server to support high quality video-information for providing consumers with multimedia services, such as audio-visual amusement, web browsing, and mobile video information. According to MSN data, the online watching record was surpassed by the recent Live Earth concert, which produced nine million bits of video information streaming content. With the growing popularity of mobile phones, mobile multimedia needs for consumers also become greater. High efficiency servers are necessary to satisfy the needs of various types of bandwidth for the MMS of smart phones (Chang & Chen, 2007). Therefore, this study is designed with the intention that MMS efficiently provide multimedia services, such as mobile video information, audio-visual amusement and web browsing.

We use literature reviews to select the dimensions and criteria for evaluating the smart phone and then confirm these important dimensions and criteria with pre-test questionnaires of experts. Pre-test questionnaires are also used to solicit other opinions of these dimensions/criteria. Finally, evaluation attributes that score at least two points (i.e., ordinary) are adopted (i.e., the evaluating scales are 0–4 points, adoption occurs for scores greater than or equal to 2 points) for determining which dimensions and criteria are important. The evaluation model, with the aforementioned three dimensions, has eleven criteria to be selected with the rules in Table 1.

3. Research methods

This section will establish the structure of the improvement model for promoting the smart phone's product value with a hybrid MCDM model, which combined the DANP and VIKOR based on the total influence matrix T from the DEMATEL technique. This

Table 1
Dimensions and criteria for evaluating smart phone.

Dimensions/criteria	Descriptions
<i>Customer equity (D₁)</i>	
Value equity (C ₁₁)	The objective evaluation of benefit derived from products and cost based on the customer
Brand equity (C ₁₂)	The subjective and invisible evaluation of the brand based on the brand awareness, the brand ethics and the brand attitude of the customer
Retention equity (C ₁₃)	Relates to how the customer insists on the brand
<i>Product function (D₂)</i>	
Memory (C ₂₁)	An electronic device manufactured by using semiconductor technology and stores data during the use of the smart phone
Processor (C ₂₂)	Programmable integrated circuit (i.e., CPU)
Touch panel (C ₂₃)	A reaction-type liquid crystal device (i.e., touch screen)
Operating system (C ₂₄)	Manages the hardware and software program resources
<i>Mobile convenience (D₃)</i>	
Remote control services (C ₃₁)	Dominates the computer from distant locations and provides improved convenience in daily life
Location based services (C ₃₂)	An information service for mobile users that can accurately obtain the position information of mobile users via a wireless communication network
Mobile wallet services (C ₃₃)	An application of mobile payment that replaces the physical wallet
Mobile multimedia services (C ₃₄)	Provides multimedia services to consumers

study aims to determine the influence relationship among dimensions/criteria with the DEMATEL technique in the DANP and to measure influential weights for each factor using the DANP based on the basic concept of the ANP. The DANP can successfully determine the key influential factors for smart phone improvement by specifying the structure from improvement model, and VIKOR can perform the evaluation. The research model is illustrated in Fig. 2. In the first procedure, a hybrid MCDM model can establish an influential network relationship with the DEMATEL technique. In the second procedure, the degree of influential weights can be obtained with the DANP. In the third procedure, the optimal alternative for performance improvement can be found with VIKOR, specifically, with the influential weights of the DANP derived from the INRM, based on the total influence matrix T of the DEMATEL technique.

3.1. Building a network relationship of influential weights with the DANP

The DANP is obtained from the DEMATEL technique with the ANP. The DEMATEL technique, as proposed by the Battelle research center in 1972, analyzes complicated problems in the real world by building a network interrelation (Gabus & Fontela, 1972). This method is effective for solving complicated problems between communities, specifically, by using a hierarchical structure to understand complicated causality structures. With these structures, the DEMATEL technique is often applied to study and to address complicated objects (Peng & Tzeng, 2013; Tzeng, Cheng, et al., 2007; Tzeng, Chiang, et al., 2007), thus enabling the determination of the degree of interrelation and interaction among the features, according to the objects' concrete features (Chiu, Chen, Tzeng, & Shyu, 2006; Chen, Lien, & Tzeng, 2010; Lin, Hsieh, & Tzeng, 2010; Lu et al., 2013). The ANP, as proposed by Saaty (1996), loosens the restriction (i.e., relaxes the assumption) of the hierarchical structure through the Analytic Hierarchy Process (AHP) (Saaty, 1980) and can be applied to solve the nonlinear

and complicated network relations. The ANP serves to solve interdependence and feedback problems of the dimensions/criteria. The basic concepts underlying the properties of the ANP can be combined with the DEMATEL technique's total influence matrix to solve this type of problem.

Some studies have applied the DANP to explore such processes as portfolio selection based on a capital asset pricing model (Ho, Tsai, Tzeng, & Fang, 2011) and organic light emitting diode technology selection (Shen, Lin, & Tzeng, 2011). The hybrid MCDM model, as proposed by Tzeng, Cheng, et al. (2007) and Tzeng, Chiang, et al. (2007) can also be used to solve different problems, such as e-learning evaluation, innovation and recombination in the electronic industry (Huang, Shyu, & Tzeng, 2006), the flight security problem (Liou, Tzeng, & Chang, 2007). With the DEMATEL technique, the total influence matrix T can be applied to the basic concepts of the ANP to seek key criteria in influencing weights. Ou Yang, Shieh, Leu, and Tzeng (2008), Ou Yang, Shieh, and Tzeng (2009, 2013) noted that although the concept of the ANP specified a simple method of supposing identical weights in the cluster per group from the normalized super matrix, it neglected the influence in various degrees. Therefore, Lee, Tzeng, Guan, Chien, and Huang (2009), Hsu, Wang, and Tzeng (2012) and Liu, Tzeng, and Lee (2012), Liu, Tzeng, Lee, and Lee (2013) normalize the total influence matrix T_c (the normalized total influence matrix T_c^β) of DEMATEL with dimensions and transposed it onto an unweighted super-matrix W (i.e., $W = (T_c^\beta)'$) of the ANP, thereafter normalizing it into a weighted super-matrix (W^β) with the normalized influence matrix T_c^β . The influential weights of the DANP can then be obtained through self-multiplication multiple times. These processes can be described according to the following steps.

Step 1: Construct the measure scales of the direct relation matrix. The questionnaires can be converted to a direct relation matrix with expert questionnaires. The expert questionnaires develop the evaluating scale through a pairwise comparison of dimensions/criteria and use scales 0, 1, 2, 3, 4, with the following measuring standards: no influence (0), low influence (1), middle influence (2), high influence (3), and extreme influence (4).

Step 2: Calculate the initial influence matrix $A = [a_{ij}]_{n \times n}$. A can be obtained from the convergence of expert opinion through a direct relation matrix, where a_{ij} represents the degree of influence of factor i on factor j .

$$A = \begin{bmatrix} a_{11} & \cdots & a_{1j} & \cdots & a_{1n} \\ \vdots & & \vdots & & \vdots \\ a_{i1} & \cdots & a_{ij} & \cdots & a_{in} \\ \vdots & & \vdots & & \vdots \\ a_{n1} & \cdots & a_{nj} & \cdots & a_{nn} \end{bmatrix} \quad (1)$$

• **Step 3: Build the normalized direct effect matrix N .** N can be obtained by normalizing A from Eqs. (2)–(3).

$$N = A/s \quad (2)$$

$$s = \max \left[\max_{1 \leq i \leq n} \sum_{j=1}^n a_{ij}, \max_{1 \leq j \leq n} \sum_{i=1}^n a_{ij} \right] \quad (3)$$

• **Step 4: Build the total influence matrix T .** T can be obtained from Eq. (4), where I is an identity matrix and $\lim_{h \rightarrow \infty} N^h = [0]_{n \times n}$.

$$\begin{aligned} T &= N + N^2 + N^3 + \cdots + N^h \\ &= N(I + N + N^2 + \cdots + N^{h-1})(I - N)^{-1} \\ &= N(I - N^h)(I - N)^{-1} = N(I - N)^{-1}, \quad \text{when } \lim_{h \rightarrow \infty} N^h = [0]_{n \times n} \end{aligned} \quad (4)$$

• **Step 5: Construct the influential network relation map (INRM).** According to Eqs. (5)–(7), the sum of each row and column for T can be obtained, where vector r (any criterion i influences all other criteria) denotes the sum of all vector rows $r = (r_1, \dots, r_i, \dots, r_n)$, and vector y (any criterion j is influenced by all other criteria) denotes the sum of all vector columns $y = (y_1, \dots, y_j, \dots, y_n)$. When i equals j , $i, j \in \{1, 2, \dots, n\}$, $(r_i + y_i)$ represents the total degree of influence among criteria, and the higher its value, the closer the criterion is to the object's central point. In addition, $(r_i - y_i)$ represents the degree of causality among criteria: if $(r_i - y_i)$ is positive, then criterion i influences other criteria, and if $(r_i - y_i)$ is negative, criterion i is influenced by other criteria. The degrees of influence and causality can provide important reference information to inform decision-making by plotting the INRM (such as Fig. 3).

$$T = [t_{ij}]_{n \times n}, \quad i, j = 1, 2, \dots, n \quad (5)$$

$$r = \left[\sum_{j=1}^n t_{ij} \right]_{n \times 1} = (r_i)_{n \times 1} = (r_1, \dots, r_i, \dots, r_n) \quad (6)$$

$$y = \left[\sum_{i=1}^n t_{ij} \right]_{1 \times n}' = (y_j)'_{1 \times n} = (y_1, \dots, y_j, \dots, y_n) \quad (7)$$

We consider the total influence matrix of criteria as $T_c = [t_{ij}]_{n \times n}$ and we regard the total influence matrix of dimensions (or clusters) as $T = [t_{ij}^D]_{m \times m}$. To obtain the dynamic degree of influence of the weights, we determine the weights and their influences in the super-matrix of the ANP by normalizing T_c by dimension/cluster.

• **Step 6: Obtain the unweighted super-matrix W by transposing the normalized total influence matrix T_c^β with the DEMATEL technique.** This step uses the basic concepts of the ANP to build the unweighted super-matrix W as follows:

We normalize the total influence matrix T_c using dimensions; thus, the normalized matrix T_c^β by dimensions can be obtained as shown in Eq. (9). For example, $T_c^{\beta 11}$ can be similarly normalized, as shown in Eqs. (10)–(11), to obtain $T_c^{\beta 11}$. Next, as shown in Eq. (12), the normalized influence matrix T_c^β is transposed to obtain the unweighted super-matrix W .

$$T_c = \begin{bmatrix} D_1 & & D_j & & D_n \\ c_{11} & c_{1m_1} & \cdots & c_{j1} & c_{jm_j} & \cdots & c_{n1} & c_{nm_n} \\ D_1 & T_c^{11} & \cdots & T_c^{1j} & \cdots & T_c^{1n} \\ \vdots & \vdots & & \vdots & & \vdots \\ D_j & T_c^{j1} & \cdots & T_c^{jj} & \cdots & T_c^{jn} \\ \vdots & \vdots & & \vdots & & \vdots \\ D_n & T_c^{n1} & \cdots & T_c^{nj} & \cdots & T_c^{nn} \end{bmatrix} \quad (8)$$

$$T_c^\beta = \begin{bmatrix} D_1 & & D_j & & D_n \\ c_{11} & c_{1m_1} & \cdots & c_{j1} & c_{jm_j} & \cdots & c_{n1} & c_{nm_n} \\ D_1 & T_c^{\beta 11} & \cdots & T_c^{\beta 1j} & \cdots & T_c^{\beta 1n} \\ \vdots & \vdots & & \vdots & & \vdots \\ D_j & T_c^{\beta j1} & \cdots & T_c^{\beta jj} & \cdots & T_c^{\beta jn} \\ \vdots & \vdots & & \vdots & & \vdots \\ D_n & T_c^{\beta n1} & \cdots & T_c^{\beta nj} & \cdots & T_c^{\beta nn} \end{bmatrix} \quad (9)$$

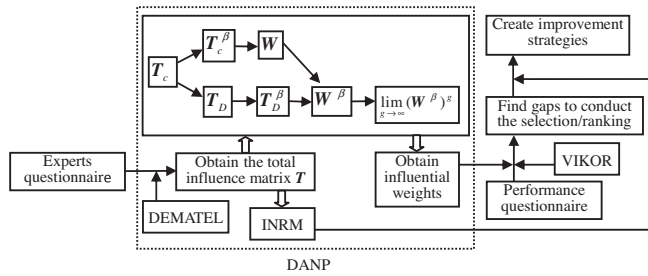


Fig. 2. Procedure of the research model.

$$d_i^{11} = \sum_{j=1}^{m_1} t_{c^j}^{11}, \quad i = 1, 2, \dots, m_1 \quad (10)$$

$$T_C^{\beta 11} = \begin{bmatrix} t_{c^{11}}^{11}/d_1^{11} & \dots & t_{c^{1j}}^{11}/d_1^{11} & \dots & t_{c^{1m_1}}^{11}/d_1^{11} \\ \vdots & & \vdots & & \vdots \\ t_{c^{i1}}^{11}/d_i^{11} & \dots & t_{c^{ij}}^{11}/d_i^{11} & \dots & t_{c^{im_1}}^{11}/d_i^{11} \\ \vdots & & \vdots & & \vdots \\ t_{c^{m_1 1}}^{11}/d_{m_1}^{11} & \dots & t_{c^{m_1 j}}^{11}/d_{m_1}^{11} & \dots & t_{c^{m_1 m_1}}^{11}/d_{m_1}^{11} \end{bmatrix}$$

$$= \begin{bmatrix} t_{c^{11}}^{\beta 11} & \dots & t_{c^{1j}}^{\beta 11} & \dots & t_{c^{1m_1}}^{\beta 11} \\ \vdots & & \vdots & & \vdots \\ t_{c^{i1}}^{\beta 11} & \dots & t_{c^{ij}}^{\beta 11} & \dots & t_{c^{im_1}}^{\beta 11} \\ \vdots & & \vdots & & \vdots \\ t_{c^{m_1 1}}^{\beta 11} & \dots & t_{c^{m_1 j}}^{\beta 11} & \dots & t_{c^{m_1 m_1}}^{\beta 11} \end{bmatrix} \quad (11)$$

$$W = (T_c^{\beta})' = D_j \begin{bmatrix} D_1 & & D_i & & D_n \\ c_{11} \dots c_{1m_1} & \dots & c_{i1} \dots c_{im_i} & \dots & c_{n1} \dots c_{nm_n} \\ \vdots & & \vdots & & \vdots \\ D_j & & D_j & & D_j \\ c_{j1} & \dots & c_{jm_j} & \dots & c_{jn} \dots c_{jm_n} \\ \vdots & & \vdots & & \vdots \\ D_n & & D_n & & D_n \\ c_{n1} & \dots & c_{nm_n} & \dots & c_{nm_n} \end{bmatrix} \begin{bmatrix} W_{11} & \dots & W_{i1} & \dots & W_{n1} \\ \vdots & & \vdots & & \vdots \\ W_{1j} & \dots & W_{ij} & \dots & W_{nj} \\ \vdots & & \vdots & & \vdots \\ W_{1n} & \dots & W_{in} & \dots & W_{nn} \end{bmatrix} \quad (12)$$

where D_n represents the n th dimension, and c_{nm_n} represents the m_n -th criterion in the n th dimension.

• **Step 7: Determine the weighted super-matrix W^{β} .** $T_D = [t_{ij}^D]_{m \times m}$, as shown in Eq. (13), must be normalized by Eq. (14).

$$T_D = \begin{bmatrix} t_{11}^{D_{11}} & \dots & t_{1j}^{D_{1j}} & \dots & t_{1m}^{D_{1m}} \\ \vdots & & \vdots & & \vdots \\ t_{i1}^{D_{i1}} & \dots & t_{ij}^{D_{ij}} & \dots & t_{im}^{D_{im}} \\ \vdots & & \vdots & & \vdots \\ t_{m1}^{D_{m1}} & \dots & t_{mj}^{D_{mj}} & \dots & t_{mm}^{D_{mm}} \end{bmatrix} \quad (13)$$

$$d_i = \sum_{j=1}^m t_{ij}^{D_{ij}}, \quad i = 1, \dots, m \quad (14)$$

Therefore, T_D^{β} can be determined after normalizing T_D , as shown in Eq. (15).

$$T_D^{\beta} = \begin{bmatrix} t_{11}^{D_{11}}/d_1 & \dots & t_{1j}^{D_{1j}}/d_1 & \dots & t_{1m}^{D_{1m}}/d_1 \\ \vdots & & \vdots & & \vdots \\ t_{i1}^{D_{i1}}/d_i & \dots & t_{ij}^{D_{ij}}/d_i & \dots & t_{im}^{D_{im}}/d_i \\ \vdots & & \vdots & & \vdots \\ t_{m1}^{D_{m1}}/d_m & \dots & t_{mj}^{D_{mj}}/d_m & \dots & t_{mm}^{D_{mm}}/d_m \end{bmatrix} = \begin{bmatrix} t_{11}^{\beta} & \dots & t_{1j}^{\beta} & \dots & t_{1m}^{\beta} \\ \vdots & & \vdots & & \vdots \\ t_{i1}^{\beta} & \dots & t_{ij}^{\beta} & \dots & t_{im}^{\beta} \\ \vdots & & \vdots & & \vdots \\ t_{m1}^{\beta} & \dots & t_{mj}^{\beta} & \dots & t_{mm}^{\beta} \end{bmatrix} \quad (15)$$

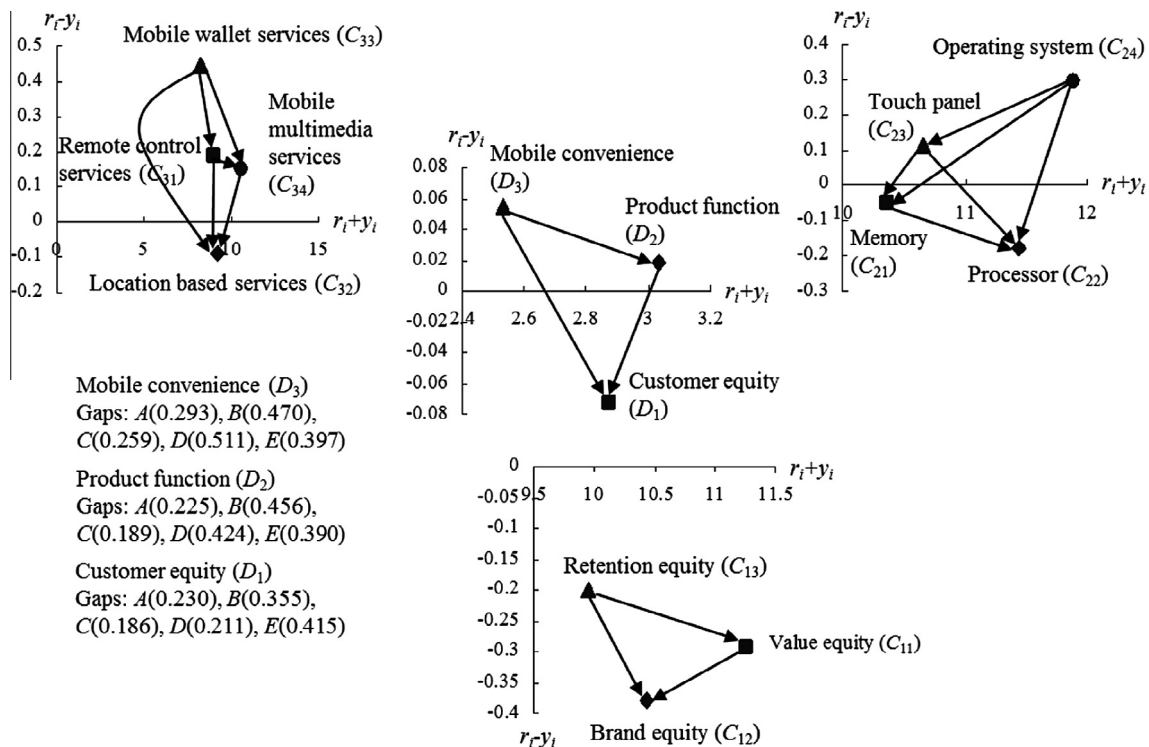


Fig. 3. The influential network relation map of each dimension and criterion.

T_D^β and W yield weights with different degrees of influence to obtain the weighted super-matrix W^β , as shown in Eq. (16).

$$W^\beta = T_D^\beta W = \begin{bmatrix} t_{11}^{\beta 11} \times W_{11} & \cdots & t_{11}^{\beta i1} \times W_{i1} & \cdots & t_{11}^{\beta m1} \times W_{n1} \\ \vdots & & \vdots & & \vdots \\ t_{1j}^{\beta 1j} \times W_{1j} & \cdots & t_{1j}^{\beta ij} \times W_{ij} & \cdots & t_{1j}^{\beta mj} \times W_{nj} \\ \vdots & & \vdots & & \vdots \\ t_{1m}^{\beta 1m} \times W_{1m} & \cdots & t_{1m}^{\beta im} \times W_{im} & \cdots & t_{1m}^{\beta mm} \times W_{nm} \end{bmatrix} \quad (16)$$

- **Step 8: Calculate the influential weights of the DANP with the limit super-matrix** $\lim_{g \rightarrow \infty} (W^\beta)^g$. The super-matrix W^β is multiplied by itself multiple times to obtain the limit weighted super-matrix (a concept based on the Markov chain) to a fixed convergence value. Then, the influential weights of the DANP can be obtained with $\lim_{g \rightarrow \infty} (W^\beta)^g$, where g represents a positive integer number. We call this process a DANP, i.e., a DEMATEL-based ANP.

3.2. A modified VIKOR for evaluating and improving the alternatives

Opricovic and Tzeng (2004) proposed that the compromise ranking method (VIKOR) is an applicable technique to implement within MCDM to solve the ranking method of multiple alternatives for inter-competition problems among evaluation criteria. The VIKOR ranking implies that the preferred alternative is proximate to the ideal solution, following the form of L_p -metric:

$$L_k^p = \left\{ \sum_{j=1}^n [w_j (|f_j^* - f_{kj}|) / (|f_j^* - f_j^-|)]^p \right\}^{1/p} \quad (17)$$

where $1 \leq p \leq \infty$; $k = 1, 2, \dots, K$; the relative influential weight w_j can be derived from the DANP. We can reveal the gaps (i.e., degrees of regret) of each alternative $k | k = 1, 2, \dots, K$ in each criterion $j | j = 1, 2, \dots, n$:

$$r_{kj} = (|f_j^* - f_{kj}|) / (|f_j^* - f_j^-|) \quad (18)$$

The ranking and gap measures $L_k^{p=1}$ (as S_k) and $L_k^{p=\infty}$ (as P_k) can be formulated with VIKOR (Opricovic, 1998; Opricovic & Tzeng, 2002; Opricovic & Tzeng, 2007; Shen, Yan, & Tzeng, 2014; Tzeng, Lin, & Opricovic, 2005; Tzeng, Teng, Chen, & Opricovic, 2002; Tzeng, Tsaur, Laiw, & Opricovic, 2002).

$$S_k = L_k^{p=1} = \sum_{j=1}^n w_j r_{kj} \quad (19)$$

$$P_k = L_k^{p=\infty} = \max_j \{ (r_{kj} | j = 1, 2, \dots, n) \} \quad (20)$$

where the purpose of VIKOR is modified not only for ranking/selecting the alternatives but also, more importantly, to reduce the gaps for achieving the aspiration level of each criterion based on the influential network relation map (such as Fig. 3). Hence, Eqs. (21)–(22) are converted into Eqs. (23)–(24) as follows.

The traditional ideal solution (positive and negative)

$$f_j^* = \max_k f_{kj}, j = 1, 2, \dots, n \quad (\text{traditional approach}) \quad (21)$$

$$f_j^- = \min_k f_{kj}, j = 1, 2, \dots, n \quad (\text{traditional approach}) \quad (22)$$

Establishing the aspiration level and the worst level (the proposed new idea for improvement)

$$\text{The aspiration levels : } f_j^* = (f_1^*, \dots, f_j^*, \dots, f_n^*) \quad (23)$$

$$\text{The worst levels : } f_j^- = (f_1^-, \dots, f_j^-, \dots, f_n^-) \quad (24)$$

In this study, we use the performance scores 0 to 4 (very bad $\leftarrow$ 0, 1, 2, 3, 4 $\rightarrow$ very good) to evaluate the questionnaires, so the aspiration level can be set at score 4 and the worst value, at score zero. Therefore, we differ from the traditional approach in setting $f_j^* = 4$ as the aspiration level and $f_j^- = 0$ as the worst value. This approach can avoid the “Choose the best among inferior choices/options/alternatives” strategy (in other words, the “Pick the best apple among a barrel of rotten apples” strategy).

The compromise solution $\min_k L_k^p$ (i.e., $\min_k S_k$) minimizes the integrating gap (i.e., the average gap), which will be improved to ensure a value closest to the aspiration level. In addition, the group utility is emphasized to make p small (e.g., $p = 1$); if p tended towards infinity, the individual maximum regrets/gaps receive a greater priority in the improvement of each dimension/criterion. Consequently, $\min_k S_k$ stresses the maximum group utility (i.e., how to eliminate the gaps in each dimension/criterion); however, $\min_k P_k$ focuses on the selection of minimum to maximum individual regrets/gaps, as shown during the improvement in the priority of each dimension and overall dimensions.

Finally, a comprehensive indicator G_k for improving and ranking the results can be obtained with Eq. (25). Therefore, G_k can be considered the basis of the ranking/improving alternative when G_k is close to zero (i.e., close to the aspiration level).

$$G_k = v(S_k - S^*) / (S^- - S^*) + (1 - v)(P_k - P^*) / (P^- - P^*), \quad v \in [0, 1] \quad (25)$$

where $S^* = \min_k S_k$, or let $S^* = 0$ (no gap, the aspiration level is achieved); $S^- = \max_k S_k$, or let $S^- = 1$ (the worst situation); $P^* = \min_k P_k$, or let $P^* = 0$ (no gap, the aspiration level is achieved); and $P^- = \max_k P_k$, or let $P^- = 1$ (the worst situation). Eq. (25) can be rewritten $G_k = vS_k + (1 - v)P_k$ when $S^* = 0$ and $P^* = 0$ (i.e., all criteria have achieved their corresponding aspiration levels), and $S^- = 0$, and $P^- = 1$ (i.e., the worst situation). How do decision makers determine the v value? When $v = 1$, only the average gap (the average regret) is considered in each dimension or overall; when $v = 0$, only the maximum gap of the improvement is considered for the criterion in each dimension or overall that should be improved to “priority”. The value obtained from $\min_k S_k$ represents the maximum group utility (the minimum average gap indicator), and the value obtained from $\max_k P_k$ represents the maximum regret (the largest gap shown as priority improvement). Thus, v represents the weight of the strategy. Generally, $v = 0.5$, which can be adjusted depending on the case; $v = 1$ indicates that only the average gap is considered, and $v = 0$ indicates that only the maximum gap is prioritized for improvement.

In this paper, the hybrid MCDM model can be used not only to rank and to select the alternatives but also to determine how to improve the alternatives to reduce gaps (such as VIKOR) based on the influential network relation map (INRM, using the DEMATEL technique). In the above formulations, we use a hybrid MCDM model to improve the gaps among dimensions/criteria for achieving the aspiration level in each dimension and criterion through the innovation and creativity of R&D in the interrelationship problem (i.e., dependence and feedback problem) among dimensions/criteria.

4. An empirical case analysis for improving the smart phone

This section explores the degrees of influence among the factors and determines the influential weights of each factor to find the key factor that each mobile communication enterprise should consider when popularizing smart phones. This process is performed using the influential weights of the DANP and VIKOR with a hybrid MCDM model. We consider five enterprises of smart phones for our case study to explain and to verify the key factors for smart phone development.

4.1. Constructing the influential network relation by DEMATEL and obtaining the influential weights by the DANP

This study builds the structure of influential relationships in the decision-making problem with the DEMATEL technique and the DANP to analyze the interactions among the three dimensions and eleven criteria based on Section 2. The total influence matrix T and the degrees of influence can then be obtained from the questionnaires of the experts (i.e., six managers of mobile phone communication store, eight managers of smart phone company and ten experienced users of smart phone). With significant confidence, average sample gap equals only 1.32% and is smaller than 5% (i.e., the significant confidence is 98.68%, greater than 95%), as demonstrated by the following (see the note below Table 2. Initial influence matrix $A = [a_{ij}]_{n \times n}$):

The relationship between the total influence matrix T and the degrees of influence are shown in Tables 3–5. Table 3 reveals that all criteria have an interacting relationship. Table 4 shows that the relationship of the three dimensions is based on expert cognition and that the dimension of mobile convenience (D_3) has the highest impact among the dimensions and thus is the most influential factor. The degree of influence of customer equity (D_1) is lowest among all dimensions. The DEMATEL technique can be used to determine the interactions among the criteria. Thus, by DEMATEL technique, this study can construct an improvement model for the smart phone, and the degree of influence of each criterion can be obtained and are shown in Table 5. The operating system (C_{24}) has the highest total degree of influence ($r_i + y_i$) and thus is considered the most important criterion by experts and has the most significant relationship to other criteria. By contrast, mobile wallet services (C_{33}) relates the least to other criteria. In addition, from observing the degree of influence of the criteria, we found that the criterion with the maximum reason degree ($r_i - y_i$) is mobile wallet services (C_{33}), which thus most easily influences other

criteria. The criterion with the minimum reason degree ($r_i - y_i$) is brand equity (C_{12}), which thus is most easily influenced by other criteria.

The DANP method provided the influential weights of criteria. Then, the unweighted super-matrix W , based on Eq. (12), can be obtained by transposing the normalized influence matrix T_c^β , as shown in Table 6. The weighted super-matrix W^β , based on Eq. (16), is shown in Table 7. The influential weights of the DANP can be obtained by limiting the power of the weighted super-matrix (a concept based on the Markov chain), as shown in Table 8.

Fig. 3 shows the influential network relation map (INRM) that explains the structure of interactions in the improvement model. Customer equity (D_1) is influenced by the product function (D_2) and mobile convenience (D_3). Therefore, customer equity (D_1) is influenced by the product function and mobile services offered by the suppliers of the smart phone and telecommunication services. Therefore, cooperation among firms is necessary to increase purchase intention and is further illustrated in Fig. 3, thus indicating the influential priority can be ordered as mobile convenience (D_3) – product function (D_2) – customer equity (D_1). When considering the improvement, all experts ranked convenience first and agreed that the first priority for improving should be mobile convenience (D_3), which can then influence the remaining dimensions: product function (D_2) and customer equity (D_1). In the case of mobile convenience (D_3), the smart phone differs from the universal phone in that it can provide a large number of convenience services

Table 4

The total influence matrix of dimensions T_D and sum of influences given/received on dimensions.

Dimensions	D_1	D_2	D_3	r_i	y_i	$r_i + y_i$	$r_i - y_i$
D_1	0.479	0.513	0.410	1.402	1.475	2.877	−0.073
D_2	0.541	0.530	0.455	1.526	1.508	3.034	0.018
D_3	0.455	0.465	0.375	1.294	1.240	2.534	0.054

Table 2
Initial influence matrix A .

A	C_{11}	C_{12}	C_{13}	C_{21}	C_{22}	C_{23}	C_{24}	C_{31}	C_{32}	C_{33}	C_{34}
C_{11}	0.000	2.958	2.625	2.625	3.250	3.250	3.208	1.792	2.208	1.708	2.667
C_{12}	3.250	0.000	2.667	2.417	2.750	2.917	2.958	1.583	1.833	1.500	2.000
C_{13}	2.833	3.042	0.000	2.250	2.667	2.625	2.625	1.833	1.792	1.625	1.958
C_{21}	2.833	2.167	2.292	0.000	3.458	2.458	2.958	1.875	2.125	1.542	2.833
C_{22}	3.375	2.875	2.417	3.083	0.000	2.458	3.375	2.250	2.417	1.833	3.042
C_{23}	3.250	3.000	2.875	2.292	2.375	0.000	2.917	2.250	2.292	1.667	3.000
C_{24}	3.250	2.875	2.667	3.333	3.500	3.083	0.000	2.833	2.625	2.333	3.208
C_{31}	1.875	1.792	1.667	2.417	2.875	2.167	2.708	0.000	2.375	2.083	2.083
C_{32}	2.333	2.250	2.333	2.000	2.333	1.792	2.208	2.333	0.000	2.167	2.167
C_{33}	1.958	2.167	2.125	1.667	1.917	1.833	2.375	2.167	2.583	0.000	1.958
C_{34}	2.833	2.833	2.667	2.750	2.958	2.583	2.750	2.292	2.167	2.000	0.000

Note: The average sample gap = $\frac{1}{n(n-1)} \sum_{i=1}^n \sum_{j=1}^n \left(\left| a_{ij}^s - a_{ij}^{s-1} \right| / a_{ij}^s \right) \times 100\% = 1.32\% < 5\%$, where n is the number of criteria, s is the sample of 24 experts and significant confidence is 98.68% (more than 95%).

Table 3
The total influence matrix of criteria T_c .

T	C_{11}	C_{12}	C_{13}	C_{21}	C_{22}	C_{23}	C_{24}	C_{31}	C_{32}	C_{33}	C_{34}
C_{11}	0.479	0.538	0.501	0.512	0.579	0.535	0.576	0.423	0.453	0.374	0.514
C_{12}	0.538	0.410	0.467	0.470	0.525	0.490	0.530	0.386	0.410	0.341	0.459
C_{13}	0.513	0.491	0.374	0.453	0.509	0.469	0.507	0.383	0.399	0.336	0.445
C_{21}	0.537	0.488	0.466	0.405	0.556	0.486	0.541	0.404	0.428	0.351	0.493
C_{22}	0.593	0.546	0.506	0.536	0.493	0.524	0.594	0.446	0.469	0.387	0.535
C_{23}	0.568	0.531	0.500	0.494	0.545	0.428	0.559	0.429	0.448	0.368	0.514
C_{24}	0.628	0.583	0.548	0.579	0.638	0.577	0.531	0.493	0.507	0.428	0.576
C_{31}	0.461	0.432	0.406	0.438	0.492	0.434	0.486	0.309	0.398	0.336	0.429
C_{32}	0.469	0.441	0.421	0.421	0.472	0.419	0.467	0.377	0.320	0.335	0.426
C_{33}	0.438	0.420	0.398	0.392	0.439	0.401	0.451	0.357	0.384	0.254	0.401
C_{34}	0.554	0.523	0.492	0.505	0.560	0.506	0.553	0.429	0.443	0.376	0.421

Table 5

Sum of influences given/received on criteria.

Criteria	r_i	y_i	$r_i + y_i$	$r_i - y_i$
C ₁₁	5.483	5.777	11.260	−0.294
C ₁₂	5.025	5.404	10.429	−0.380
C ₁₃	4.881	5.079	9.960	−0.199
C ₂₁	5.154	5.205	10.359	−0.051
C ₂₂	5.629	5.808	11.437	−0.179
C ₂₃	5.384	5.269	10.653	0.115
C ₂₄	6.088	5.795	11.884	0.293
C ₃₁	4.622	4.435	9.057	0.186
C ₃₂	4.569	4.660	9.228	−0.091
C ₃₃	4.334	3.885	8.220	0.449
C ₃₄	5.361	5.212	10.573	0.149

to make daily life more comfortable. Thus, mobile wallet services (C₃₃), remote control services (C₃₁) and mobile multimedia services (C₃₄) offered by telecommunication services suppliers influence location based services (C₃₂). Furthermore, mobile wallet services (C₃₃), remote control services (C₃₁) and mobile multimedia services (C₃₄) influence the perception of convenience for mobile convenience (D₃). The product function (D₂), operating system (C₂₄) and touch panel (C₂₃) designed by the suppliers of the smart phone influence the memory (C₂₁) and processor (C₂₂) and will influence the maximum achievable efficiency of the product function (D₂). Finally, in the case of customer equity (D₁), the customer is influenced by mobile convenience (D₃) and product function (D₂), and the firm can more fully understand the importance of retention equity (C₁₃) to influence value equity (C₁₁) and brand equity (C₁₂) to satisfy customer needs.

4.2. Evaluating the performance with VIKOR

Our case study of the five enterprises of smart phones in the Taiwanese market can proceed by performance evaluation and improvement with VIKOR, based on the DANP influential weights, as shown in Table 9. The total/dimension gaps from each criterion

can be obtained from the product of each local weight and its gap, after which each firm's rankings can be obtained. Furthermore, the improvement of these gaps to enhance each dimension/criterion's performance is considered.

Table 9 revealed that for firm A, C, and E, the criterion with the largest gap is mobile wallet services (C₃₃), whereas for firms B, that criterion is remote control services (C₃₁), and for firm D, the criteria with the largest gaps are remote control (C₃₁) and mobile wallet services (C₃₃). Therefore, the 5 firms can proceed with priority improvement with the criterion or criteria with the largest gap. In addition, firm A has the smallest gap in the touch panel (C₂₃); firm B has a relatively small gap in brand equity (C₁₂), retention equity (C₁₃) and mobile multimedia services (C₃₄); firm C is relatively liked by the customer in brand equity (C₁₂) and the operating system (C₂₄); firm D is approved by consumers in terms of retention equity (C₁₃); and firm E is relatively favored by consumers in terms of the memory (C₂₁) and mobile multimedia services (C₃₄). Therefore, every firm can promote its competitive advantage by improving these gaps (i.e., approaching the aspiration level).

A gap represents the distance between a criterion's performance and aspiration level. Among the firms, firm C offers the best investment, given its number one ranking. The comprehensive indicator (G_k) of firm C is closest to the aspiration level and has the lowest value (0.296). To achieve the aspiration level in each dimension and criterion for firm C, the gap values of priority improvement for decision makers of firm C can be ordered as mobile convenience (D₃) (0.259) – product function (D₂) (0.189) – customer equity (D₁) (0.186). For decision makers, enhancing the mobile convenience services should provide easier simpler way to achieve the aspiration level. In mobile convenience (D₃), the gap values of priority improvement are ordered as mobile wallet services (C₃₃) (0.375) – remote control services (C₃₁) (0.346) – mobile multimedia services (C₃₄) (0.183) – location based services (C₃₂) (0.163). Decision makers can provide the ideal mobile payment to achieve the desired level of mobile convenience. In the product function (D₂), the gap values of priority improvement are

Table 6The unweighted super-matrix $\bar{W}$.

Criteria	C ₁₁	C ₁₂	C ₁₃	C ₂₁	C ₂₂	C ₂₃	C ₂₄	C ₃₁	C ₃₂	C ₃₃	C ₃₄
C ₁₁	0.315	0.380	0.372	0.360	0.360	0.355	0.357	0.355	0.352	0.349	0.353
C ₁₂	0.354	0.290	0.356	0.327	0.332	0.332	0.332	0.333	0.331	0.334	0.333
C ₁₃	0.330	0.330	0.271	0.313	0.308	0.313	0.311	0.312	0.316	0.317	0.314
C ₂₁	0.232	0.233	0.234	0.204	0.250	0.244	0.249	0.237	0.237	0.233	0.238
C ₂₂	0.263	0.261	0.263	0.280	0.230	0.269	0.275	0.266	0.265	0.261	0.264
C ₂₃	0.243	0.243	0.242	0.244	0.244	0.211	0.248	0.234	0.236	0.238	0.238
C ₂₄	0.262	0.263	0.262	0.272	0.276	0.276	0.228	0.263	0.263	0.268	0.260
C ₃₁	0.240	0.242	0.245	0.241	0.243	0.244	0.246	0.210	0.259	0.256	0.257
C ₃₂	0.257	0.257	0.255	0.255	0.255	0.255	0.253	0.271	0.219	0.275	0.266
C ₃₃	0.212	0.214	0.215	0.209	0.211	0.209	0.214	0.228	0.230	0.182	0.225
C ₃₄	0.291	0.287	0.285	0.294	0.291	0.292	0.287	0.291	0.292	0.287	0.252

Table 7The weighted super-matrix $\bar{W}^{\#}$.

Criteria	C ₁₁	C ₁₂	C ₁₃	C ₂₁	C ₂₂	C ₂₃	C ₂₄	C ₃₁	C ₃₂	C ₃₃	C ₃₄
C ₁₁	0.108	0.130	0.127	0.128	0.128	0.126	0.127	0.125	0.124	0.123	0.124
C ₁₂	0.121	0.099	0.122	0.116	0.118	0.118	0.118	0.117	0.116	0.118	0.117
C ₁₃	0.113	0.113	0.093	0.111	0.109	0.111	0.110	0.110	0.111	0.111	0.110
C ₂₁	0.085	0.085	0.086	0.071	0.087	0.085	0.086	0.085	0.085	0.084	0.085
C ₂₂	0.096	0.095	0.096	0.097	0.080	0.094	0.095	0.096	0.095	0.094	0.095
C ₂₃	0.089	0.089	0.089	0.085	0.085	0.073	0.086	0.084	0.085	0.086	0.086
C ₂₄	0.096	0.096	0.096	0.095	0.096	0.096	0.079	0.094	0.094	0.096	0.093
C ₃₁	0.070	0.071	0.072	0.072	0.072	0.073	0.073	0.061	0.075	0.074	0.074
C ₃₂	0.075	0.075	0.075	0.076	0.076	0.076	0.075	0.078	0.064	0.080	0.077
C ₃₃	0.062	0.063	0.063	0.062	0.063	0.062	0.064	0.066	0.066	0.053	0.065
C ₃₄	0.085	0.084	0.083	0.088	0.087	0.087	0.086	0.084	0.085	0.083	0.073

Table 8The influential weights of DANP when $\lim_{g \rightarrow \infty} (\mathbf{W}^g)$.

Criteria	C_{11}	C_{12}	C_{13}	C_{21}	C_{22}	C_{23}	C_{24}	C_{31}	C_{32}	C_{33}	C_{34}
DANP weights	0.124	0.116	0.109	0.084	0.094	0.085	0.094	0.072	0.075	0.063	0.084

Table 9

The performance evaluation of the case study using VIKOR.

Dimensions/criteria	Local weights	Global weights	Gaps				
			Firm A	Firm B	Firm C	Firm D	Firm E
<i>Customer equity</i> (D_1)	0.349		0.230	0.355	0.186	0.211	0.415
Value equity (C_{11})	0.355	0.124	0.231	0.375	0.202	0.250	0.375
Brand equity (C_{12})	0.332	0.116	0.192	0.344	0.135	0.250	0.438
Retention equity (C_{13})	0.312	0.109	0.269	0.344	0.221	0.125	0.438
<i>Product function</i> (D_2)	0.357		0.225	0.456	0.189	0.424	0.390
Memory (C_{21})	0.235	0.084	0.298	0.375	0.260	0.375	0.313
Processor (C_{22})	0.263	0.094	0.250	0.500	0.212	0.500	0.375
Touch panel (C_{23})	0.239	0.085	0.163	0.438	0.154	0.375	0.500
Operating system (C_{24})	0.263	0.094	0.192	0.500	0.135	0.438	0.375
<i>Mobile convenience</i> (D_3)	0.294		0.293	0.470	0.259	0.511	0.397
Remote control services (C_{31})	0.244	0.072	0.337	0.563	0.346	0.750	0.375
Location based services (C_{32})	0.256	0.075	0.298	0.500	0.163	0.375	0.375
Mobile wallet services (C_{33})	0.214	0.063	0.385	0.500	0.375	0.750	0.563
Mobile multimedia services (C_{34})	0.287	0.084	0.183	0.344	0.183	0.250	0.313
S_k			0.247	0.425	0.208	0.375	0.401
P_k			0.385	0.563	0.375	0.750	0.563
G_k			0.320	0.498	0.296	0.567	0.486
Ranking			(2)	(4)	(1)	(5)	(3)

Note: Gap $r_{kj} = (|f_j^* - f_{kj}|) / (|f_j^* - f_j^-|)$, where r_{kj} represents relative gap in j criterion for k alternative, f_{kj} represents the performance value in each criterion j for k alternative, f_j^* represents the aspiration level (setting $f_j^* = 4$), f_j^- represents the worst value (setting $f_j^- = 0$).

ordered as memory (C_{21}) (0.260) – processor (C_{22}) (0.212) – touch panel (C_{23}) (0.154) – operating system (C_{24}) (0.135). Decision makers can provide high-speed access, high capacity and low power consumption to achieve the desired level of the product function. In customer equity (D_1), the gap values of priority improvement are ordered as retention equity (C_{13}) (0.221) – value equity (C_{11}) (0.202) – brand equity (C_{12}) (0.135). Decision makers can provide very important person (VIP) and affinity programs that help achieve the desired level of the customer equity.

4.3. Results and discussions

According to real world relationships, the DEMATEL technique could be used to establish the valuation model of the smart phone, specifically, to find the interrelationships among dimensions/criteria and to obtain the total influence matrix by criteria (the traditional concept, which assumes that the dimensions/criteria are independent, obtains the total comparative matrix). Then, we used the basic concepts of the ANP with the clustored normalized total influence matrix $\mathbf{T}_c^B$ by dimensions (or clusters/groups), with which the unweighted super-matrix $\mathbf{W} = (\mathbf{T}_c^B)'$ can be easily obtained; the weighted super-matrix $\mathbf{W}^B = \mathbf{T}_D^B \mathbf{W}$ also can be obtained from the product of the normalized total influence matrix $\mathbf{T}_D^B$ by dimensions and the unweighted super-matrix. Finally, the relative influential weights of the DANP can be obtained by calculating $\lim_{g \rightarrow \infty} (\mathbf{W}^g)$ (the traditional concept only determines relative important weights). Furthermore, we used VIKOR to combine the influential weights with each normalized performance (gap $r_{kj} = (|f_j^* - f_{kj}|) / (|f_j^* - f_j^-|)$, based on the aspiration level f_j^* and the worst value f_j^-), to integrate each criterion into each dimensional performance and the total performance. We can subsequently improve the problems of the smart phone according to the influential network relation map to reduce the gap (r_{kj}) for achieving the aspiration level (the traditional concept can perform only selection/

ranking, not improvement), based on the interrelationships of dependence and the feedback problem in the real world.

In this paper, based on the empirical case of five enterprises of the smart phone, a hybrid MCDM model combining the DANP and VIKOR obtained results as follows. First, the DEMATEL technique is used to determine the influential relationships among dimensions/criteria and to establish their INRM within dimensions/criteria through pairwise comparisons, as shown in Fig. 3. Therefore, the three dimensions can be easily shown to influence each other, such as mobile convenience (D_3) influences customer equity (D_1) and product function (D_2), but product function (D_2) influences customer equity (D_1). These influential relationships will support managers' decision making. For example, the managers will consider how to promote the market share of smart phones and actions such as requesting firms to improve mobile convenience. Another option is that the managers can reference D_3 to advise their firms to improve mobile wallet services (C_{33}) for upgrading their mobile convenience first. In other words, managers can reference the INRM of the DEMATEL technique to improve their priority of dimensions/criteria in the evaluation/improvement model for the smart phone. Second, how does the DANP differ from the ANP? The ANP is based on the assumed relationships among dimensions to obtain relative important weights to achieve selection/ranking. The DANP can obtain relative influential weights based on real world relationships; hence, combining the DANP and VIKOR in weighting can be used in not only ranking and selection but also improvement. In addition to the DEMATEL technique, which can construct interrelationships among dimensions/criteria, the ANP thus can be used to resolve the problems of interdependence and feedback. Therefore, based on the DANP (using the basic concepts of the ANP in the influential matrix of the DEMATEL technique), the problems of interdependence and feedback in the real world can be solved. As Table 8 shows, the DANP was used to obtain the influential weights of dimensions/criteria for the empirical case. Based on the DANP, the global and the local influential weights of the dimensions/criteria can be obtained. Then, by

combining the DANP and VIKOR, the total average gaps (S_k) of firms A, B, C, D, and E are 0.247, 0.425, 0.208, 0.375 and 0.401, respectively. According to the gap, we find that firm C offered the best investment alternative, i.e., firm C had the lowest total average gap of all firms. Firm D, by contrast, must prioritize improvement because it had the largest maximum gap (P_k). The next point discusses how the smart phone can be improved for future use. Third, this study not only used the best selection but also analyzed which gaps of dimensions/criteria should be prioritized in improvement. Considering how people subsequently can reduce the gaps for achieving the aspiration level (resulting in no gap) in firm C is an important topic in our research (as shown in Table 10). For the improvement plan of the smart phone shown in Table 10, the influential relationship of dimensions and criteria are illustrated with an INRM (Fig. 3). Based on the degrees of influence, the improvements can be prioritized in the following order: mobile convenience (D_3), product function (D_2), and customer equity (D_1). These dimensions revealed that mobile convenience (D_3) is most influential in satisfying customer needs. The influential network of criteria produces an identical effect within individual dimensions. In particular, mobile wallet services (C_{33}), the operating system (C_{24}) and retention equity (C_{13}) are more influential in the individual dimension than are other criteria, thus indicating that mobile wallet services (C_{33}) can improve mobile convenience (D_3), including mobile commercial innovation, dynamic information exchange, security and competitiveness. Moreover, the operating system (C_{24}) can improve the product function (D_2), including the effective management and distribution of resources. Finally, retention equity (C_{13}) can improve customer equity (D_1), including loyalty programs, affinity programs and knowledge-building programs, thereby offering decision makers multiple solutions for priority improvement. Considering the influential effects, the strategies can be designed as shown in Table 10. In addition, as shown in Tables 9 and 10, the dimension of mobile convenience (D_3), with the largest gap value (0.259), should be prioritized in improvement if firm C's decision makers seek to achieve a zero gap. Likewise, the results revealed that mobile convenience (D_3) best predicts customer satisfaction. Smart phones have been considered as a value-added product that will provide the consumers with significant added value in mobility, convenience and personalization. Therefore, priority improvement for mobile convenience (D_3) can present the customers' needs in real world.

Why and how trends in future prospects of MCDM model? Which problems will be improved for satisfying the users'/customers'/social needs in marketing situations and how overall considering

problems in dimensions and criteria can be achieved the aspiration level? However, we find that the traditional MCDM field (Büyüközkan, 2009; Büyüközkan et al., 2008; Işıklar & Büyüközkan, 2007; Chen, Hu, et al., 2010; Zavadskas & Turskis, 2011) ignored some important new concepts and trends, needed some assumptions limit/defects to solve real world problems. New concepts and trends of hybrid MCDM in this paper can be used to solve actual problems, and the details are explained as follows. First, the traditional model assumes that the criteria in value-created are independent and hierarchical in structure; however, criteria are often interdependent in real world problems; because "Statistics and Economics are unrealistic in the real world", so DEMATEL technique can be used to seek the interrelationship matrix and build an INRM for solving the relationship problems in real world. Second, the relative good solution from the existing alternatives is replaced by the aspiration level to avoid "Choose the best among inferior choices/alternatives", i.e., avoid "Pick the best apple among a barrel of rotten apples". Third, the emphasis in hybrid MCDM field has shifted from ranking and selection when determining the most preferable approaches to performance improvement of existing methods based on INRM, because "we need a systematic approach to problem-solving; instead of addressing the systems of the problem, we need to identify the sources of the problem".

5. Conclusion

This study explores smart phone improvements by using a hybrid MCDM model, a method which determines an interrelationship matrix and builds an INRM for solving the relationship problems in the real world. The dimensions and criteria that influence the performance of smart phones have been identified in prior literature. These are outlined in this study and serve as bridging mechanisms for the smart phone enhancements. There are two main contributions of this study. First, the evaluation of smart phone is a decision-making problem that is composed of complex interactions and dependences. In this study we develop a framework for smart phone improvements through the knowledge obtained from previous studies. Second, we designed the hybrid MCDM model (DEMATEL, DANP, and VIKOR) to develop an improvement method. This method can handle the complex interactions and interdependences among dimensions and criteria, thus producing results that allow the users to build a visual cause-and-effect diagram for evaluating the various strategy processes. This diagram can provide the decision makers a deeper understanding of smart phone improvements. In the concluding part of this study, we demonstrated how the results can provide guidance to manag-

Table 10
The proposed smart phone improvement plan.

Formula	Plan (order of priority improvement)
F1: influential network of dimensions	$D_3 - D_2 - D_1$
F2: influential network of criteria within individual dimensions	$D_3: C_{33} - C_{31} - C_{34} - C_{32}$ $C_{31} - C_{34} - C_{32}$ $C_{34} - C_{32}$ $D_2: C_{24} - C_{23} - C_{21} - C_{22}$ $C_{23} - C_{21} - C_{22}$ $C_{21} - C_{22}$ $D_1: C_{13} - C_{11} - C_{12}$ $C_{11} - C_{12}$ $D_3 - D_2 - D_1$ $D_3: C_{33} - C_{31} - C_{34} - C_{32}$ $D_2: C_{21} - C_{22} - C_{23} - C_{24}$ $D_1: C_{13} - C_{11} - C_{12}$
F3: order of gap value for dimensions in firm C (by gap value from high to low)	
F4: order of gap value of criteria for individual dimensions in firm C (by gap value from high to low)	

Note: dimension: customer equity (D_1), product function (D_2), mobile convenience (D_3). Criteria: value equity (C_{11}), brand equity (C_{12}), retention equity (C_{13}), memory (C_{21}), processor (C_{22}), touch panel (C_{23}), operating system (C_{24}), remote control services (C_{31}), location based services (C_{32}), mobile wallet services (C_{33}), mobile multimedia services (C_{34}).

ers by identifying the key criteria for decision-making and finding the best way to explore smart phone improvements.

Future research can expand the hybrid MCDM method into a general evaluation framework for exploring the smart phone improvements. And it can also use different methods, such as longitudinal studies, to identify other criteria or multiple objective decision making (MODM) models. These models have changeable spaces that can help the users in their win–win planning/designing to achieve the aspiration level, which is better than only achieving the ideal point during decision-making.

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