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EMPIRICAL ARTICLE

Exploring mobile banking services for user behavior in intention adoption: using new hybrid MADM model

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Abstract Mobile banking services are one of the most promising recent technological innovations. In this study, we developed a conceptual model to explore mobile banking services for user behavior in the financial banking industry in intention adoption. The aim of this study is to explore the effect of user behavior and guidance on the mobile banking services intention adoption structure model among customers based on decomposed theory of planned behavior and trust-related behaviors based on the knowledge of experts. In this study, we use a new hybrid model, the multiple attribute decision making (MADM) model, which combines decision making trial and evaluation laboratory (DEMATEL) for building an influential network relationship map (INRM), DANP (DEMATEL-based ANP) for determining the influential weights of criteria, and the VIKOR method using the influential weights to evaluate and integrate the criteria in the gaps and reduce the gaps to satisfy the users' behavior needs based on INRM. An empirical case of Taiwan's financial banking industry is used as an example to demonstrate the application of the proposed hybrid MADM model and its efficiency. In the results, we find that the proposed user behavior framework can offer a deeper understanding

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of the variables/criteria that influence the interrelationship for the intention adoption of mobile banking services by DEMATEL technique. We can also combine the influential weights of DANP with weighting gaps using the VIKOR method to evaluate how to reduce these gaps and provide the best improvement strategies to satisfy the mobile banking services for users' behavior needs.

Keywords Mobile banking services · User behavior · MADM (multiple attribute decision making) · DEMATEL (decision making trial and evaluation laboratory) · DANP (DEMATEL-based ANP) · VIKOR method

1 Introduction

In recent years, mobile banking services have emerged as one of the most promising technological innovations and have attracted considerable attention. Mobile banking service is a payment method using mobile phones as a new channel to provide and deliver financial banking services, which include both new services such as electronic or online payments, and traditional services, such as cash transferring, depositing checks, and paying bills conveniently, easily, and quickly. More people are communicating electronically which has also enabled financial banking to market their products and services via mobile phones. Additionally, internet use has also increased as internet access has become more convenient, available, and cheaper. Most people have a mobile phone, with an increasing number having internet capabilities, enabling mobile banking services (Ratten 2011). It is also cheaper for financial institutions to communicate with their customers via mobile phones than traditional advertising media, such as television and newspapers. These trends have led to the increased electronic availability of banking services and increased adoption of mobile banking services (Ratten 2011).

To endure in the competitive environment of current banking services, financial banking industry needs to consider the best management of costs of using numerous information technologies and uses the best practices to minimum costs. Mobile banking services greatly reduce banks' costs while improving client satisfaction because of the ease of access to financial transactions anywhere, anytime, that can be achieved using a mobile phone instead of waiting in line at bank counters (Andersson and Heinonen 2002; Kim et al. 2007). This trend of mobile banking service indicates a remarkable potential to the financial banking industry. Financial banking can maintain existing banking users in providing mobile banking services into the current information systems and has an opportunity to convert mobile phone users into banking consumers. On the other hand, maintaining mobile banking customers and attracting new customers may not be easy (Devaraj et al. 2002; Gefen et al. 2003). Hence, it is an important issue to understand what elements/criteria contribute to users' intention to use mobile banking services. Recent studies have shown an interest in exploring the intention adoption of the new financial banking channel. Nevertheless, most mobile banking service researches have applied a wide variety of frameworks and methods, making it difficult to compare these results of different researches and evolve an user behavior intention adoption theory in this field (Suoranta and Mattila 2004; Mallat et al. 2004; Riivari 2005; Scornavacca and Hoehle 2007; Herzberg 2007; Beiginia et al. 2011; Kazemi et al. 2013).

In theoretical aspects, the decomposed theory of planned behavior (DTPB) is a well-defined mode for explaining information system adoption behavior. Based on DTPB, adoption behavior is determined by behavior intentions toward a specific system, where the intentions are determined by three dimensions: (1) attitude, (2) subjective norms, and (3) perceived behavior control (Taylor and Todd 1995). The critical advantage of using DTPB is that it provides a framework for investigating the effects of external elements on information system adoption. Several researches have pointed out that user behavior for mobile banking services adoption can be appropriately explained by DTPB (Beiginia et al. 2011; Kazemi et al. 2013). Nevertheless, the explanatory power of the models was only under 40–60 % of the variance in an individual's intention adoption to apply information technology (Venkatesh and Davis 1996; Teo et al. 1999; Venkatesh 2000; Moon and Kim 2001; Gefen et al. 2003; Ong et al. 2004; Pikkarainen et al. 2004). In order to more realize behavioral intention to mobile banking services and to find the elements of mobile banking services adoption, it is necessary to propose an integrated model.

Therefore, the purpose of this research is to examine and evaluate elements of user behavior intention adoption in improving mobile banking services, exploiting dimensions from these researches in an integrated model for achieving aspiration level in each dimension and criterion. In particular, this study adopts trust-related behaviors as another key dimension of behavioral intention because mobile commerce or e-commerce transactions are just conducted without meeting face-to-face (Grazioli and Jarvenpaa 2000; Gefen et al. 2003). Explicitly, this study proposed a user behavior for a mobile banking services framework based on the DTPB and trust-related behaviors by focusing on the elements that influence user decisions about adopting mobile banking services in information systems for exploring user behavior in multistage (behavior intention and actual usage). The main advantage of this structure is the association of a greater number of predictor elements that are able to provide a fuller description of the user's intention toward and implementation of mobile banking services.

The traditional approach to mobile banking services assumes that the elements of user behavior are independent and hierarchical in structure; however, the elements are often interdependent in real-world problem. And, exploring mobile banking services has become a dynamic interrelationship in multi-attribute decision making (MADM) problem that must take into consideration several tangible and intangible elements. There are many mathematical techniques for the evaluation of mobile banking, such as the fuzzy analytic hierarchy process (AHP) (Lin 2011), and decision making trial and evaluation laboratory (DEMATEL). To the best of our knowledge, no study has been undertaken to discuss both the dynamic interdependency between criteria and the diverse opinions of decision-makers involved in user behavior by which to improve and select mobile banking services. So our proposed model considers multiple criteria and uses the MADM model that combines DEMATEL to build an influential network relation map (INRM), DANP (DEMATEL-based ANP) to determine the influential weights of criteria, and the weightings of VIKOR method by using the influential weights of DANP to evaluate and integrate the criteria in the gaps and reduce the gaps for satisfying user behavior needs based on INRM. The hybrid method endures the limitations of present decision models and can be used to help us analyze the criteria that influence mobile banking services for user behavior in the real world. In particular, we use Taiwan's financial banking industry as an example case to study the interdependence among the elements that influence mobile banking services for user behavior in the financial banking industry as well as evaluate alternative user behavior processes to achieve the aspiration levels of performance from mobile banking services.

This hybrid model offers a more useful way to solve the problems of evaluating the mobile banking services for user behavior in intention adoption improvement-selection problem. The contributions of this research are threefold. First, the evaluation of the information integration model can be considered a decision-making problem composed of complex dependences and interactions. This study conducted a review of the existing literature to generate 9 criteria and three information integration dimensions (attitude-related behaviors, perceived behavioral control, and trust-related behaviors) to evaluate the mobile banking services for user behavior in intention adoption models in the financial banking industry. Second, this study integrated DDANPV methods to develop an evaluation method that prioritizes the relative influential weights of the information integration dimensions and the criteria. Finally, the results of this study provide practical guidance for designing mobile banking services.

The remainder of this paper is organized as follows. Section 2 reviews the prior literatures to form the dimensions and criteria of mobile banking service for user behavior model. In Sect. 3, the hybrid MADM model is described. In Sect. 4, an empirical case study with applications is provided and the analysis of the result is discussed. Finally, conclusions are presented in Sect. 5.

2 Literature review

DTPB was developed by Taylor and Todd (1995). They developed the theory of planned behavior through breaking down framework of attitude, subjective norm, and perceived behavioral control (Luarn and Lin 2005). This resulted in increased power to explicate behavioral intentions and exact realizing of behavioral proceedings (Pedersen 2005). This study employs the DTPB (Taylor and Todd 1995) as the theoretical framework to understand mobile banking user behavior intention. In other fields, the framework of the DTPB has been successfully shown to be capable of explaining behavior intention such as the use of mobile banking (Shih and Fang 2004), the adoption of instructional technology (Shiue 2007), the continuance of electronic service (Hsu and Chiu 2004), etc. However, Davis (1989) argued that subjective norms are uncertain and hard to measure and as a consequence proposed the technology acceptance model (TAM) which assumes that intension is affected by both attitude and perceived usefulness. Previous studies indicated that subjective norm did not affect behavioral intention adoption in individual-oriented information technology such as word process, but affected behavioral intention in group-oriented information technology such as e-mail (Gefen et al. 2003), computer resource center (Taylor and Todd 1995), and online game (Hsu and Lu 2004), and many studies state that trust issues are an important topic in related researches such as mobile applications (Yan et al. 2013). Therefore, this study uses attitude-related behaviors, perceived behavioral control, and trust-related behaviors, as explanatory, and evaluates the elements for attitude and behavioral intention regarding the use of mobile banking services based on expert knowledge. This integrated research model is proposed to address this decision and evaluate user behavior issues. All infrastructural dimensions and critical evaluation criteria hypothesized in this research and the natures of their expected relationships with user's attitude toward intending and continuing to use mobile banking services are discussed next.

2.1 Attitude-related behaviors

Mobile banking services can be considered a technological innovation because it allows customers to conduct banking transactions without temporal and spatial constraints and connect banking services conveniently, easily, and quickly using mobile devices (Laukkanen 2007). The importance of innovation attributes has also been documented in the literature (Rogers 1995). Several studies reported on the influence of user perceptions of the innovation on their adoption decisions toward internet-based information systems (Tan and Thoen 2001; Teo and Pok 2003; Papies and Clement 2008; Lean et al. 2009). The innovation diffusion theory provides a set of attribute-related behaviors that may affect adoption decisions (Rogers 1995). These attributes include relative advantage (the degree which an innovation can benefit the organization), ease of use (opposite of complexity, the degree to which an innovation is easy to use), and compatibility (the degree to which an innovation is consistent with the adopter's existing values, beliefs, and experiences) (Rogers 1995; Lin 2011). Among these attribute-related behaviors, relative advantage, complexity, and compatibility were the most frequently identified factors in the adoption and diffusion of Internet-based technologies (Liao et al. 1999; Papies and Clement 2008; Vijayasarathy 2004). Hence, this study examines the extent to which these three predict attitude toward adopting (or continuing to use) mobile banking services.

Relative advantage is defined as the degree to which an innovation is perceived as a better alternative to currently available products or services and can be related to diverse economic, social, convenience, and satisfaction dimensions (Rogers 1962, 1983; Hanafizadeh et al. 2014). The inclusion of relative advantage in the model precluded the inclusion of the TAM's perceived usefulness because they are similar in content, with relative advantage being more comprehensive and encompassing more diverse dimensions than perceived usefulness. In the proposed framework, the more an individual perceives the relative advantages of mobile banking services, the better his/her attitude toward it. *Compatibility* is the degree to which the innovation fits with the potential adopter's existing values, previous experiences, and current needs (Rogers 1983). To the extent that the use of an innovation violates a cultural or social norm, it is less likely to be adopted. Exposure to, and experience with, related products may increase perceived compatibility. Finally, an innovation is more likely to be adopted if there is a direct and immediate need for the function the innovation will perform. *Complexity* represents the degree to which an innovation is perceived to be difficult to understand, learn, or operate (Rogers 1983). Generally, the simpler an innovation is to understand and use, the more likely it is to be adopted. Thus, the complexity would be expected to be negatively related to attitude. Complexity (and its corollary, ease of use) has been found to be an important factor in technology adoption decisions (Davis 1989; Moore and Benbasat 1991; Hanafizadeh et al. 2014).

2.2 Perceived behavioral control

Perceived behavioral control is defined as the resources and opportunities available to an individual who offer the conditions necessary for adopting a certain behavior (Ajzen 1991, 2005, 2012). In the proposed framework, perceived behavioral control is based on the potential user's perception about whether he/she is capable of using mobile banking services and possesses the required knowledge and resources to adopt the mobile banking services. Taylor and Todd (1995) decomposed this dimension into self-efficacy, resource-facilitating conditions, and technology-facilitating conditions. Following Bandura (1986), *self-efficacy* is defined as one's judgments of his or her capability of performing a behavior. Applied to mobile banking services, self-efficacy describes consumers' judgments of their own capabilities to obtain product information and purchase products or services with mobile banking (Shen et al. 2010). *Resource-facilitating conditions* refer to resource elements, such as time and money, and the resource compatibility issues that constrain usage (Taylor and Todd 1995; Smarkola 2008; Hanafizadeh et al. 2014). *Technology-facilitating conditions refers* to technology factors, such as hardware, software, and technology compatibility issues that constrain usage (Taylor and Todd 1995; Smarkola 2008; Hanafizadeh et al. 2014).

2.3 Trust-related behaviors

Mobile banking services are conducted through the wireless Internet, unlike traditional banking. It is necessary to distinguish between trust beliefs about a bank and trust in the wireless Internet as a platform for financial transactions. In this study, we focus on factors that drive existing customers of a bank to further adopt recently introduced wireless banking services. Therefore, in this study, on trust in new information technology phenomena, we conjointly examine three factors of trust based on the trust topology suggested by McKnight and Chervany (2002): disposition to trust, structural assurance, and trust belief. Disposition to trust, from the perspective of trust attributes, is defined as a general inclination to exhibit faith or belief in humanity and adopt a trusting stance toward others (McKnight et al. 2002). Disposition to trust is a general tendency to trust others and can be considered a personality trait (McKnight et al. 2002; Tan and Sutherland 2004; Luo et al. 2010). Structural assurance is the trust perception of the institutional environment (McKnight et al. 2002; Luo et al. 2010). In the perspective of mobile banking services, structural assurance is the perception of the availability of the necessary legal and technical structures such as encryption, promises/guarantees, insurances, regulations, and other procedures in the wireless Internet to ensure the successful completion of financial transactions with a bank. Trust belief is the perception that the trustworthiness of the service provider consists of a set of specific beliefs about integrity, benevolence, and competence (Gefen et al. 2003; McKnight et al. 2002; Luo et al. 2010).

Based on this mobile banking service for user behavior framework, three dimensions are included: (1) attitude-related behaviors, (2) perceived behavioral control, and (3) trust-related behaviors. These dimensions have potentially significant impacts on mobile banking services for user behavior in the financial banking industry and are thus highlighted as main evaluation dimensions. Furthermore, the criteria are laid out based on a literature review. Each dimension is affected by three criteria: the attitude-related behavior dimension is affected by relative advantage, compatibility, and complexity; the perceived behavioral control dimension is affected by self-efficacy, resource-facilitating conditions, and technology-facilitating conditions; and the trust-related behavior dimension is affected by disposition to trust, structural assurance, and trust belief (see Table 1).

3 Methodology

MADM is a methodology that can consider multiple criteria at the same time and helps the decision-maker evaluate and estimate the best case according to the characteristics of a limited number of cases (Tzeng and Huang 2011). The hybrid MADM analytical tools used in this study include the DEMATEL technique, DANP, and VIKOR method. First, DEMATEL technique was used to build the effect on each criterion and explore the relevance of the performance parameters. Subsequently, the DANP approach, based on influence relation matrix of the DEMATEL technique and using basic concept of ANP (Saaty 1996) to build the unweighted supermatrix and weighted supermatrix, was adopted to calculate the influential weights of criteria and dimensions. Ou Yang et al. (2008) proposed these methods to solve the dependence and feedback problems of the criteria to suit the real case. Finally, VIKOR method was used to empirically evaluate the overall gaps in mobile banking services for user behavior in multiple stages (the intention stage and adoption stage). The research processes are illustrated in Fig. 1.

3.1 Establishing a network relationship by DEMATEL technique

DEMATEL technique is an analytical method for building a structural model (see Appendix 1) for solving complex problems using a matrix and related mathematical theories to calculate the cause and effect of each element (Tzeng et al. 2005; Huang et al. 2007; Liou and Tzeng 2012; Chiu et al. 2013; Liu et al. 2013; Lu et al. 2013;

Table 1 Explanation of criteria

Dimensions/criteria	Descriptions	
Attitude-related behaviors (D_1)		
Relative advantage (C_1)	The degree to which an innovation provides benefits that supersede those of its precursor and may incorporate factors such as economic benefits, image enhancement, convenience, and satisfaction	Rogers (1962), Rogers (1983), Hsbollah and Idris (2009), Hanafizadeh et al. (2014)
Compatibility (C_2)	The degree to which an innovation is perceived as being consistent with the individual's values, past experiences, and needs. The more mobile banking service is perceived as being compatible with such values, experiences, and needs, the better the attitudes towards it	Rogers (1983), Hanafizadeh et al. (2014)
Complexity (C_3)	The degree to which an innovation is perceived to be difficult to understand, learn, or operate	Rogers (1983), Davis (1989), Moore and Benbasat (1991), Hanafizadeh et al. (2014)
Perceived behavioral control (D_2)		
Self-efficacy (C_4)	An individual's judgments of his/her capability to perform a behavior. Applied to mobile banking services, self-efficacy describes consumers' judgments of their own capabilities to obtain product information and purchase products or service with mobile banking services	Bandura (1986), Shen et al. (2010), Hanafizadeh et al. (2014)
Resource-facilitating conditions (C_5)	Related to resource factors, such as time and money, and resource compatibility issues that constrain usage	Taylor and Todd (1995), Hanafizadeh et al. (2014)
Technology-facilitating conditions (C_6)	Related to technological factors, such as hardware and software, and technology compatibility issues that constrain usage	Taylor and Todd (1995), Hanafizadeh et al. (2014)
Trust-related behaviors (D_3)		
Disposition to trust (C_7)	A general tendency to trust others; can be considered a personality trait	McKnight et al. (2002), Luo et al. (2010), Yan et al. 2013
Structural assurance (C_8)	Perceived availability of the necessary legal and technical structures, such as encryption, promises/guarantees, insurances, regulations, or other procedures, in the wireless Internet to ensure the successful completion of financial transactions with a bank	McKnight et al. (2002), Luo et al. (2010)
Trust belief (C_9)	Perceived trustworthiness of the service provider, consisting of a set of specific beliefs about integrity, benevolence, and competence	Gefen et al. (2003), McKnight et al. (2002), Luo et al. (2010)

Hu et al. 2014). The DEMATEL technique comprises five steps. The first step is to build the system which has n elements/criteria and develop the evaluation scale using pair-wise dimensions to perform the comparison and an integer scale from 0 to 4, representing no influence (0), low influence (1), medium influence (2), high influence (3), and extremely high influence (4) as a natural language for pair-wise

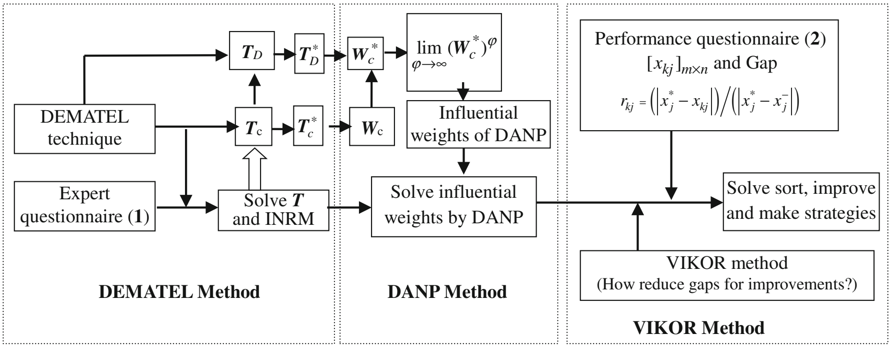

Fig. 1 Model procedure of the current research

comparison. The second step is to calculate the initial matrix to directly obtain the influential matrix (Chen et al. 2011). The third step is to normalize the matrix such that at least one column or row, but not all column and row, sums to one. The fourth step is to obtain the total influence matrix $\boldsymbol{T}$, and the fifth step is to obtain the prominence and relationships to build an influential network relationship map (INRM). Basic concept of the INRM of DEMATEL technique can distinguish the direct/indirect influential relationships among the criteria (i.e., INRM can measure the degree of any one criterion "to influence the all other criteria and to be influenced from the all other criteria"), allowing decision-makers to identify the key criteria to evaluate strategies for improving user behavior multistage performance in the real financial banking industry studied herein.

3.2 Finding the influential weights by DANP

After using total influence matrix $\boldsymbol{T}$ ($\boldsymbol{T}_c$ by criteria and $\boldsymbol{T}_D$ by dimensions) and applying the basic concept of ANP (Saaty 1996), unweighted supermatrix $\boldsymbol{W} = (\boldsymbol{T}_c^*)'$ and weighted supermatrix $\boldsymbol{W}^* = \boldsymbol{T}_D^* \boldsymbol{W}$can be found, and then the global influential weights ($w_1,\ldots, w_j,\ldots, w_n$) of DANP (DEMATEL-based ANP, called DANP) can be obtained by $\lim_{\varphi\to\infty}(\boldsymbol{W}_c^*)^{\varphi}$ (see Appendix 2). This approach yields more practical results in the real-world dynamic situation.

3.3 Evaluating the total performance by VIKOR method

VIKOR method was developed by Opricovic (1998) using the concept of compromise to evaluate the standards of different projects among the competition from the MADM model (Opricovic and Tzeng 2002, 2003, 2004, 2007). VIKOR method uses the class distance function based on the concept of the positive-ideal (or the aspiration level, as denoted herein) solution and negative-ideal (or the worst level, as denoted herein) solution, and puts the results in order (Liu et al. 2012; Chiu et al. 2013). For the normalized class distance function, it is better to be near the positive-ideal point (the aspiration level) and far from the negative-ideal point (the worst value) (Yu 1973). VIKOR is comprised the following steps. The first step is to check the best and worst values of the assessment criteria for normalization. The second step is to calculate the mean group utility based on the sum of all individual criterion regrets (i.e., average overall performance gaps, as well as those for each dimension and criterion and strategies for reducing these gaps in our this study), and calculate the maximal regret (i.e., maximal gap) of an individual criterion for improvement priority, both overall and for each dimension. The third step is to obtain the comprehensive/integrating indicators and ranked results provided to the decision-maker for implementing improvement strategies and reducing competitiveness gaps overall and in each dimensional/criterion performance (see Appendix 3).

4 An empirical study of the mobile banking services user behavior in Taiwan

In this section, an empirical study that only focused on Taiwan is displayed to illustrate the application of the proposed model for evaluating and selecting the best method that can help decision-makers to understand how to improve their evaluations of mobile banking services for user behavior for achieving aspiration level in criteria, dimensions, and overall.

4.1 Data collection

The data were collected from 42 knowledge experts who well understand mobile banking services trends and usage (in consensus, the statistical significance confidence is 99.937 %, which is greater than 95 %; i.e., gap error only is 0.063 %, <5 %). Owing to the 3rd Generation (3G), the applications of smartphone are popular and widely used in recent years, about 5 years in Taiwan. Therefore, the knowledge experts have more than 5 years of experience in useful mobile commerce which fulfills the request of content validity. Expert perspectives on all criteria within the criteria were collected via personal interviews and a questionnaire. Expert elicitation was conducted in June 2013, and it took 40–50 min for each subject to complete a questionnaire.

4.2 Constructing the influential network relationship by DEMATEL technique

In this paper, we confirmed DEMATEL decision-making structure and analyzed the user behavior perspective on mobile banking services from three dimensions with 9 criteria. Using the expert questionnaires, we obtained the total influence matrix $\boldsymbol{T}$ of the dimensions and criteria shown in Tables 2 and 3. We find experts' thoughts and opinions in three dimensions, and the relationship between the extents of the impact can also be found, which is compared to other dimensions in Table 2. According to the total influence prominence ($d_i + s_i$), "attitude-related behaviors (D_1)" have the strongest influence on the strength of the relationship and is, therefore, the most important influencing dimension. In contrast, "trust-related behaviors (D_3)" have the least effect. According to the influence relationship ($d_i - s_i$), we can also find that "perceived behavioral control (D_2)" most directly influences the other dimensions, and "trust-related behaviors (D_3)" are the most vulnerable to being influenced.

Based on Table 3, we can obtain all the criteria of the impact of the relationships with each criterion. Table 4 shows the relationship between the extents of the direct or indirect influences and compares them with those of other criteria. "Technology-facilitating conditions (C_6)" are the most important criterion for consideration; in addition, "structural assurance (C_8)" affects other criteria least. Furthermore, Table 4 also shows that "self-efficacy (C_4)" has the strongest influence on other criteria and that "technology-facilitating conditions (C_6)" are the most strongly influenced by other criteria.

4.3 Calculating the influential weights by DANP model

We use DEMATEL to confirm the influential relationship among the criteria and expect to obtain the most accurate influential weights. The purpose of DANP is to solve the interrelationship of interdependence and feedback problems among criteria. Therefore, we structure the quality assessment model using DEMATEL technique based on basic concept of ANP, and then our DANP (DEMATEL-based ANP) can obtain the influential weights (called global weights) of each criterion, as shown in Tables 4 and 5.

In addition, we also find that the critical criteria in the user behavior in the financial banking industry of mobile banking services are technology-facilitating conditions (C_6), trust belief (C_9), and compatibility (C_2). Furthermore, the influential weights are combined with the DEMATEL technique to assess the priority of problem-solving based on the gaps identified by the VIKOR method and the influence network relationship map (INRM).

4.4 Evaluating and integrating the total Gaps by VIKOR method

An empirical study involving mobile banking services for user behavior in multiple stages (behavior intention stage and actual usage stage) is used to evaluate and improve the total accreditation gaps using the VIKOR method, as listed in Table 5. Decision-makers can identify problem-solving issues according to this integrated index from the perspective of the criteria as a whole or that of an individual dimension.

Using the indices of overall dimensions and criteria, the gap values can be determined by the priority sequence improvement for reaching the aspiration level. In the intention stage, resource-facilitating conditions (C_5), with a higher gap value of 0.367, are the first criterion to be improved, followed by structural assurance (C_8) and technology-facilitating conditions (C_6). Of all the criteria, finance banking administrators are the most attentive to resource-facilitating conditions in the intention stage; in the adoption stage, resource-facilitating conditions (C_5), with a higher gap value of 0.369, are the first criterion to be improved. This criterion is followed by disposition to trust (C_7) and technology-facilitating conditions (C_6). At

Table 2 The total effect matrix of $\boldsymbol{T}_D$ and sum of effects on dimensions

Dimensions	D_1	D_2	D_3	d_i	s_i	$d_i + s_i$	$d_i - s_i$
Attitude-related behaviors (D_1)	0.827	0.808	0.816	2.451	2.534	4.985	−0.083
Perceived behavioral control (D_2)	0.890	0.780	0.824	2.494	2.324	4.818	0.171
Trust-related behaviors (D_3)	0.817	0.736	0.767	2.320	2.408	4.728	−0.087

Table 3 The total effect matrix of $\boldsymbol{T}_c$ for criteria

Criteria	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
Relative advantage (C_1)	0.772	0.848	0.898	0.734	0.756	0.975	0.832	0.785	0.921
Compatibility (C_2)	0.872	0.833	0.923	0.804	0.811	1.015	0.867	0.805	0.928
Complexity (C_3)	0.800	0.811	0.691	0.649	0.675	0.853	0.729	0.675	0.801
Self-efficacy (C_4)	0.892	0.945	0.915	0.661	0.777	0.982	0.835	0.775	0.910
Resource-facilitating conditions (C_5)	0.786	0.859	0.830	0.685	0.609	0.869	0.741	0.702	0.818
Technology-facilitating conditions (C_6)	0.922	0.958	0.901	0.773	0.786	0.879	0.861	0.816	0.962
Disposition to trust (C_7)	0.884	0.885	0.862	0.697	0.726	0.942	0.729	0.800	0.930
Structural assurance (C_8)	0.691	0.701	0.673	0.546	0.572	0.730	0.681	0.541	0.744
Trust belief (C_9)	0.884	0.895	0.880	0.721	0.736	0.951	0.868	0.807	0.807

$\frac{1}{n^2}\sum_{i=1}^{n}\sum_{j=1}^{n}\frac{\left|t_{ij}^{p}-t_{ij}^{p-1}\right|}{t_{ij}^{p}} \times 100\,\% = 0.063\,\% < 5\ \%$, i.e., significant confidence is 99.937 %, where $p = 42$ denotes the number of experts and t_{ij}^{p} is the average influence of i criterion on j; and n denotes number of criteria, here $n = 9$ and $n \times n$ matrix

Table 4 The sum of effects, the weight, and ranking of each criterion

Dimensions/criteria	d_i	s_i	$d_i + s_i$	$d_i - s_i$	Influential weights (local weights)
Attitude-related behaviors (D_1)					0.349
Relative advantage (C_1)	2.517	2.444	4.961	0.074	0.329
Compatibility (C_2)	2.628	2.491	5.119	0.136	0.339
Complexity (C_3)	2.301	2.511	4.812	−0.210	0.331
Perceived behavioral control (D_2)					0.320
Self-efficacy (C_4)	2.420	2.119	4.539	0.302	0.300
Resource-facilitating conditions (C_5)	2.162	2.172	4.333	−0.010	0.308
Technology-facilitating conditions (C_6)	2.438	2.730	5.168	−0.292	0.391
Trust-related behaviors (D_3)					0.331
Disposition to trust (C_7)	2.459	2.278	4.737	0.181	0.330
Structural assurance (C_8)	1.966	2.147	4.113	−0.181	0.309
Trust belief (C_9)	2.482	2.481	4.963	0.001	0.361

Table 5 The gap evaluation of mobile banking services intention adoption by VIKOR

Dimensions/criteria	Local weight	Global weight (FDANP)	Mobile banking services gap (r_{kj})	
			Behavior intention (A_1)	Actual usage (A_2)
Attitude-related behaviors (D_1)	0.349		0.191	0.142
Relative advantage (C_1)	0.329	0.115	0.107	0.088
Compatibility (C_2)	0.339	0.118	0.205	0.129
Complexity (C_3)	0.331	0.116	0.260	0.210
Perceived behavioral control (D_2)	0.320		0.293	0.268
Self-efficacy (C_4)	0.300	0.096	0.224	0.121
Resource-facilitating conditions (C_5)	0.308	0.099	0.367	0.369
Technology-facilitating conditions (C_6)	0.391	0.125	0.288	0.300
Trust-related behaviors (D_3)	0.331		0.295	0.288
Disposition to trust (C_7)	0.330	0.109	0.267	0.302
Structural assurance (C_8)	0.309	0.102	0.336	0.271
Trust belief (C_9)	0.361	0.120	0.286	0.288
S_{A1}	Total average gaps		0.258	0.231

Relative gaps to aspired value: $f_{kj} = (x_j^* - x_{kj})/(x_j^* - x_j^-)$, where f_{kj} denotes the relative gap with k alternatives in j criterion, x_{kj} denotes the performance value in each criterion j with k alternatives and scales from 0 (complete dissatisfaction) to 10 (extreme satisfaction), x_j^* denotes the aspired value (setting $x_j^* = 10$) in criterion j, and x_j^- denotes the worst value (setting $x_j^- = 0$) in criterion j

the same time, the expert finance banking administrators pay the most attention to resource-facilitating conditions in the adoption stage. These findings indicate the improvement priority sequence necessary for the overall criteria to reach the aspiration level, from the most to the least important criteria.

Improvement priority can also be applied to the individual dimension. In the attitude-related behaviors (D_1) of the intention stage, for instance, the priority gap values are ordered as follows: complexity (C_3), compatibility (C_2), and relative advantage (C_1). In the perceived behavioral control (D_2) of the intention stage, the priority gap values are ordered as follows: resource-facilitating conditions (C_5), technology-facilitating conditions (C_6), and self-efficacy (C_4). In the trust-related behaviors (D_3) of the intention stage, the improvement priorities are ordered as follows: structural assurance (C_8), trust belief (C_9), and disposition to trust (C_7). In the adoption stage, the improvement priorities are ordered as follows: (C_3), (C_2), and (C_1) in the attitude-related behaviors (D_1); (C_5), and (C_6), and (C_4) in the perceived behavioral control (D_2); and (C_7), (C_9), and (C_8) in the trust-related behaviors (D_3). Using the gap values provided by the panel experts above, the improvement priority schemes are unique and comprehensive, both in terms of the separate dimensions and overall, as shown in Table 5.

For decision-makers, understanding the improvement priorities for client mobile banking services for user behavior must be easier to understand than the gaps in multiple stages.

4.5 Results and discussions

The empirical results are discussed as follows. First, according to the DEMATEL model, we recognize the interrelationships among each dimension and criterion using the influence relationship network map for each dimension and criterion (as Fig. 2 shows). In Fig. 2, the perceived behavioral control (D_2) affects other dimensions, namely attitude-related behaviors (D_1) and trust-related behaviors (D_3); visibly perceived behavioral control (D_2) plays an important role and has the strongest influence on other dimensions. Thus, managers should improve it first, followed by attitude-related behaviors (D_1) and trust-related behaviors (D_3), when evaluating and improving mobile banking services for user behaviors in the financial banking industry.

Second, after analyzing the dimensions, we describe the criteria considered in each dimension. According to the results, we present an influence relationship-digraph-map of the criteria in Fig. 2. Hence, for the influence relationship among these criteria, in the attitude-related behaviors dimension (D_1), compatibility (C_2) was the most influential criterion and should be improved first, followed by relative advantage (C_1) and complexity (C_3) (see Fig. 2 for more details on the causal relationship in D_1); in the perceived behavioral control dimension (D_2), self-efficacy (C_4) was the most influential criterion and should be improved first, followed by resource-facilitating conditions (C_5) and technology-facilitating conditions (C_6) (see Fig. 2 for more details on the causal relationship in D_2); in the trust-related behaviors dimension (D_3), disposition to trust (C_7) was the most influential criterion and should be improved first, followed by trust belief (C_9) and structural assurance (C_8) (see Fig. 2 for more details on the causal relationships in D_3). Each of the evaluation dimensions and criteria creates the necessary behaviors for inducing mobile banking services for user behaviors in the financial banking industry. Therefore, managers should evaluate all of the dimensions and criteria for the mobile banking services for user behavior in accordance with Fig. 2. This evaluation method can be used in most of the financial banking industries in the world. However, top managers should bear in mind that, when applying this model, some differences will exist between each industry. The level of importance for the 9 criteria may vary according to the particulars of each financial banking industry, and the managers should compare the evaluation methods for each mobile banking services for user behavior model before deciding upon the optimal adoption method.

Third, the most important criterion calculated by DANP when evaluating mobile banking services for user behavior decisions was technology-facilitating conditions, weighted at 0.125, as shown in Table 5. Some new users of technology such as mobile banking services may be fearful and cautious when considering a new technology or technological service. Therefore, these consumers need assurance that reliable support will always be available should they need it. Mobile banking services are more likely to be adopted if the technological-facilitating conditions are better. On the other hand, the financial banking industry could proactively showcase functionalities and provide reassurance of their commitment in advertisements. Technology-facilitating conditions were, therefore, the most significant criterion when evaluating mobile banking services in the financial banking industry.

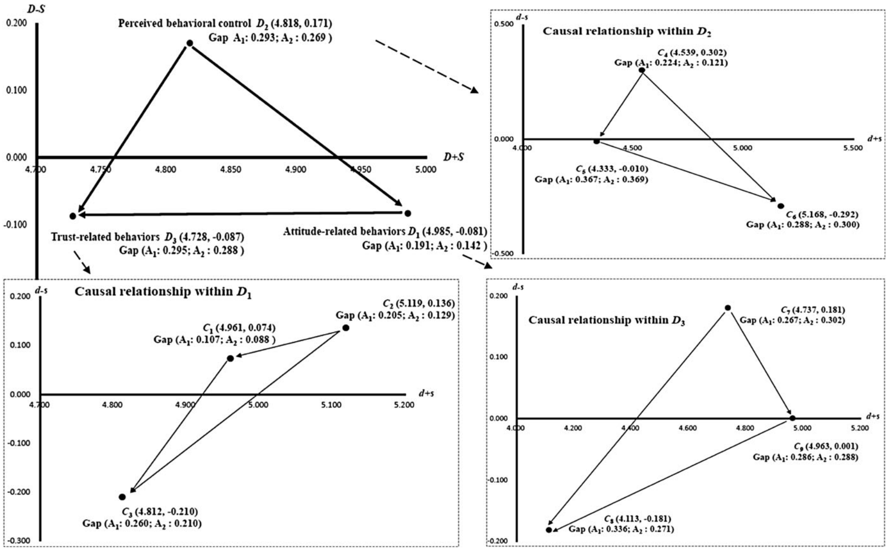

Fig. 2 The influential network relationship map of each dimension and criterion

Table 6 Sequence of improvement priority for multi-stages of mobile banking services for user behavior

Formula	Sequence of improvement priority	
F1: Influential network of dimensions	(D_2), (D_1), (D_3)	
F2: Influential network of criteria within individual dimensions	(D_1): (C_2), (C_1), (C_3)	
	(D_2): (C_4), (C_5), (C_6)	
	(D_3): (C_7), (C_9), (C_8)	
F3: Sequence of dimension to rise to aspired/desired level in multi-stages (by gap value, from high to low)	In behavior initiation	(D_3), (D_2), (D_1)
	In actual usage	(D_3), (D_2), (D_1)
F4: Sequence of criteria to rise to aspired/desired level within individual dimension in multi-stages (by gap value, from high to low)	In behavior initiation	
	(D_1): (C_3), (C_2), (C_1)	
	(D_2): (C_5), (C_6), (C_4)	
	(D_3): (C_8), (C_9), (C_7)	
	In actual usage	
	(D_1): (C_3), (C_2), (C_1)	
	(D_2): (C_5), (C_6), (C_4)	
	(D_3): (C_7), (C_9), (C_8)	

Finally, the overall gap values (i.e., the distance to 0) in Table 5 that indicate room for improvement are 0.258 in the intention stage, and 0.231 in the actual usage stage. From the multiple-stage perspective, the trust-related behaviors (D_3), featuring the largest gap (0.295) in the behavior intention stage, and the trust-related behaviors (D_3), featuring the largest gap value (0.288) in the actual usage stage, should be the first priority for improvement if decision-makers wish to achieve the desired level. For long-term improvement, the decision-makers should manage internal motivation carefully, as mentioned above. Given these empirical findings, our results, as holistically formulated in Table 6, fulfill the purpose of this research. Evaluating the mobile banking services for user behavior with the multiple-stages model provided by this study can extend to most financial industries involving mobile banking services for user behavior. However, financial banking administrators should be cautious when applying this model. The importance of the 9 criteria may vary according to the situation, and administrators should compare the mobile banking services for user behavior and define the gap in that stage before making a decision on the optimal technology use.

5 Conclusions

This research integrates the hybrid model such as the extended DTPB and the trust issues into a unified model of mobile banking. The proposed method can be used not only to handle the interactions and interdependences within a set of dimensions and criteria but also to produce more valuable information that can be used to build a visual cause-and-effect diagram for evaluating for user behavior models. The findings of this study indicate that the evaluation results are solid. Analysis of the evaluation results provides guidance to financial banking industry managers by identifying the key criteria facilitating the evaluation of user behavior models and finding the best way to improve existing mobile banking services for user behavior in intention adoption.

In the managerial implications, there are twofold. First, this new hybrid evaluation method for the information integration of mobile banking services for user behavior in intention adoption provides a guide for future top leaders of the financial banking industry, even if they do not completely understand how to evaluate the details of mobile banking service for user behavior in intention adoption models. Furthermore, the INRMs developed by the DEMATEL method help decision-makers understand how to improve their evaluations of mobile banking services for user behavior. To confirm the method proposed by this study, we used mobile banking services for user behavior applications to evaluate new channel fields for the financial banking industry. Second, the result indicates that the business effect is the critical element, and that the design and development of mobile banking services for user behavior model are the proper applications of our model in financial banking industry. This result verifies that the information integration and the mobile banking services for user behavior in the intention adoption structure are the most critical information integration fields in mobile banking services development.

Notwithstanding the above findings, this study has some limitations which should be dealt with in future works. First, the evaluation criteria of mobile banking services were generated from the literature review; these methods may exclude some possible influences on mobile banking effectiveness. Future research can use longitudinal studies; interviews and focus group are also required to observe the continuity in the use of mobile banking services. Next, although we developed an integrated model of mobile banking services, future research should extend this model with inclusion of diverse theoretical model and diverse antecedent. Future research can add and shed light on other relevant dimensions that better explain user intention adoption of mobile banking, such as context awareness value (e.g., timing, identification, location and activity). This is a dimension that we also found important during the investigation. Finally, this study is a case study which focused on Taiwan, which is a small island economy compared with many others, some with far more banking institutions. Future research can examine the mobile banking services evaluation model for different countries, and thus proves the practicality of the hybrid evaluation procedure proposed by this study.

Appendix 1: DEMATEL technique

DEMATEL technique is used to build an influence relationship matrix for dimensions/criteria to measure the cause and effect on each element. This technique is widely used in various types of complex studies to understand the intricacies of the problem structure. The DEMATEL technique contains five steps.

The first step confirms the number of elements in a system, n, and develops scales for measuring the influential relationship in each element, comparing contexts/criteria by pair-wise comparison, using a scale of 0–4 to represent a complete lack of influence (0), low influence (1), medium influence (2), high influence (3), and extremely high influence (4) by natural language.

The second step identifies an initial influence matrix, comparing influence interaction degree pairs to directly obtain the influence matrix $\boldsymbol{Z} = [z_{ij}]_{n\times n}$, where z_{ij} represents the degree that criterion i affects criterion j. If the ith criterion directly affects the jth criterion, then $z_{ij} \neq 0$; otherwise, $z_{ij} = 0$.

The third step normalizes the direct influence matrix to obtain the matrix $\boldsymbol{A}$ from Eqs. (1) and (2). The diagonal term of matrix $\boldsymbol{A}$ is zero, and the maximum sum of any row or column is 1.

$$\boldsymbol{A} = s\boldsymbol{Z}, \tag{1}$$

where

$$s = \min_{i,j}\left\{\frac{1}{\max_i \sum_{j=1}^{n} |z_{ij}|}, \frac{1}{\max_j \sum_{i=1}^{n} |z_{ij}|}\right\}, \quad i,j = 1,2,\ldots,n. \tag{2}$$

The fourth step obtains the total influence matrix $\boldsymbol{T}$ from Eq. (3):

$$\boldsymbol{T} = \boldsymbol{A} + \boldsymbol{A}^2 + \cdots + \boldsymbol{A}^h = \boldsymbol{A}(\boldsymbol{I} - \boldsymbol{A})^{-1}, \text{when} \lim_{h\to\infty} \boldsymbol{A}^h = [0]_{n\times n}, \tag{3}$$

where $\boldsymbol{A} = [a_{ij}]_{n\times n}$, $0 \le a_{ij} < 1, 0 < \sum_{j=1}^{n} a_{ij} \le 1,\ 0 < \sum_{i=1}^{n} a_{ij} \le 1$.If the total of at least one row or column is equal to 1 (but not all) in $\sum_{j=1}^{n} a_{ij}$ and $\sum_{i=1}^{n} a_{ij}$, then we can guarantee $\lim_{h\to\infty} \boldsymbol{A}^h = [0]_{n\times n}$, and $\boldsymbol{I}$ is the identity matrix.

The fifth step obtains prominence and relation. By totaling each row and column of the total influence matrix $\boldsymbol{T} = [t_{ij}]$, we obtain the sum of all row and column vectors as follows:

$$\boldsymbol{d} = [d_i]_{n\times 1} = \left[\sum\nolimits_{j=1}^{n} t_{ij}\right]_{n\times 1} = (d_1, \ldots, d_i, \ldots, d_n)',$$

$$\boldsymbol{s} = [s_j]'_{1\times n} = \left[\sum\nolimits_{i=1}^{n} t_{ij}\right]'_{1\times n} = (s_1, \ldots, s_j, \ldots, s_n)'.$$

The value d_i, the sum of all rows in the total influence matrix $\boldsymbol{T}$, represents the degree that the criterion directly or indirectly affects all other criteria. The value s_j, the sum of all columns in $\boldsymbol{T}$, represents the degree that the criterion is affected by all other criteria. According to the definition, when $j = i$, then $d_i + s_i$ represents the degree of the total influence relationship of i criterion which denotes to include i criterion affects all other criteria and is affected by all other criteria, meaning "prominence"; $d_i - s_i$ represents the degree of the effect on and from other criteria, showing the "net influence relationship". If $(d_i - s_i)$ is positive, then criterion i affects other criteria, and if $(d_i - s_i)$ is negative, then criterion i is influenced by other criteria.

Appendix 2: influential weights of DANP

We can use the DEMATEL technique to not only build the interacting relationships among the factors/criteria but also obtain the most accurate influential weights. We improve the traditional ANP to solve the interrelationship of dependence and feedback problems among factors/criteria. Therefore, we use the basic concept of ANP (Saaty 1996) as a basis with total influence matrix of DEMATEL technique to solve the influential weights. Thus, DANP (DEMATEL-based ANP) contains the following steps.

The first step develops the expert influence questionnaire structure of DEMATEL technique. The questionnaires are clearly described and broken down into components.

The second step develops an unweighted supermatrix $W = (\boldsymbol{T}_c^{\alpha})'$, transposing each normalized dimension (or called context/cluster) with the total degree of influence $\boldsymbol{T}_c^{\alpha}$ obtained from the total influence matrix T_c using the DEMATEL technique, as shown in Eq. (4) from Eq. (3).

$$\boldsymbol{T}_c = \begin{array}{c} \\ \\ \boldsymbol{D}_1 \begin{array}{c} c_{11} \\ c_{12} \\ \vdots \\ c_{1m_1} \end{array} \\ \vdots \\ \boldsymbol{D}_i \begin{array}{c} c_{i1} \\ c_{i2} \\ \vdots \\ c_{im_i} \end{array} \\ \vdots \\ \boldsymbol{D}_n \begin{array}{c} c_{n1} \\ c_{n2} \\ \vdots \\ c_{nm_n} \end{array} \end{array} \begin{array}{c} \begin{array}{ccccc} \boldsymbol{D}_1 & & \boldsymbol{D}_j & & \boldsymbol{D}_n \\ c_{11}\ldots c_{1m_1} & \cdots & c_{j1}\ldots c_{jm_j} & \cdots & c_{n1}\ldots c_{nm_n} \end{array} \\ \begin{bmatrix} \boldsymbol{T}_c^{11} & \cdots & \boldsymbol{T}_c^{1j} & \cdots & \boldsymbol{T}_c^{1n} \\ \vdots & & \vdots & & \vdots \\ \boldsymbol{T}_c^{i1} & \cdots & \boldsymbol{T}_c^{ij} & \cdots & \boldsymbol{T}_c^{in} \\ \vdots & & \vdots & & \vdots \\ \boldsymbol{T}_c^{n1} & \cdots & \boldsymbol{T}_c^{nj} & \cdots & \boldsymbol{T}_c^{nn} \end{bmatrix} \end{array} \tag{4}$$

The normalized T_c, with a total degree of influence, provides $\boldsymbol{T}_c^{\alpha}$ from the dimensions (contexts/clusters) shown in Eq. (5).

$$\boldsymbol{T}_c^{\alpha} = \begin{array}{c} \\ \boldsymbol{D}_1 \; c_{11}, c_{12}, \ldots, c_{1m_1} \\ \vdots \\ \boldsymbol{D}_i \; c_{i1}, c_{i2}, \ldots, c_{im_i} \\ \vdots \\ \boldsymbol{D}_n \; c_{n1}, c_{n2}, \ldots, c_{nm_n} \end{array} \overset{\begin{matrix} \boldsymbol{D}_1 & & \boldsymbol{D}_j & & \boldsymbol{D}_n \\ c_{11}\ldots c_{1m_1} & & c_{j1}\ldots c_{jm_j} & \cdots & c_{n1}\ldots c_{nm_n} \end{matrix}}{\begin{bmatrix} \boldsymbol{T}_c^{\alpha 11} & \cdots & \boldsymbol{T}_c^{\alpha 1j} & \cdots & \boldsymbol{T}_c^{\alpha 1n} \\ \vdots & & \vdots & & \vdots \\ \boldsymbol{T}_c^{\alpha i1} & \cdots & \boldsymbol{T}_c^{\alpha ij} & \cdots & \boldsymbol{T}_c^{\alpha in} \\ \vdots & & \vdots & & \vdots \\ \boldsymbol{T}_c^{\alpha n1} & \cdots & \boldsymbol{T}_c^{\alpha nj} & \cdots & \boldsymbol{T}_c^{\alpha nn} \end{bmatrix}} \tag{5}$$

We use $\boldsymbol{T}_c^{\alpha 11}$ to demonstrate the basic concept as example in Eqs. (6) and (7).

$$d_i^{11} = \sum\nolimits_{j=1}^{m_1} t_{cij}^{11}, i = 1, 2, \ldots, m_1, \tag{6}$$

$$\boldsymbol{T}_c^{\alpha 11} = \begin{bmatrix} t_{c11}^{11}/d_1^{11} & \cdots & t_{c1j}^{11}/d_1^{11} & \cdots & t_{c1m_1}^{11}/d_1^{11} \\ \vdots & & \vdots & & \vdots \\ t_{ci1}^{11}/d_i^{11} & \cdots & t_{cij}^{11}/d_i^{11} & \cdots & t_{cim_1}^{11}/d_i^{11} \\ \vdots & & \vdots & & \vdots \\ t_{cm_1 1}^{11}/d_{m_1}^{11} & \cdots & t_{cm_1 j}^{11}/d_{m_1}^{11} & \cdots & t_{cm_1 m_1}^{11}/d_{m_1}^{11} \end{bmatrix} = \begin{bmatrix} t_{c11}^{\alpha 11} & \cdots & t_{c1j}^{\alpha 11} & \cdots & t_{c1m}^{\alpha 11} \\ \vdots & & \vdots & & \vdots \\ t_{ci1}^{\alpha 11} & \cdots & t_{cij}^{\alpha 11} & \cdots & t_{cim_1}^{\alpha 11} \\ \vdots & & \vdots & & \vdots \\ t_{cm_1 1}^{\alpha 11} & \cdots & t_{cm_1 1}^{\alpha 11} & \cdots & t_{cm_1 m_1}^{\alpha 11} \end{bmatrix}. \tag{7}$$

We normalize the total influence matrix T_c into the normalized total influence matrix $\boldsymbol{T}_c^{\alpha}$ using its contexts; then, the unweighted supermatrix $\boldsymbol{W}$ is obtained by transposing $\boldsymbol{T}_c^{\alpha}$, i.e., $W = (\boldsymbol{T}_c^{\alpha})'$, according to the basic concept of ANP in an unweighted supermatrix $\boldsymbol{W}$, as shown in Eq. (8).

$$\boldsymbol{W} = (\boldsymbol{T}_c^{\alpha})' = \begin{array}{c} \\ \boldsymbol{D}_1 \; c_{11}, c_{12}, \ldots, c_{1m_1} \\ \vdots \\ \boldsymbol{D}_j \; c_{j1}, c_{j2}, \ldots, c_{jm_j} \\ \vdots \\ \boldsymbol{D}_n \; c_{n1}, c_{n2}, \ldots, c_{nm_n} \end{array} \overset{\begin{matrix} \boldsymbol{D}_1 & & \boldsymbol{D}_i & & \boldsymbol{D}_n \\ c_{11}\ldots c_{1m_1} & \cdots & c_{i1}\ldots c_{im_i} & \cdots & c_{n1}\ldots c_{nm_n} \end{matrix}}{\begin{bmatrix} \boldsymbol{W}^{11} & \cdots & \boldsymbol{W}^{i1} & \cdots & \boldsymbol{W}^{n1} \\ \vdots & & \vdots & & \vdots \\ \boldsymbol{W}^{1j} & \cdots & \boldsymbol{W}^{ij} & \cdots & \boldsymbol{W}^{nj} \\ \vdots & & \vdots & & \vdots \\ \boldsymbol{W}^{1n} & \cdots & \boldsymbol{W}^{in} & \cdots & \boldsymbol{W}^{nn} \end{bmatrix}} \tag{8}$$

In addition, Eq. (9) produces matrix $\boldsymbol{W}^{11}$. If the groups or criteria are independent, then the corresponding entry in the matrix is blank or zero. Matrix $\boldsymbol{W}^{nn}$ is obtained in a similar manner.

$$\boldsymbol{W}^{11} = (\boldsymbol{T}^{11})' = \begin{matrix} c_{11} \\ \vdots \\ c_{1j} \\ \vdots \\ c_{1m_1} \end{matrix} \begin{bmatrix} t_{c^{11}}^{\alpha 11} & \cdots & t_{ci1}^{\alpha 11} & \cdots & t_{cm_1 1}^{\alpha 11} \\ \vdots & & \vdots & & \vdots \\ t_{c^{1j}}^{\alpha 11} & \cdots & t_{cij}^{\alpha 11} & \cdots & t_{cm_1 j}^{\alpha 11} \\ \vdots & & \vdots & & \vdots \\ t_{c^{1m_1}}^{\alpha 11} & \cdots & t_{cim_1}^{\alpha 11} & \cdots & t_{cm_1 m_1}^{\alpha 11} \end{bmatrix}. \tag{9}$$

The third step obtains the weighting supermatrix, contextualizing the total influence relationship matrix $\boldsymbol{T}_D$, as in Eq. (10). Let each context of matrix $\boldsymbol{T}_D$ be normalized with the total degree of influence to obtain $\boldsymbol{T}_D^{\alpha}$. Eq. (11) shows the following result:

$$d_i = \sum_{j=1}^{n} t_D^{ij}, i = 1, 2, \ldots, n \quad \text{and } t_D^{\alpha ij} = t_D^{ij}/d_i, i = 1, 2, \ldots, n$$

$$\boldsymbol{T}_D = \begin{bmatrix} t_D^{11} & \cdots & t_D^{1j} & \cdots & t_D^{1n} \\ \vdots & & \vdots & & \vdots \\ t_D^{i1} & \cdots & t_D^{ij} & \cdots & t_D^{in} \\ \vdots & & \vdots & & \vdots \\ t_D^{n1} & \cdots & t_D^{nj} & \cdots & t_D^{nn} \end{bmatrix}. \tag{10}$$

$$\boldsymbol{T}_D^{\alpha} = \begin{bmatrix} t_D^{11}/d_1 & \cdots & t_D^{1j}/d_1 & \cdots & t_D^{1n}/d_1 \\ \vdots & & \vdots & & \vdots \\ t_D^{i1}/d_i & \cdots & t_D^{ij}/d_i & \cdots & t_D^{in}/d_i \\ \vdots & & \vdots & & \vdots \\ t_D^{n1}/d_n & \cdots & t_D^{nj}/d_n & \cdots & t_D^{nn}/d_n \end{bmatrix} = \begin{bmatrix} t_D^{\alpha 11} & \cdots & t_D^{\alpha 1j} & \cdots & t_D^{\alpha 1n} \\ \vdots & & \vdots & & \vdots \\ t_D^{\alpha i1} & \cdots & t_D^{\alpha ij} & \cdots & t_D^{\alpha in} \\ \vdots & & \vdots & & \vdots \\ t_D^{\alpha n1} & \cdots & t_D^{\alpha nj} & \cdots & t_D^{\alpha nn} \end{bmatrix} \tag{11}$$

Multiplying the normalized matrix $\boldsymbol{T}_D^{\alpha}$ by the unweighted supermatrix $\boldsymbol{W}$ gives the normalized supermatrix $\boldsymbol{W}^{\alpha}$, as shown in Eq. (12).

$$\boldsymbol{W}^{\alpha} = \boldsymbol{T}_D^{\alpha}\boldsymbol{W} = \begin{bmatrix} t_D^{\alpha 11} \times \boldsymbol{W}^{11} & \cdots & t_D^{\alpha i1} \times \boldsymbol{W}^{i1} & \cdots & t_D^{\alpha n1} \times \boldsymbol{W}^{n1} \\ \vdots & & \vdots & & \vdots \\ t_D^{\alpha 1j} \times \boldsymbol{W}^{1j} & \cdots & t_D^{\alpha ij} \times \boldsymbol{W}^{ij} & \cdots & t_D^{\alpha nj} \times \boldsymbol{W}^{nj} \\ \vdots & & \vdots & & \vdots \\ t_D^{\alpha 1n} \times \boldsymbol{W}^{1n} & \cdots & t_D^{\alpha in} \times \boldsymbol{W}^{in} & \cdots & t_D^{\alpha nn} \times \boldsymbol{W}^{nn} \end{bmatrix}. \tag{12}$$

The fourth step obtains the normalized supermatrix $\boldsymbol{W}^{\alpha}$. We can obtain the supermatrix limit by multiplying the normalized spuermatrix $\boldsymbol{W}^{\alpha}$ by itself several times until the supermatrix has converged and become a long-term stable supermatrix to a sufficiently large power g. Therefore, the weights of the influence of each criterion are obtained by $\lim_{g \to \infty} (\boldsymbol{W}^{\alpha})^{g}$, where g represents any number for the power/exponent. We use these processes to obtain the weights of influence.

Appendix 3: VIKOR method

The VIKOR method, developed by Opricovic and Tzeng (2003, 2004, 2007), solves the issues of conflicting criteria experienced by MADM. This method is based on the positive-ideal (or the desired level) and negative-ideal (or the least-desired) solutions, with a preference for staying close to the positive-ideal point. This is basic concept according to traditional thinking. The gap concept measures the proximity to the positive-ideal point. We describe the VIKOR method below.

The first step determines the values x_j^* and x_j^- in the quality criterion assessment criteria. The value x_j^* represents the positive-ideal point (desired levels or aspiration level in each criterion), which is the best score in criterion j. The value x_j^- represents the negative-ideal point, which is the worst score in criterion j. The development of the VIKOR method began with the following form of the L_p metric:

$$L_k^p = \left\{ \sum_{j=1}^{n} \left[w_j \left(\left| x_j^* - x_{kj} \right| \right) \Big/ \left(\left| x_j^* - x_j^- \right| \right) \right]^p \right\}^{1/p}, \tag{13}$$

where $1 \leq p \leq \infty$; $k = 1, 2, \ldots, m$, and the influential weight w_j is derived from DANP. In the article, we use the new concepts of Eqs. (14) and (15) to obtain the following results for the improvement gaps of each context/criterion based on interdependence and feedback problems:

$$x_j^* = \max_k x_{kj}, \quad j = 1, 2, \ldots, n \text{ (traditional approach)},$$
$$\text{We set the aspiration levels (new approach), vector } \boldsymbol{x}^* = (x_1^*, x_2^*, \cdots, x_n^*), \tag{14}$$

$$\begin{aligned} & x_j^- = \min_k x_{kj}, \quad j = 1, 2, \ldots, n \text{ (traditional approach)}, \\ & \text{We set the worst values (new approach), vector } \boldsymbol{x}^- = (x_1^-, x_2^-, \cdots, x_n^-). \end{aligned} \tag{15}$$

In basic concept of this new approach, we use the performance scores from 0 to 10 (complete dissatisfaction (0), ← 0, 1, 2, 3,…, 7, 8, 9, 10 → extreme satisfaction (10)) in questionnaires; therefore, that aspiration level can be set at 10 score and the worst value at zero score. Therefore, in this study, we set $x_j^* = 10, j = 1, 2,\ldots, n$ as the aspiration level and $x_j^- = 0, j = 1,2,\ldots,n$ as the worst value, which differs from traditional approach. In this approach, we set x_j^* as the aspiration level and x_j^- as the worst value because this approach allow us to avoid "Choose the best among inferior choices/options/alternatives (i.e., pick the best apple among a barrel of rotten apples)."

The second step calculates the minimal mean of the group utility F_k (minimal average gap) and maximal regret Q_k (maximal gap for all criteria or for each context of criteria to give improvement priority).

$$L_k^{p=1} = F_k = \sum_{j=1}^{n} w_j r_{kj} = \sum_{j=1}^{n} w_j \left(\left| x_j^* - x_{kj} \right| \right) / \left(\left| x_j^* - x_j^- \right| \right), \quad (16)$$

$$L_k^{p=\infty} = Q_k = \max_j \left\{ r_{kj} | j = 1, 2, \ldots, n \right\}, \quad (17)$$

where $r_{kj} = (|x_j^* - x_{kj}|)/(|x_j^* - x_{kj}|)(|x_j^* - x_j^-|)(|x_j^* - x_j^-|)$ represents the gap ratio (on a normalization scale) and F_k represents the ratios of the average gap from the aspiration level x_j^* to the performance value x_{kj} in criterion j of alternative k. In this article, we focus on minimizing the gap r_{kj} for all criteria $j = 1, 2,\ldots,n$. Then, w_j represents the relative influential weight of criterion j; w_j can be obtained from DANP based on the DEMATEL technique. Q_k represents the maximum gap in all criteria (or the context of each criterion of the k-th alternative) for prioritizing improvement.

The third step provides the comprehensive indicator R_k and its ranked results. Equation (17) computes these values. From Eq. (17), we observe how mobile banking for user behavior implementation can be improved to reduce the gaps for achieving the aspiration level based on the influential network relation map.

$$R_k = v(F_k - F^*)/(F^- - F^*) + (1 - v)(Q_k - Q^*)/(Q^- - Q^*). \quad (18)$$

Using the values derived from $S^* = \min_k S_k$ (traditional approach) or $F^* = 0$ (achieving the aspiration level where the gap is zero, our approach), $F^- = \max_k F_k$ (traditional approach) or $F^- = 1$ (the worst situation, our approach); $Q^* = \min_k Q_k$ (traditional approach) or $Q^* = 0$ (achieving the desired level, our approach), $Q^- = \max_k Q_k$ (traditional approach) or $Q^- = 1$ (the worst situation, our approach). Thus, in our approach, the gap for $S^* = 0$ and $F^- = 1$, and $Q^* = 0$, and $Q^- = 1$, we can re-write Eq. (17) as $R_k = vF_k + (1 - v)Q_k$(i.e., weighting two objectives F_k and Q_k). The weight $v = 1$ only considers how we can minimize the average gap (average regret), and the weight $v = 0$ only determines how to select the maximum gap for improvement. In general, $v = 0.5$, but this value can be adjusted depending on the situation.

Based on the above concepts, we can easily determine how to improve the gaps r_{kj} ($k = 1, 2,\ldots, m$; $j = 1, 2,\ldots, n$) and the improvement priority according to the influential network relationship map for the achieving aspiration level.

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