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ASSESSING THE DIFFUSION OF FINTECH INNOVATION IN FINANCIAL INDUSTRY: USING THE ROUGH MCDM MODEL

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Abstract. We develop a conceptual structure to explore how financial technology (FinTech) innovation is being implemented to deal with vague, inconsistent and ambiguous knowledge in actual world. The structure of this study is built upon the technology, organization, environment (TOE) context, which one uses the concept of multi-criteria estimation to measure the significance of FinTech innovation. We develop an integrated MCDM (multiple criteria decision-making) model through rough set theory help administrators obtain a strategic influence relation map for enhancing performance approaching towards the aspiration value. This model involves three steps: primary, we apply this rough number to define group views which reflect upon experts' real experiences; second, we use the rough DEMATEL-based ANP-(RDANP) to acquire the rough influential weights and rough influential network relationship map (RINRM) based on this TOE structure and its corresponding attributes; finally, we utilize the rough modified VIKOR with the influence to analyze the gap between the performance value and the aspirated level. The empirical case was originated from financial industry in Taiwan. According to the weighting results the expected benefits, technology integration, and competitive pressure were the most important criteria. Our results also illustrate how FinTech innovation can be used for promoting financial services.

Keywords: financial technology (FinTech) innovation; technology, organization, environment (TOE); rough MCDM (multiple criteria decision-making); rough influential network relationship map (RINRM).

JEL Classification: C02, C60, D22, D81, M10, O30.

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1. Introduction

FinTech technology (FinTech) is a developing innovation in the financial sector. The current speedy growth of FinTech is a significant appearance of financial sector innovation and is having a profound influence on the financial industries (Hasan et al., 2020; Cruz-García et al., 2021; Lee et al., 2021). These borders and shops have closed during lockdown owing to COVID-19, and Fintech has accelerated development, making a significant chance for Fintech companies (Fu & Mishra, 2022). It has reduced transaction costs and has assisted to alleviate the information asymmetry issue rising from the barriers of distance (Grennan & Michaely, 2021). With changes in the financial marketplace and the numerous needs of consumers, the conventional financial sector has started altering its risk governing, commerce procedures, and service models (Liu et al., 2020; Lee & Shin, 2018). FinTech is a service innovation that is prepared to take a novel path in financial services. FinTech offers novel channels of profit, fulfills consumers' needs, and improves regulatory capability. Numerous innovative FinTech service models have appeared in the financial marketplace (Muthukannan et al., 2020). However, the diffusion effect of financial technology refers to the way in which new financial technologies are adopted and spread throughout the financial system. The diffusion of innovation model can be used to simulate this process and to detect these key influences which impact the financial technology adoption. Nevertheless, due to the unique features of financial technology diffusion issues, adjustments may be necessary to the standard diffusion models used in other fields (Zhao et al., 2022; Makina, 2019; BenYishay et al., 2020). The adjustments may include accounting for regulatory frameworks, consumer behavior, and network effects. By adjusting the model, researchers can provide more accurate predictions of how financial technology will impact the financial industry (BenYishay et al., 2020). To fully understand the diffusion of FinTech innovation as an important research topic, we focus on applying many financial technologies innovation for systematizing procedures in the financial industries covering regular works and nonregular strategies. Similarly, the diffusion process is rarely clarified linearly or smoothly (BenYishay et al., 2020). Previous studies on diffusion of innovation has exposed that innovation need to be integrated or combined into the value chain to create any significant value for business entities (BenYishay et al., 2020; Makina, 2019). According to the dissemination of innovation literatures (Zhao et al., 2022; Coffie et al., 2021), we define the innovation of FinTech as the stage of initial evaluation of FinTech innovation by financial companies, that is, from the start-up stage to formal adoption, and lastly to full deployment. In the regularization phase, FinTech innovation has developed a necessary sector of this value chain of corporation.

The FinTech innovation involves changes, which coevolve to use systems and novel technologies (BenYishay et al., 2020; Coffie et al., 2021). In addition to technology, Zavolokina et al. (2016) recognized important organizational factors, including cross-departmental coordination and management support that may affect FinTech innovation, as well as environmental effects. For instance, Lu et al. (2015) found that the application of business to business mobile commerce is significantly influenced by the technical-organization-environment (TOE) structure of small- to medium-size enterprises (SMEs). However, these TOE factors have been checked separately based on different models and different data. The comprehensive theoretical structure of leading empirical research that fell short of these studies. This prompted us to set up a combined model to explore contextual factors and implementation phases. However, there have few studies to the implementation or improvement of the FinTech innovation in evaluating in the diffusion of the FinTech innovation process performance. This TOE framework is valuable to determine the primary assessment factors for the financial industry' the diffusion of the FinTech service in this study. The study includes numerous perspectives, such as "technological", "organizational", and environmental", perspective. Hence, the primary factors followed the TOE is able to mainly proposal and improve the diffusion of the FinTech innovation process performances in the financial industry.

Moreover, the study combined multiple criteria decision-making (MCDM) is the method used to consider evaluation factors through a set of comprehensive examinations with governable viewpoints of observation. The integrated approach can overcome uncertainty issue, and vagueness in yield of specialists and responses the most consistent protocol comments about the evaluation factors (Chang et al., 2021). Clearly, the execution of FinTech innovation evaluations for financial industry consist of numerous issues, thus implying an MCDM issue. Hence, to solve these research's gap, the study purposes at realizing the dynamics and factors behind this assessment for FinTech innovation, based on the concepts of the FinTech innovation, and uses rough mathematics, and rough MCDM, which is a verified approach for collecting the views of experts and determining reliable consequences. The strategy implemented by FinTech innovation is vague, independent, and self-righteous changes based on the practice and experience of specialist/expert. Some traditional MCDM prototypes cannot be classified as intricate network among the dissimilar hierarchical structures of environmental elements in the financial industry. This model MCDM usually uses the average judgment of specialist/expert regarding the decision-making procedure (Lu et al., 2022, 2020). Nevertheless, the method may be incorrect because there are considerable differences in the opinions/observations of experts. Therefore, we can apply rough numbers for determining the vague and subjective consensus decisions of specialists/experts. Rough numbers have a flexible boundary that can replicate the fuzzy and subjective decisions of decision makers (Lu et al., 2020, 2022, 2023; Liou et al., 2019). This approach develops a rough MCDM prototype that uses a rough number to evaluate the fuzziness and ambiguity of opinions based on the domain experts with practical experience. We use decision-making trial and evaluation laboratory (DEMATEL) method based on an ANP (DANP) through a rough technique to acquire rough influence weights and a rough influence network relation map (RINRM) of FinTech innovation and their parallel features. This approach is suitable for the VIKOR method that roughly affects the weight and roughly modifies it to analyze/improve how the performance gap value can be close to zero. The provided model can overcome the limitations of present judgment models, and can be used to investigating issues which impact real-world diffusion of multiple-phase performances. In this article, we examine the financial industry in Taiwan as a case study, searching for these interdependence concerns that influence FinTech innovation estimates, and provide alternatives that can be used to achieve the best innovation and multiple-phase performance during the diffusion of FinTech innovation.

Although the financial industry has explored the combination of TOE structure with IT innovation and improvement, managers still must improve their determination when adopting FinTech innovation for enhancing level in services, procedures, practices, and design. Due to the lack of factors to evaluate the application of FinTech innovation in former research, this current study investigates the potential progress of FinTech innovation in the financial industry from multiple phase. It can propose a suitable strategy for estimating performance improvement. Therefore, this research makes two contributions: first, it can establish a theoretical foundation that links the implementation of financial technology innovation with the multiple-phase performance of the financial industry; second, it can estimate the influence of FinTech innovation on diverse perspectives of multiple-phase performances in Taiwan, and Greater China. In the light of fierce competition, multiple-stage performance improvement is a serious topic in the financial industry. Hence, this purpose of the study is to investigate the effects/influences of technological perspectives (expected benefits, technology integration, security and privacy, and standards uncertainty), organizational perspectives (top management support, firm size, financial commitment, and organizational innovativeness), and environmental perspectives (regulatory environment, partner support, competitive pressure, and market expectation) on FinTech innovation implementation. The method and the assumed relationship of the model will be tested applying data collected from Taiwan's top financial industry managers and related researchers. In addition, the results of this research can empirically influence each other's perspective dimensions/criteria of financial technology innovation decisions by applying collective opinions of experts in practical experience instead of using some isolated cases. Through this management perspective and give the current and future administrative significance of FinTech innovation, the results of this research can help administrators FinTech innovation target appropriate decision models to effectively support FinTech innovation.

This remainder of the study is ordered as next. Section 2 is the literature reviews on information-technology/information-system implementation and TOE structure measurement models for FinTech innovation. Section 3 offers a rough MCDM prototype. Section 4 illustrates the offered methods in a case study by applying expert questionnaires that were acquired from Taiwan's financial industry as case study. Lastly, conclusions are offered in Section 5.

2. Theoretical background and literature review

The section inspects the perspectives of financial technology innovation and the estimation of factors related to the diffusion process. Estimations are selected and analyzed using expert questionnaires combined with the technological, organizational, and environmental literature to determine IT/IS adoption problems. Subsequently, we use the TOE structure to explore related estimation factors (which are integrated with IT/IS verification and review procedures) to measure the multiple-phase diffusion procedures. Significant investigations on these areas are concisely reviewed as follows.

2.1. FinTech innovation perspective

The association between organizational change and the application of FinTech innovation has always been a major concern in IT/IS innovation. FinTech is changing and creating competitors and financial services outside the traditional sectors (Goldstein et al., 2019). The appearance of IS-driven managerial transformations can be characterized as IT innovation (Coffie et al., 2021; Tomasi et al., 2018). According to the literature on technological innovation (Schilling, 2020), IT innovation implementation frequently involves novel procedures, production systems, or methods; it expects to sustain or enhance corporate performance and solve problems under extrinsic surroundings. The initial formulae of FinTech practices with dissimilar characteristics, including business process combinations, information exchange competences, and joint strategic support, have helped execute value chain actions (Gai et al., 2018).

The innovation of FinTech has also considerably affected commerce procedure variations, partnerships, and even commercial change (Gai et al., 2018; Liu et al., 2020; Lee & Shin, 2018); thus, FinTech innovation could be observed as an "IT innovation". This procedure of IT innovation diffusion has been separated into a diversity of phases, such as knowledge awareness, estimation, adoption, implementation, and expansion (Zhu et al., 2006); comprehension, adoption, implementation, and assimilation (Swanson & Ramiller, 2004); and initiation, adoption, and assimilation (Nam et al., 2019). As indicated, these phases can be grouped into two more universal phases: primary adoption choice and continued use. These are often mentioned as implementation and adoption decision (initiation) (Rogers, 2003). Therefore, according to the above-mentioned literature review and theoretical considerations, the research is consistent with two phases of FinTech innovation: the diffusion process, the estimation of financial technology innovation and the performance of FinTech innovation in multiple phases during the diffusion procedure.

The former denotes that the financial industries have started to estimate implementation of FinTech. The latter includes the performance of the financial industry using FinTech to maintain numerous commerce models.

2.2. FinTech innovation perspective

Based on the diffusion literature (Rogers, 2003), assimilating an IT innovation begins with a corporation's initial evaluation and awareness of the innovation (Nam et al., 2019; Rogers, 2003). This first phase, "… *amounts both to identifying and prioritizing needs and problems on the one hand and searching the organization's environment to locate innovations of potential usefulness to meet the organization's problems*" (Rogers, 2003). In this phase, the extent to which an innovation solves an issue determines whether the product will be used (Porter & Millar, 1985). Therefore, enhancing performance is a significant factor in motivating a corporation to implement IT practices. When examining FinTech innovation and its diffusion procedure, we regard its initiation as the first phase of the use diffusion procedure.

The second phase, following the technology implementation literature (Rogers, 2003), we explain FinTech innovation as deciding to use FinTech for value chain actions, including physically obtaining the technology and assigning resources. Researchers have compared the firms' internal structure before IT implementation decisions with the internal structure of IT practices that have not been adopted, and found significant differences in the internal resources and external environment between non-adopters and adopters (Nam et al., 2019; Zhu et al., 2003). Given that the judgment to adopt IT practices legitimizes the need to allocate new resources (Coffie et al., 2021), the phase is considered needed for an extensive technology application.

The third phase of the FinTech innovation diffusion procedure is the phase where it becomes important in a corporation's value chain activities. FinTech innovation is not always the mark of a corporation with a strong technological culture. The assimilation theory proposes that IT demonstrates an "assimilation gap", i.e., extensive use tends to lag after its implementation: "A novel technology might be presented amid great enthusiasm and enjoy widespread primary attainment, but nevertheless still fails to be thoroughly deployed among many acquiring firms" (Fichman & Kemerer, 1999). When IT innovation such as FinTech is implemented, it must be improved, integrated into relevant routines, and institutionalized. Upon its initial adoption, the corporation and its associates generally do not have enough information to use the system at its full potential; therefore, there are frequent misalignments between user surroundings and the novel technology (Schilling, 2020; Fichman & Kemerer, 1999). Moreover, integrating the process into the information system's relevant routines is a significant component of IS achievement (Nam et al., 2019). Routinization is another significant aspect that merits further research.

According to the literature review, we identify initiation, adoption, and routinization as the main phases for evaluating the FinTech innovation diffusion procedure. This is the same as the notional work of Thompson (1965), in which innovation implementation is analyzed by considering an initiation adoption implementation sequence. Empirically supported by subsequent literature (Zmud, 1982), Thompson (1965) defined implementation as "*the extent to which development*, *feedback*, *and adjustment activities are performed to ensure the innovation becomes ingrained within business activities*". This definition is the same as our routinization theory and proposals that advance the theory for a multiple-phase model. We now draw upon a TOE structure and identify its perspectives and factors.

2.3. The TOE perspectives of FinTech innovation

Previous literature has suggested that the TOE structure affords a proper initial argument for the investigation of an information system (Tornatzky & Fleischer, 1990). A theoretical model for FinTech innovation needs to account for principles that influence a business's susceptibility to use FinTech innovation, which is rooted in an administration's definite technological, organizational, and environmental settings. The TOE structure categorizes three perspectives that influence the procedures of adopting, implementing, and applying technological innovations. The technological perspective refers to the organization's new technology and the current technology in use. The organizational perspective describes explicative measures concerning the business and the resource amounts and size that are obtainable from within. Moreover, the environmental perspective is where a corporation has commercial activities concerning industries, government authorities, and competitors (Tornatzky & Fleischer, 1990). The structure is based on innovation diffusion theory, in which technological features and interior and exterior organizational features are emphasized as the drivers of technology diffusion (Rogers, 2003; Nam et al., 2019).

Some researchers have successfully applied the TOE structure to their studies (Oliveira et al., 2019; Cruz-Jesus et al., 2019; Abed, 2020). Cruz-Jesus et al., (2019) considered how TOE features affect the influence of a customer relationship management (CRM) system on the adoption phases in the construction, financial and banking, services, manufacturing, commerce, and distribution sectors. Abed (2020) inspected the TOE features in the adoption of social commerce in Saudi Arabian SMEs. Subsequently, Oliveira et al. (2019) established a model that considers TOE factors as the main driver for software-as-a-service (SaaS) adoption. They examined the model by applying a survey distributed to 2,000 leading companies listed by Dun & Bradstreet. Their investigation illustrated the value of applying the TOE structure in realizing how to implement the innovation of a multifaceted information system. Moreover, they suggested that future research address the possible application of the TOE model developed in their study for other technologies (Oliveira et al., 2019).

As a broad IT or innovation diffusion theory, the TOE structure can help study dissimilar innovations in each phase. Therefore, in the research, we established a theoretical model for FinTech innovation estimation by applying perspectives/factors with the diffusion process (initiation, adoption, and routinization) according to this TOE structure. Consistent with the TOE structure, we review and specify three perspectives: technological perspectives (expected benefits, technology integration, security and privacy, and standards uncertainty), organizational perspectives (firm size, top management support, financial commitment, and organizational innovativeness), and environmental perspectives (regulatory environment, partner support, competitive pressure, and market expectation), as shown in Table 1.

Table 1. Explanation of factors

Perspective/factor	Descriptions	
Technological perspective (*A*)		
Expected benefits (A_1)	It refers to a company that expects the strategic and operational benefits of adopting FinTech.	Brous et al. (2020)
Technology integration (A_2)	It refers to decreasing incompatibility among legacy systems andimproving the information systems' responsiveness.	Cruz-Jesus et al. (2019); Henningsson and Kettinger (2016); Lu et al. (2013)
Security and privacy (A_3)	It refers to the FinTech platform being deemed secure for conducting transactions by Internet and data exchange. Examples include security and personal data protection when using FinTech.	Abed (2020); Sun et al. (2018)
Standards uncertainty (A_4)	It refers to the inability to accurately forecast whether FinTech can deliver the intended outcomes and be stable over time.	Montiel et al. (2019)
Organizational perspective (*B*)		
Firm size (B_1)	It refers to large firms that usually have enough resources to pilot, experiment, and decide what standards and technology they need.	Knott and Vieregger (2020)
Top management support (B_2)	It refers to top management that can offer support, vision, and a promise to positively influence the FinTech innovation process.	Abed (2020); Cruz-Jesus et al. (2019); Oliveira et al. (2019)
Financial commitment (B_3)	It refers to the firm which can provide the resources of finance for FinTech, and is especially committed to investing in hardware, system integration, system enhancement, and employee training.	Chari et al. (2020)
Organizational innovativeness (B_4)	It refers to a company's willingness to make some changes, such as product innovation, process innovation, and service innovation, and potential sites must help make changes for FinTech.	Riivari and Lämsä (2019); Acar and Özşahin (2018)
Environmental perspective (*C*)		
Regulatory environment (C_1)	It refers to the FinTech concept that is related to governmental policies that influence information technology diffusion.	Lu et al. (2013); Sun et al. (2018)
Partner support (C_2)	It refers to the degree to which a company's suppliers and customers are ready and able to execute commerce activities by applying FinTech.	Lu et al. (2013)
Competitive pressure (C_3)	It refers to peer pressure to apply novel technology, a driving force for the application of novel technology due to its tendency to push companies to find competitive edges through innovation.	Cruz-Jesus et al. (2019)
Market expectation (C_4)	It refers to FinTech being pervasively adopted in the financial sector in the future.	Brooks et al. (2014)

3. Methods

The paper applies the DANP and modified VIKOR methods to assemble the MCDM model with rough numbers and resolve these problems of effect and feedback interrelations among certain factors/perspectives. This model also detects techniques that enhance these relation gaps in performance for individual factors/perspectives. Figure 1 illustrates this study's procedure.

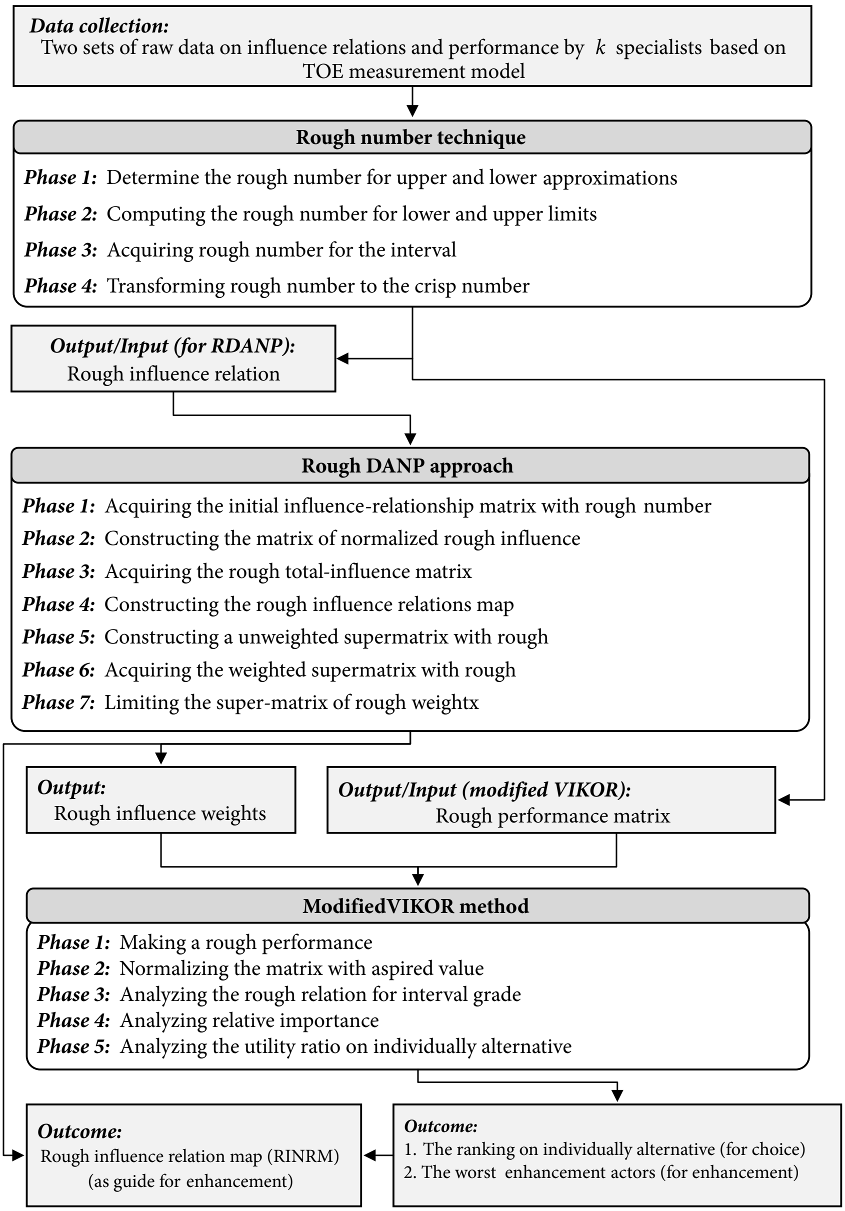

Figure 1. The procedure of rough MCDM model enhancement

The rough number method is applied to construct a gap level when experts acquire data. The DANP with the rough number technique can be applied to assemble the RINRM and measure these rough influence weights for individual perspectives/factors. This rough modified VIKOR technique using rough influence weights can be then used to evaluate the gaps in performance relationships for the factors and perspectives. Last, by applying RINRM and performance relation gaps in RINRM, we can systematically improve the FinTech innovation toward for achieving the aspiration level.

3.1. Rough number

We use these procedures and concepts rough set to address imprecise and subjective language scales to cover the feelings and opinions that appear in real life. Liou et al. (2019) stated that academic concepts could be extended to imprecise human ideas and determine subjectivity. They established the rough number method to convert real statistics into an interval number. This rough number can more precisely understand specialists' observations and do not involve supplementary data (Pamucar et al., 2019). Hence, the rough number method has currently been used on a series of issues, such as assessments of third-party logistics providers (Pamucar et al., 2019), and sustainable supplier selection (Song et al., 2017). These mathematical formulations are described in detail in the next. This method involves four phases:

First phase: Determine the rough number for upper and lower approximations.

Suppose the Q is a series of the space, which covers all the objectives, and there is a series of z classes of specialist opinions. These $P = \{f_1, f_2, \ldots, f_z\}$ are ordered in the manner $f_1 < f_2 < \ldots < f_z$, and U is a random objective in Q. These upper and lower approximate values of f_z can be explained as Eqs (1) and (2).

$$\text{Upper approximation: } \overline{Apr}\left(f_z\right) = \cup\left\{U \in Q / P\left(U\right) \geq f_z\right\}; \quad (1)$$

$$\text{Lower approximation: } \underline{Apr}\left(f_z\right) = \cup\left\{U \in Q / P\left(U\right) \leq f_z\right\}. \quad (2)$$

Second phase: Computing the rough number for lower and upper limits.

The opinions of specialists can be explained through upper and lower limits as rough (i.e., $\overline{Lim}\left(f_z\right)$, $\underline{Lim}\left(f_z\right)$), and the levels are applied to calculate the average of factors in the upper/lower approximate values separately, as Eq. (3):

$$\overline{Lim}\left(f_z\right) = \frac{\sum_{j=1}^{M_Q} u_j}{M_Q}, \underline{Lim}\left(f_z\right) = \frac{\sum_{j=1}^{M_H} b_j}{M_H}, \quad (3)$$

where u_j & b_j represent the factors in the upper and lower approximate values of f_z, respectively. M_H and M_Q denote the objects with total numbers associated with upper and lower approximate values of f_z, respectively.

Next phase: Acquiring rough numbers for the interval.

Through Eqs (1)–(3), the opinions of specialists can be transformed into $PM(f_z)$, as Eq. (4) (a series of rough numbers):

$$PM\left(f_z\right) = \left[f_z^Q, f_z^H\right] = \left[\overline{Lim}\left(f_z\right), \underline{Lim}\left(f_z\right)\right]. \quad (4)$$

Additionally, suppose there are double rough numbers $PM(\beta)=\left[\overline{Lim}(\beta),\underline{Lim}(\beta)\right]$ and $PM(\alpha)=\left[\overline{Lim}(\alpha),\underline{Lim}(\alpha)\right]$. As ξ is a nonzero constant, the rough number through arithmetic operations can be explained as Eqs (5)–(8) (Song et al. 2017).

$$PM(\beta)\times\xi=\left[\overline{Lim}(\beta),\underline{Lim}(\beta)\right]\times\xi=\left[\overline{Lim}(\beta)\times\xi,\underline{Lim}(\beta)\times\xi\right]; \tag{5}$$

$$PM(\beta)+RN(\alpha)=\left[\overline{Lim}(\beta),\underline{Lim}(\beta)\right]+\left[\overline{Lim}(\alpha),\underline{Lim}(\alpha)\right]=$$
$$\left[\underline{Lim}(\alpha)+\underline{Lim}(\beta),\overline{Lim}(\alpha)+\overline{Lim}(\beta)\right]; \tag{6}$$

$$PM(\beta)\times PM(\alpha)=\left[\overline{Lim}(\beta),\underline{Lim}(\beta)\right]\times\left[\overline{Lim}(\alpha),\underline{Lim}(\alpha)\right]=$$
$$\left[\underline{Lim}(\alpha)\times\underline{Lim}(\beta),\overline{Lim}(\alpha)\times\overline{Lim}(\beta)\right]. \tag{7}$$

Final phase: Transforming the rough number to the crisp number.

To contrast analysis rankings or outcomes, we can apply the calculation below to transform the rough number to the crisp number:

$$f_z^{deP}=\frac{\left[f_z^H+f_z^Q\right]}{2}/2. \tag{8}$$

3.2. Rough DANP technique

This DEMATEL method includes assembling a fundamental model that solves multiplex issues by a matrix and mathematics to investigate the influences of separate factors (Lu et al. 2020, 2022). DEMATEL technique is combined with the fundamental ANP concepts to acquire a series of influence weights for individual perspectives and factors. This calculation procedure employed in the DANP technique with rough numbers is evaluated by DEMATEL and ANP technique concepts with rough number data. The mathematical formulations are in the next. This technique involves seven phases:

First phase: Acquiring the initial influence-relationship matrix $\tilde{\boldsymbol{T}}$ with the rough number.

Assume there are m factors in our estimation structure, and v specialists are asked to estimate the clear, direct influence level that perspective/factor j has on perspective or factor i by applying a scale from 0 (no effect) to 4 (very strong effect). Then, we apply Eqs (9)–(14) to estimate the rough data for the v respondents to acquire a primary matrix of rough influence relations $\tilde{\boldsymbol{T}}=[\tilde{t}_{ji}]_{m\times m}=[t_{ji}^H,t_{ji}^Y]_{m\times m}$.

Second phase: Constructing the matrix of normalized rough influence $\tilde{\boldsymbol{R}}$.

The matrix of rough influence $\tilde{\boldsymbol{R}}$ is normalized on the matrix of rough primary relationship $\tilde{\boldsymbol{T}}$ applied as the following:

$$\tilde{\boldsymbol{R}}=\varepsilon\times\tilde{\boldsymbol{T}},\ f_z^{deP}=\frac{\left[f_z^H+f_z^Q\right]}{2}/2; \tag{9}$$

$$\varepsilon=\min\left\{1/\max_j\sum_{i=1}^m t_{ji}^Q,1/\max_i\sum_{j=1}^m t_{ji}^Q\right\},\ \ j,i\in\{1,2,\dots,m\}\ f_z^{deP}=\frac{\left[f_z^H+f_z^Q\right]}{2}/2, \tag{10}$$

where $\tilde{\boldsymbol{R}} = [\tilde{r}_{ij}]_{n\times n} = \left[r_{ij}^{H}, r_{ij}^{Q}\right], 0 \le \tilde{r}_{ij} < 1$. This sum is equal to 1 for one column or one row as $\sum_{i=1}^{m} r_{ij}^{Q}$ and $\sum_{j=1}^{m} di_{ij}^{Q}$.

Third phase: Acquiring the rough total influence matrix $\tilde{\boldsymbol{A}}$.

This matrix of rough total influence $\tilde{\boldsymbol{A}}$ is acquired through the summation of the rough direct effects and the rough indirect effects by applying the following equation:

$$\tilde{\boldsymbol{A}} = \tilde{\boldsymbol{R}} + \tilde{\boldsymbol{R}}^2 + \tilde{\boldsymbol{R}}^3 + \ldots + \tilde{\boldsymbol{R}}^{\Theta} = \tilde{\boldsymbol{R}}(\boldsymbol{L} + \tilde{\boldsymbol{R}} + \tilde{\boldsymbol{R}}^2 + \ldots + \tilde{\boldsymbol{R}}^{\Theta-1})[(\boldsymbol{I} - \tilde{\boldsymbol{D}})(\boldsymbol{I} - \tilde{\boldsymbol{D}})^{-1}] =$$
$$\tilde{\boldsymbol{R}}(\boldsymbol{L} - \tilde{\boldsymbol{R}}^{\Theta})(\boldsymbol{L} - \tilde{\boldsymbol{R}})^{-1} = \tilde{\boldsymbol{R}}(\boldsymbol{L} - \tilde{\boldsymbol{R}})^{-1}, \text{ when } \Theta \to \infty,\ \tilde{\boldsymbol{R}}^{\Theta} = [0]_{m\times m}, \tag{11}$$

where $\boldsymbol{L}$ is the identity matrix.

Fourth phase: Constructing the rough influence relations map (RIRM).

These column and row amounts of the total influence matrix with rough $\tilde{\boldsymbol{T}}$ are acquired by applying two $\tilde{\boldsymbol{g}}$ and $\tilde{\boldsymbol{e}}$ vectors, respectively:

$$\tilde{\boldsymbol{A}} = [\tilde{a}_{ji}]_{m\times m} = \left[a_{ji}^{H}, a_{ji}^{Q}\right],\ j, i \in \{1, 2, \ldots, m\}; \tag{12}$$

$$\tilde{\boldsymbol{g}} = [\tilde{g}_j]_{m\times 1} = \left[\sum_{i=1}^{m} a_{ji}^{H}, \sum_{i=1}^{m} a_{ji}^{U}\right]_{m\times 1},\quad \tilde{\boldsymbol{e}} = [\tilde{e}_j]_{m\times 1} = \left[\sum_{j=1}^{m} e_{ji}^{H}, \sum_{j=1}^{m} e_{ji}^{Q}\right]_{1\times m}^{\prime} \tag{13}$$

as this superscript' indicates transposition.

$\tilde{\boldsymbol{e}}$ is the row sum $\sum_{j=1}^{m} \tilde{a}_{ji}$ in the matrix $\tilde{\boldsymbol{A}}$, which indicates the sum of the rough total effect that the perspective/factor j receives from other perspectives/factors.

$\tilde{\boldsymbol{g}}$ is the row sum $\sum_{i=1}^{m} \tilde{e}_{ji}$ in the matrix $\tilde{\boldsymbol{A}}$, which indicates the sum of the rough total effect that the perspective/factor j has on other perspectives/factors.

Furthermore, this prominence $(\tilde{\boldsymbol{g}} + \tilde{\boldsymbol{e}})$ is the total influence with roughness which perspective or factor j has in the estimation structure. The cause & effect net $(\tilde{\boldsymbol{g}} - \tilde{\boldsymbol{e}})$ is the total influence with the roughness of perspective/factor i, which has a net influence with roughness on the other perspectives/factors. As $(\tilde{\boldsymbol{g}} + \tilde{\boldsymbol{e}})$ is positive, perspective or factor j has a rough influence on the other perspectives or factors; as it is negative, it affects with rough on perspective/factor i since the other perspectives/factors.

Fifth phase: Constructing an unweighted supermatrix with rough $\tilde{\boldsymbol{K}}$.

Primarily, the apiece value is normalized by applying the total influence according to the matrix of total influence relations, as m is the number of factors in a perspective and $\boldsymbol{A}_d^{ji}$ is a $m_i \times m_j$ matrix. Formerly, $\boldsymbol{A}_d$ is normalized by applying the total influence to acquire $\tilde{\boldsymbol{A}}_d^{\beta} = \left[\tilde{\boldsymbol{A}}_d^{\beta ji}\right] = \left[a_d^{\beta H}, t_d^{\beta Q}\right]_{m\times m|n<m, \sum_{i=1}^{n} n_i = m}$. Last, the matrix of total influence relations with roughness is transposed and normalized to acquire the unweighted supermatrix with roughness based on the correlated relations among perspectives:

$$\tilde{\boldsymbol{K}} = (\tilde{\boldsymbol{A}}_d^{\beta})' = \begin{array}{cc} & \begin{array}{ccc} R_1 & R_j & R_m \\ d_{11}...d_{1n_1} \;...\; & d_{j1}...d_{jm_j} \;\cdots\; & d_{m1}...d_{mn_m} \end{array} \\ \begin{array}{c} R_1 \; d_{11} \\ d_{12} \\ \vdots \\ d_{1m_1} \\ \vdots \\ R_i \; d_{i1} \\ d_{i2} \\ \vdots \\ d_{in_j} \\ \vdots \\ R_m \; d_{m1} \\ d_{m2} \\ \vdots \\ d_{mn_m} \end{array} & \begin{bmatrix} \tilde{\boldsymbol{K}}^{11} & \cdots & \tilde{\boldsymbol{K}}^{j1} & \cdots & \tilde{\boldsymbol{K}}^{m1} \\ \vdots & & \vdots & & \vdots \\ \tilde{\boldsymbol{K}}^{1i} & \cdots & \tilde{\boldsymbol{K}}^{ji} & \cdots & \tilde{\boldsymbol{K}}^{mi} \\ \vdots & & \vdots & & \vdots \\ \tilde{\boldsymbol{K}}^{1m} & \cdots & \tilde{\boldsymbol{K}}^{jm} & \cdots & \tilde{\boldsymbol{K}}^{mm} \end{bmatrix} \end{array} = \left[\boldsymbol{K}_d^{\beta H}, \boldsymbol{K}_d^{\beta Q}\right]_{m\times m|n<m,\ \sum_{i=1}^{n} n_i = m}. \tag{14}$$

Next phase: Acquiring the weighted supermatrix with rough $\tilde{\boldsymbol{K}}^{\phi}$.

The weighted supermatrix with rough $\tilde{\boldsymbol{K}}^{\phi}$ is acquired by normalizing the total influence matrix with rough $\tilde{\boldsymbol{A}}_R^{\beta}$ by applying the unweighted supermatrix with rough $\tilde{\boldsymbol{K}}$ as the next equation, as Eq. (15):

$$\boldsymbol{A}_R^{\beta} = \begin{bmatrix} \tilde{a}_R^{11} & \cdots & \tilde{a}_R^{1i} & \cdots & \tilde{a}_R^{1n} \\ \vdots & & \vdots & & \vdots \\ \tilde{a}_R^{j1} & \cdots & \tilde{a}_R^{ji} & \cdots & \tilde{a}_R^{jn} \\ \vdots & & \vdots & & \vdots \\ \tilde{a}_R^{n1} & \cdots & \tilde{a}_R^{ni} & \cdots & \tilde{a}_R^{nn} \end{bmatrix} = \left[\boldsymbol{A}_R^{\beta H}, \boldsymbol{A}_R^{\beta Q}\right]_{n\times m}. \tag{15}$$

Here, $\boldsymbol{A}_R^{\beta H}$ is normalized to the total influence matrix with rough $\tilde{\boldsymbol{A}}_R$ of perspectives and acquires a novel normalized total influence with rough matrix $\boldsymbol{A}_R^{\beta}$ of perspectives, as Eq. (16):

$$\boldsymbol{A}_R^{\beta H} = \begin{bmatrix} a_R^{11H}/r_1^H & \cdots & a_D^{1jL}/r_1^H & \cdots & a_D^{1mL}/r_1^H \\ \vdots & & \vdots & & \vdots \\ a_R^{j1H}/r_j^H & \cdots & a_R^{jiH}/r_j^H & \cdots & a_R^{jmH}/r_j^H \\ \vdots & & \vdots & & \vdots \\ a_R^{m1H}/r_n^H & \cdots & a_R^{miH}/r_n^H & \cdots & a_R^{mmH}/r_n^H \end{bmatrix} = \begin{bmatrix} a_R^{\beta 11H} & \cdots & a_R^{\beta 1iH} & \cdots & a_R^{\beta 1nH} \\ \vdots & & \vdots & & \vdots \\ a_R^{\beta j1H} & \cdots & a_R^{\beta jiH} & \cdots & a_R^{\beta jnH} \\ \vdots & & \vdots & & \vdots \\ a_R^{\beta n1L} & \cdots & a_R^{\beta niH} & \cdots & a_R^{\beta nnH} \end{bmatrix}_{n\times n}. \tag{16}$$

Then, we multiply the matrix of normalized total influence $\boldsymbol{A}_R^{\beta}$ of perspectives through the unweighted supermatrix $\tilde{\boldsymbol{K}}$ to achieve the lately weighted supermatrix $\tilde{\boldsymbol{K}}^{\phi}$, as Eq. (17):

$$\boldsymbol{K}^{\phi H} = \boldsymbol{A}_R^{\beta H}\boldsymbol{K}^H = \begin{bmatrix} a_R^{\beta 11H}\times\boldsymbol{K}^{11H} & \cdots & a_R^{\beta j1H}\times\boldsymbol{K}^{j1H} & \cdots & a_R^{\beta m1H}\times\boldsymbol{K}^{n1H} \\ \vdots & & \vdots & & \vdots \\ a_R^{\beta 1jH}\times\boldsymbol{K}^{1jH} & \cdots & a_R^{\beta jiH}\times\boldsymbol{K}^{jiH} & \cdots & a_R^{\beta niH}\times\boldsymbol{K}^{niH} \\ \vdots & & \vdots & & \vdots \\ a_R^{\beta 1nH}\times\boldsymbol{K}^{1nH} & \cdots & a_R^{\beta jnH}\times\boldsymbol{K}^{jnH} & \cdots & a_R^{\beta mnH}\times\boldsymbol{K}^{mnH} \end{bmatrix}_{m\times m|n<m,\ \sum_{i=1}^{n} n_i = m}. \tag{17}$$

Final phase: Limiting the supermatrix of rough weight $\lim\limits_{\Omega\to\infty}(\tilde{\boldsymbol{K}}^{\phi})^{\Omega}$.

The supermatrix of rough weight $\tilde{\boldsymbol{K}}^{\phi}$ multiplies numerous times through itself to acquire a limited matrix with rough weight $\lim\limits_{\Omega\to\infty}(\tilde{\boldsymbol{K}}^{\phi})^{\Omega}$. Formerly, the influence weights of the separate factors can be acquired by $\lim\limits_{\Omega\to\infty}(\boldsymbol{K}^{\phi H})^{\Omega}$ and $\lim\limits_{\Omega\to\infty}(\boldsymbol{K}^{\phi Q})^{\Omega}$, separately. Namely, the DANP influence weights can be acquired by applying the limited supermatrix with rough weight $\tilde{\boldsymbol{K}}^{\phi}$ through power ζ. Furthermore, the regulated ratio of influence weights with roughness can be acquired by applying the matrixes through ratios $\boldsymbol{A}_R^H$ and $\boldsymbol{A}_R^Q$ in $\tilde{\boldsymbol{A}}_R$. The summation of the lower and upper values in the influence weights is roughly less than one and equals one, separately.

3.3. Rough modified VIKOR technique

The VIKOR technique goes according to the concept of applying the "class distance function" as an MCDM technique to solve conflicting independence factors (Lu et al., 2020). We use the modified VIKOR technique to combine individual factors into individual perspective performances and to integrate influence weights with individual normalized performances, which turns into total performance (Lu et al., 2015). In the approach, we establish a target aspirational level to avoid choosing the most favorable alternative among disadvantaged sets. The original VIKOR selection and ranking imply which favorite option is approximate to the positive ideal result. The rough-modified VIKOR can be separated into the following phases.

First phase: Search the worst value s_i^- and the best value s_i^* in valuation factors. The s_i^*, positive ideal-point, denotes the level aspired to in the individual factors estimated via the experts. By comparison, the negative ideal-point s_i^- denotes the worst numbers for the individual factors. Eqs (18) and (19) are applied to acquire these outcomes.

$$\text{Set the aspired values } s_i^* = \max_w \{s_{wi} \mid w = 1,2,\ldots,m\},\ i = 1,2,\ldots,m, \tag{18}$$

$$\text{or set the worst values } s_i^- = \min_w \{s_{wi} \mid w = 1,2,\ldots,m\},\ i = 1,2,\ldots,m. \tag{19}$$

The enhancement of the rough-modified VIKOR method follows by the L_p metric, as Eq. (20):

$$\tilde{L}_w^h = \left\{ \sum_{j=1}^{n} [\tilde{k}_i \otimes (|\, \tilde{s}_i^* - \tilde{s}_{wi} \,|) / (|\, \tilde{s}_i^* - \tilde{s}_i^- \,|)]^h \right\}^{1/y}, \tag{20}$$

where $1 \le h \le \infty$; $w = 1,2,\ldots,n$ and influence rough weight $\tilde{k}_i$ is derived from the rough DANP. $\tilde{s}_{wi}$ is the rough performance value in alternative w of element i; then, use the scores of performances from 0 to 5 in surveys. Therefore, the aspirational value can be built at a score of 5 and the weakest value at a score of zero. Then, we can set $\tilde{s}_j^* = (5,5)$ as the aspirational value and $\tilde{s}_j^- = (0,0)$ as the weakest value, which differs from the original research. $\tilde{L}_w^{p=1}$ (as $\tilde{Y}_w$) and $\tilde{L}_w^{p=\infty}$ (as $\tilde{X}_w$**)** can be used to formulate the rough gap measures and rough ranking by the rough-modified VIKOR method for enhancement (Eqs (21) and (22)).

$$\tilde{Y}_w = \tilde{L}_w^{p=1} = \sum_{m=1}^{m} [\tilde{k}_i \otimes (\left|\tilde{s}_i^* - \tilde{s}_{wi}\right|) / (\left|\tilde{s}_i^* - \tilde{s}_i^-\right|)]; \tag{21}$$

$$\tilde{X}_w = \tilde{L}_w^{p=\infty} = \max_i \left\{ (\left|\tilde{s}_i^* - \tilde{s}_{wi}\right|) / (\left|\tilde{s}_i^* - \tilde{s}_i^-\right|) \middle| i = 1,2,\ldots,m \right\}. \tag{22}$$

Second Phase: Analyze the maximal rough regret $\tilde{X}_w$ and rough mean of the group utility $\tilde{Y}_w$ (that denotes the maximal rough gap with w alternative of different factors for priority enhancement). $\tilde{k}_i$ shows the factors with the rough influence weights since rough DANP; $\tilde{r}_{wi} = (\left|\tilde{s}_i^* - \tilde{s}_{wi}\right|) / (\left|\tilde{s}_i^* - \tilde{s}_i^-\right|)$ shows the normalized rough gap by w alternative in i factor. The numbers can be calculated through Eqs (23) and (24) separately.

$$\tilde{Y}_w = \sum_{i=1}^{m} \tilde{k}_i \otimes \tilde{r}_{wi} = \sum_{i=1}^{m} \tilde{k}_i \otimes \left(\left|\tilde{s}_i^* - \tilde{s}_{wj}\right|\right) \Big/ \left(\left|\tilde{s}_i^* - \tilde{s}_i^-\right|\right); \tag{23}$$

$$\tilde{X}_w = \max_i \left\{\tilde{r}_{wi} \mid i = 1, 2, \ldots, m\right\}. \tag{24}$$

Final Phase: Acquire the complete factor $\tilde{R}_w$ and sort out these results.

These values can be calculated through $\tilde{R}_w = f\tilde{Y}_w + (1-f)\tilde{X}_w$; when the aspired value is $\tilde{Y}^* = (0,0)$ and $\tilde{X}^* = (0,0)$, and the worst value is $\tilde{Y}^- = (1,1)$ and $\tilde{X}^- = (1,1)$ (worst situation), we set $f \in [0,1]$.

4. Empirical research

This section states an empirical case of FinTech innovation to determine the value of the offered research model in Taiwan.

4.1. Problem description

FinTech is known as one of the financial industry's most important applications. It is proliferating due to advantageous rules, information technology, and the new sharing economy. FinTech is remolding the financial industry by enhancing the value of financial services, lowering costs, and offering more varied and steady financial conditions. For identifying the influence weights of numerous factors and determining the main influencing factors in the diffusion of the FinTech innovation process, we, therefore, recommend the MCDM model with a rough number, which evaluates the degrees of importance for these factors. The case is used to prove the presentation of the recommended integrated MCDM model with rough numbers for assessing and selecting the best improvement approaches. The model will assist managers in understanding how to improve their estimations concerning FinTech innovation as well as its diffusion to achieve the determined multiple-phase performance gaps in factors and perspectives.

4.2. Data collection

Through the review of literatures and 15 experts' views by conducting focus groups four times, separately time we used about 3 hours (we discussed the FinTech innovation issues, the TOE elements of effect on the FinTech innovation through literature review and discussed with financial industry top managers, scholars and financial technology experts in depth about the elements of impact in Taiwan's financial industry). The information was collected from 15 experienced experts and scholars with an average tenure of more than 18 years in these fields of financial industries and financial technology in Taiwan were asked for advice concerning this investigation. To ensure the smooth improvement of data collection, we primarily use a matrix filling method to conduct the trial filling and pre-test. Reply since filling in the matrix was that it was not easy for specialists to compare the name and code of individually factor, as filling in that matrix. Therefore, we improve the way of fulfilling the survey by designing an investigation like to Likert scales, and to explain the corresponding conceptions and instructions in detail, so the experts can easily and seriously fill this investigation.

The study employed six financial technology experts in charge of information technology, six financial industry top managers, and three financial industry scholars to fill out our survey. The information of experts' background is shown in Table 2. To verify the reliability of these experts, this paper arranged the interviews by face-to-face to make sure which the meanings of these surveys asked could be realized. They agreed that all elements are crucial and comprehensive, demonstrating that the elements must be implemented into this study. From the FinTech innovation measurement model's diffusion for perspectives and factors, as shown in Table 1, these specialists were asked to evaluate the effects of factors based on a 5-point Likert scale ("very strong effect" (4) to "no effect" (0)). The statistical significance confidence is 97.09% (confidence interval greater than 95%), and the gap error is 2.91% (less than 5%).

Table 2. Background information of the experts

Category	Number of experts
Working Level	
Financial technology experts	6
Top managers in financial industry	6
Researchers in financial industry	3
Years of working experiences	
Between 10 and 14 years	2
Between 15 and 19 years	8
More than 20 years	5
Education Level	
Ph.D.	5
Master	9
Bachelor	1

4.3. Assembling the rough weights and RINRM by applying the DANP method

All factors that were established to influence the data are offered with linguistic variables. Although the overall collected data show a high consensus, using normal standards to indicate the specialists' observations in each pairwise survey appears to be unreasonable. Hence, we use rough numbers to represent their numerous assessments.

The other interval values with rough numbers of factors make up the primary direct relations matrix $\tilde{\boldsymbol{T}}$, and which can be acquired. Thus, the matrix $\tilde{\boldsymbol{T}}$ of rough primary direct relations was acquired and is shown in Table 3.

The matrix $\tilde{\boldsymbol{T}}$ of rough primary direct relationships was applied in $\tilde{\boldsymbol{T}} = [\tilde{t}_{ji}]_{m\times m} = [t_{ji}^{H}, a_{ji}^{Q}]_{m\times m}$ and Eq. (9) to acquire the normalized rough influence relations matrix $\tilde{\boldsymbol{R}}$. Originally, Eq. (11) was applied to derive the matrix $\tilde{\boldsymbol{A}}_d$ of rough total influence. The matrix $\tilde{\boldsymbol{A}}_R$ of total influence for the perspectives was acquired by averaging the rough total influence $\tilde{\boldsymbol{A}}_d$ inside the relevant perspectives. Eq. (12) can apply the total influence matrix of factors $\tilde{\boldsymbol{A}}_d$ with rough and perspectives $\tilde{\boldsymbol{A}}_R$ to acquire the rough effect, given $(\tilde{\boldsymbol{g}})$ and the rough effect received $(\tilde{\boldsymbol{e}})$ for individual factors/perspectives (Table 4).

Table 3. Rough initial-influence direct relations matrix.

$\tilde{\boldsymbol{T}}$	A_1	A_2	A_3	A_4	B_1	B_2	B_3	B_4	C_1	C_2	C_3	C_4
A_1	–	(2.75, 3.64)	(2.04, 2.36)	(2.36, 2.84)	(1.30, 2.70)	(2.30, 3.70)	(2.30, 3.70)	(1.92, 3.25)	(1.92, 3.25)	(1.75, 2.64)	(3.16, 3.64)	(1.46, 2.98)
A_2	(3.04, 3.36)	–	(1.68, 3.09)	(1.92, 3.25)	(1.08, 1.72)	(1.69, 2.74)	(1.91, 3.32)	(1.75, 2.64)	(1.24, 3.12)	(1.92, 3.25)	(1.40, 2.67)	(1.21, 2.48)
A_3	(2.65, 3.35)	(2.52, 3.79)	–	(2.02, 3.54)	(1.21, 2.48)	(1.69, 2.74)	(1.46, 2.98)	(1.32, 2.28)	(2.52, 3.79)	(1.75, 3.08)	(1.91, 3.32)	(1.91, 3.32)
A_4	(1.75, 3.08)	(2.26, 3.31)	(2.36, 3.25)	–	(1.00, 1.00)	(1.16, 1.64)	(0.75, 2.08)	(1.16, 1.64)	(1.92, 3.25)	(1.17, 2.06)	(1.47, 2.53)	(1.47, 2.53)
B_1	(1.30, 2.70)	(2.28, 2.92)	(1.65, 2.35)	(1.65, 2.35)	–	(2.47, 3.53)	(2.33, 3.60)	(2.26, 3.31)	(0.96, 2.68)	(1.36, 2.25)	(1.94, 2.83)	(1.36, 2.25)
B_2	(2.52, 3.79)	(1.68, 3.09)	(1.47, 2.53)	(1.75, 3.08)	(1.63, 3.23)	–	(2.75, 3.64)	(3.36, 3.84)	(1.12, 2.08)	(1.92, 3.25)	(2.28, 2.92)	(2.28, 2.92)
B_3	(3.36, 3.84)	(2.52, 3.79)	(1.30, 2.70)	(1.17, 206)	(3.16, 3.64)	(2.94, 3.83)	–	(1.75, 3.08)	(1.40, 2.67)	(1.75, 2.64)	(2.26, 3.31)	(2.26, 2.31)
B_4	(2.75, 3.64)	(3.36, 3.84)	(1.72, 2.68)	(1.47, 2.53)	(1.40, 2.67)	(1.75, 3.08)	(2.16, 2.64)	–	(1.92, 3.25)	(1.64, 1.96)	1.92, 3.25)	(1.69, 2.74)
C_1	(1.68, 3.09)	(1.68, 3.09)	(2.08, 3.52)	(1.36, 2.25)	(1.04, 1.36)	(1.16, 1.64)	(1.30, 2.70)	(2.30, 3.70)	–	(1.16, 1.64)	(1.17, 2.06)	(1.75, 2.64)
C_2	(1.94, 2.83)	(2.26, 3.31)	(1.47, 2.53)	(1.92, 3.25)	(1.00, 1.00)	(1.36, 2.25)	(1.17, 2.06)	(1.16, 1.64)	(1.36, 2.25)	–	(1.75, 3.08)	(1.75, 2.64)
C_3	(2.65, 3.35)	(1.47, 2.53)	(1.75, 3.08)	(1.94, 2.83)	(1.75, 2.64)	(2.36, 3.25)	(1.92, 3.25)	(2.36, 3.25)	(1.36, 2.25)	(1.69, 2.74)	–	(1.94, 2.83)
C_4	(1.92, 3.25)	(1.30, 2.70)	(1.46, 2.98)	(2.16, 2.64)	(1.08, 1.72)	(1.75, 2.64)	(1.92, 3.25)	(1.36, 2.25)	(1.75, 2.64)	(1.75, 2.64)	(2.33, 3.60)	–

Through these roughness outcomes of the study (Table 5), we discover that "technology (A)" has the largest total effect and is the most effective perspective. The perspective "organization (B)" has the smallest effect on other perspectives. From the net cause/effect influence relations ($\boldsymbol{g}$–$\boldsymbol{e}$), "organization (B)" is determined as having the largest effect on the other perspectives.

Figure 2 illustrates these effects. The effects' importance can be ordered as organization (B) $\succ$ environment (C) $\succ$ technology (A). When thinking about how to improve diffusion performance, the specialists all considered the organization (B) to be the most effective, as it influences the environment (C) and the technology (A).

From the technology (A) perspective, security and privacy (A_3) directly affect expected benefits (A_1), standards uncertainty (A_4), and technology integration (A_2), indicating that the enhancement priority should be (A_3) $\succ$ (A_1) $\succ$ (A_4) $\succ$ (A_2). In organization (B), firm size (B_1) directly affects financial commitment (B_3), top management support (B_2), and organizational innovativeness (B_4), denoting that the priority of enhancement must be (B_1) $\succ$ (B_3) $\succ$ (B_2) $\succ$ (B_4). Similarly, this priority of enhancement should be (C_4) $\succ$ (C_3) $\succ$ (C_2) $\succ$ (C_1) in the environment (C). For administrators looking for results in a multifaceted structure with numerous perspectives and factors, the derived RINRM shown in Figure 2 is simple and clearly determines the enhancement significance inside the multifaceted arrangement.

Table 4. Rough effects given and received for individual factors/perspectives.

	Effects given	Effects received	Prominence	Net cause/ effect		Effects given	Effects received	Prominence	Net cause/ effect
A_1	(9.53, 17.27)	(16.54, 27.84)	(26.07, 35.11)	(–7.02, –10.57)	A_1	(4.33, 7.20)	(4.77, 7.51)	(9.10, 14.71)	(–0.44, –0.30)
					A_2	(3.58, 6.58)	(4.47, 7.44)	(8.05, 14.02)	(–0.90, –0.86)
					A_3	(3.89, 7.14)	(3.58, 6.49)	(7.46, 13.62)	(0.31, 0.65)
					A_4	(3.09, 5.56)	(3.73, 6.40)	(6.82, 11.96)	(–0.63, –0.85)
B_2	(10.56, 17.82)	(14.50, 25.02)	(25.06, 42.84)	(–3.95, –7.20)	B_1	(3.72, 6.47)	(2.98, 5.16)	(6.70, 11.62)	(0.74, 1.31)
					B_2	(4.30, 7.14)	(3.88, 6.49)	(8.17, 13.63)	(0.42, 0.65)
					B_3	(4.49, 7.26)	(3.77, 6.91)	(8.26, 14.18)	(0.72, 0.35)
					B_4	(4.08 6.47)	(3.88, 6.46)	(7.96, 13.20)	(0.21, 0.29)
C_3	(8.77, 15.72)	(14.35, 25.79)	(23.12, 41.51)	(–5.58, –10.07)	C_1	(3.17, 5.87)	(3.31, 6.53)	(6.48, 12,40)	(–0.15, –0.66)
					C_2	(3.22, 5.63)	(3.40, 5.94)	(6.62, 11.57)	(–0.18, –0.31)
					C_3	(4.00, 6.70)	(4.07, 6.90)	(8.07, 13.60)	(–0.07, –0.20)
					C_4	(3.53, 6.36)	(3.57, 6.42)	(7.10, 12.78)	(–0.04, –0.06)

Table 5. Deroughness effects received and given by individual factors/perspectives

	Effects given	Effects received	Prominence	Net cause/ effect		Effects given	Effects received	Prominence	Net cause/ effect
A	13.40	22.19	35.59	–8.80	A_1	5.77	6.14	11.90	–0.37
					A_2	5.08	5.96	11.04	–0.88
					A_3	5.51	5.03	10.55	0.48
					A_4	4.32	5.06	9.39	–0.74
B	14.19	19.76	33.95	–5.57	B_1	5.09	4.07	9.16	1.03
					B_2	5.72	5.18	10.90	0.53
					B_3	5.88	5.34	11.22	0.53
					B_4	5.41	5.17	10.58	0.25
C	12.24	20.07	32.31	–7.82	C_1	4.52	4.92	9.44	–0.40
					C_2	4.43	4.67	9.09	–0.24
					C_3	5.35	5.48	10.83	–0.14
					C_4	4.95	4.99	9.94	–0.05

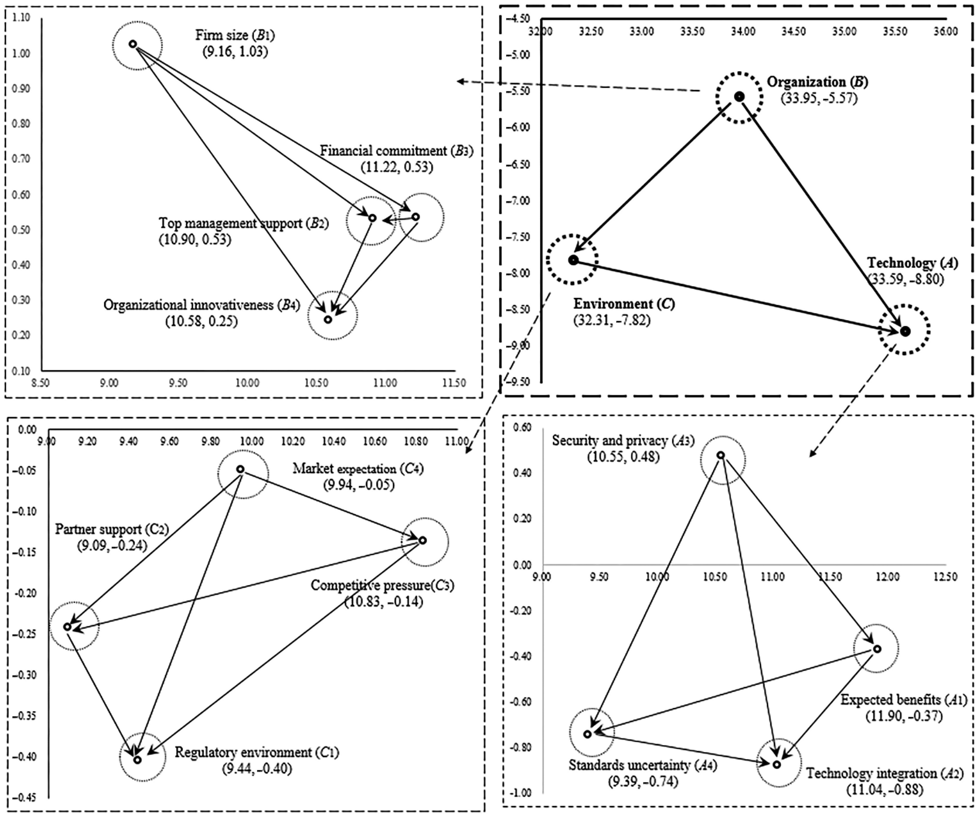

Figure 2. Rough influence relations map (RIRM)

After assembling the RIRM, we use DANP with a rough number to acquire the rough influence weights by factors. These factors for the total influence matrix ($\tilde{\boldsymbol{A}}_d$) are applied to assemble an unweighted supermatrix with rough numbers by Eq. (14). With dissimilar degrees of the rough effect among the perspectives, we use Eqs (15)–(17) to estimate the weighted super-matrix with rough $\tilde{\boldsymbol{K}}^{\phi}$. According to the ANP and Markov chain concepts, we design the limits of the weighted supermatrix with rough $\tilde{\boldsymbol{K}}^{\phi}$ by increasing it to limited powers until the weighted super-matrix with rough numbers congregates.

We next derive the rough global and local weights for the perspectives and factors by the acquired limits of the weighted matrix with rough numbers (see Table 6). Using the rough method, the DANP can acquire these rough local weights of calculation characteristics at separable ranked values and also acquire the rough global weights, thus approving the separate factors with absolute weight in all perspectives. Technology (A) has the highest weight among the perspectives. The most serious factors from the environmental and organizational perspectives are expected benefits (A_1), technology integration (A_2), and competitive pressure (C_3).

Table 6. Rough influence weights by individual perspective/factor

Perspective	Roughness Local Weigh	Rank		Local Weight	Rough-ness	Rank	Global Weight	Rough-ness	Rank
Technology (A)	(0.364, 0.354) 0.359	1	A_1	0.275	0.275	1	(0.105, 0.095)	0.100	1
			A_2	0.264	0.264	2	(0.098, 0.094)	0.096	2
			A_3	0.222	0.222	4	(0.079, 0.083)	0.081	8
			A_4	0.224	0.224	3	(0.082, 0.081)	0.082	7
Organization (B)	(0.319, 0.318) 0.319	3	B_1	0.205	0.205	4	(0.066, 0.066)	0.066	12
			B_2	0.263	0.263	2	(0.085, 0.083)	0.084	5
			B_3	0.268	0.268	1	(0.083, 0.088)	0.086	4
			B_4	0.262	0.262	3	(0.085, 0.082)	0.084	6
Environment (C)	(0.316, 0.328) 0.322	2	C_1	0.247	0.247	3	(0.073, 0.083)	0.078	10
			C_2	0.238	0.238	4	(0.075, 0.076)	0.075	11
			C_3	0.280	0.280	1	(0.090, 0.088)	0.089	3
			C_4	0.253	0.253	2	(0.079, 0.082)	0.080	9

4.4. Evaluating the rough gap performances by the rough-modified VIKOR

This section illuminates how to measure the degrees of rough virtual usefulness among existing FinTech innovation aspiration values and performances for the 12 factors. Primarily, the performance values for individual factors are inquired by gathering the 15 specialists' performance values for individual factors. The multiple phases for initiation, adoption, and routinization performance are applied to define the rough estimation data, which are stated as the gaps (Table 7). By integrating the rough influence weights and the modified VIKOR phases, we acquire the rough scores of the upper and lower bounds, the degree of value, and the last rank of the individual approach (Table 8).

Applying the overall and factor/perspective indices, the values of gaps can be resolved by improving the precedence array to obtain the aspirational values. In the initiation phase, the higher gap value is the firm size (B_1) (0.900). It is the primary factor that needs to be improved, followed by those of standards uncertainty (A_4) and technology integration (A_2).

Table 7. Rough estimation scores of alternatives with aspiration level

Factors	Global weight	Aspiration level	Initiation performance	Adoption performance	Routinization performance
Technology (*A*)			(0.861, 0.627)	(0.674, 0.561)	(0.731, 0.562)
Expected benefits (A_1)	(0.105, 0.095)	(0.00, 0.00)	(0.851, 0.587)	(0.709, 0.568)	(0.782, 0.574)
Technology Integration (A_2)	(0.098, 0.094)	(0.00, 0.00)	(0.887, 0.629)	(0.564, 0.516)	(0.698, 0.546)
Security and privacy (A_3)	(0.079, 0.083)	(0.00, 0.00)	(0.836, 0.644)	(0.668, 0.572)	(0.712, 0.534)
Standards uncertainty (A_4)	(0.082, 0.081)	(0.00, 0.00)	(0.867, 0.659)	(0.768, 0.569)	(0.725, 0.592)
Organization (*B*)			(0.703, 0.600)	(0.718, 0.594)	(0.803, 0.586)
Firm size (B_1)	(0.066, 0.066)	(0.00, 0.00)	(0.935, 0.865)	(0.798, 0.646)	(0.871, 0.613)
Top management support (B_2)	(0.085, 0.083)	(0.00, 0.00)	(0.606, 0.517)	(0.628, 0.532)	(0.807, 0.593)
Financial commitment (B_3)	(0.083, 0.088)	(0.00, 0.00)	(0.653, 0.547)	(0.782, 0.574)	(0.756, 0.564)
Organizational innovativeness (B_4)	(0.085, 0.082)	(0.00, 0.00)	(0.670, 0.530)	(0.684, 0.636)	(0.792, 0.579)
Environment (*C*)			(0.606, 0.458)	(0.610, 0.486)	(0.605, 0.521)
Regulatory environment (C_1)	(0.073, 0.083)	(0.00, 0.00)	(0.841, 0.633)	(0.768, 0.596)	(0.683, 0.594)
Partner support (C_2)	(0.075, 0.076)	(0.00, 0.00)	(0.850, 0.657)	(0.804, 0.632)	(0.856, 0.695)
Competitive pressure (C_3)	(0.090, 0.088)	(0.00, 0.00)	(0.743, 0.550)	(0.854, 0.702)	(0.864, 0.775)
Market expectation (C_4)	(0.079, 0.082)	(0.00, 0.00)	(0.768, 0.596)	(0.832, 0.691)	(0.856, 0.692)
			(0.730, 0.565)	(0.668, 0.548)	(0.714, 0.557)

Table 8. Relative significance of each factor

Factors	Initiation performance	Adoption performance	Routinization performance
Technology (*A*)	0.744	0.618	0.647
Expected benefits (A_1)	0.719	0.639	0.678
Technology integration (A_2)	0.758	0.540	0.622
Security and privacy (A_3)	0.740	0.620	0.623
Standards uncertainty (A_4)	0.763	0.682	0.659
Organization (*B*)	0.651	0.656	0.694
Firm size (B_1)	0.900	0.722	0.742
Top management support (B_2)	0.562	0.580	0.700
Financial commitment (B_3)	0.600	0.678	0.660
Organizational innovativeness (B_4)	0.600	0.660	0.685
Environment (*C*)	0.532	0.548	0.563
Regulatory environment (C_1)	0.737	0.682	0.639
Partner support (C_2)	0.754	0.718	0.776
Competitive pressure (C_3)	0.646	0.778	0.819
Market expectation (C_4)	0.682	0.761	0.774
Total gaps	0.647	0.608	0.636

Of all the factors, decision-makers attached the most importance to firm size in the initiation phase. In the adoption phase, competitive pressure has a higher gap value (C_3) (0.778) and is a primary factor that needs to be improved. These factors are followed by the expectations of the market (C_4) and firm size (B_1). Decision-makers are the most impacted by competitive pressure in the adoption phase. In the routinization phase, competitive pressure has a higher gap value (C_3) (0.819) and is the primary factor that needs to be enhanced, followed by partner support (C_2) and market expectation (C_4). Decision-makers gave the most consideration to competitive pressure in the routinization phase. These outcomes show the enhancement importance sequence for all factors in the attainment of their aspirational values, from most to least important in order of priority.

Enhancement priorities can be used for each perspective. For example, in the initiation phase from the technological perspective (A), the gap of priority values runs as follows: standards uncertainty (A_4), technology integration (A_2), security and privacy (A_3), and expected benefits (A_1). From the organizational perspective (B), the gap in priority values runs as follows: firm size (B_1), financial commitment (B_3), organizational innovativeness (B_4), and top management support (B_2). From the environmental perspective (C), enhancement priorities are ordered as follows: partner support (C_2), regulatory environment (C_1), market expectation (C_4), and competitive pressure (C_3). For the individual perspective in the adoption phase, enhancement priorities run as follows: (A_4), (A_1), (A_3), and (A_2) from the technological perspective (A); (B_1), (B_3), (B_4), and (B_2) from the organizational perspective (B); and (C_3), (C_4), (C_2), and (C_1) from the environmental perspective (C). In the routinization of the separate perspectives, enhancement priorities run as follows: (A_1), (A_4), (A_3), and (A_2) in the technological perspective (A); (B_1), (B_2), (B_4), and (B_3) in the organizational perspective (B); and (C_3), (C_2), (C_4), and (C_1) in the environmental perspective (C).

4.5. Implications and discussion

Most existing approaches can not capture these multifaceted interrelations among numerous perspectives and factors which influence FinTech innovation diffusion performance. The study can distinguish the interrelations among separate factors and perspectives. In this empirical study of FinTech innovation diffusion performance improvement in Taiwan's financial industries, we primarily investigate the relationships between influences in the perspectives and factors by applying RIRM (Figure 2). Based on Figure 2 the choices for the enhancement were prioritized as follows: organization $\succ$ environment $\succ$ technology. For managers, this array is an important piece of information and demonstrates that strategic matters must be resolved first. These determinations will impact the existing perspectives and resolve numerous issues concurrently. This RIRM offered herein helps us illustrate the influence of networks containing nonlinear relations through either factors or perspectives. Second, these factors, such as security and privacy (A_3), firm size (B_1), and market expectation (C_4), affect other factors in each perspective, as demonstrated in Figure 2. Third, the most important factor calculated through RDANP is expected benefits (A_1), weighted at 0.100 (Table 5). This factor is the most important for estimating FinTech innovation to improve diffusion performance in the financial industry. Furthermore, these weights of influence are integrated with the rough DEMATEL method to clarify the priority of reducing the gaps identified by the rough modified VIKOR and RINRM.

In Table 8, the overall gap values that indicate scope for improvement are 0.647 in the initiation phase, 0.608 in the adoption phase, and 0.636 in the routinization phase. Under the TOE, technology (*A*) shows the largest gap (0.744) in the initiation phase, organization (*B*) has the largest gap (0.656) in the adoption phase, and organization (*B*) has the largest gap (0.694) in the routinization phase.

These empirical outcomes also decide these issues considered within the separate perspective. Table 9 reviews the sequence of influence elements within separately perspective. From the separate technology perspective (*A*), security and privacy (A_3) is the most influential factor and need to enhanced primary, followed by expected benefits (A_1), standards uncertainty (A_4), and technology integration (A_2). After using the values of gap presented via these panel of specialists, these significant patterns of improvement are deemed comprehensive and unique, in terms of both holistic and separate perspectives. For the administrators in the Taiwanese financial industry, realizing the enhancement priorities for satisfying FinTech innovation diffusion is significant. Most articles which focused on FinTech innovation factors and evaluation did not argue the relationship between FinTech service innovation and strategy adoption diffusion. Given the consequences shown in Table 9, these empirical consequences understand the purpose of the study to offer the priorities for enhancement to influence the FinTech innovation diffusion performance. For example, to decrease the performance gaps among the present state and the aspirated level of the initiation performance, the priorities for improvement are the technological perspective (*A*), organizational perspective (*B*), and environmental perspective (*C*). However, managers need to determine their primary priorities for augmentation as they aim to understand desired levels. After using these values

Table 9. Sequence of improvement priority for the strategy of FinTech innovation diffusion performance

<table>
<tr><th>Formula</th><th colspan="2">Sequence of enhancement priority</th></tr>
<tr><td>F1: Influential network of perspectives</td><td colspan="2">(B), (C), (A)</td></tr>
<tr><td rowspan="3">F2: Influential network of factors within individual perspective</td><td colspan="2">(A): (A_3), (A_1), (A_4), (A_2)</td></tr>
<tr><td colspan="2">(B): (B_1), (B_3), (B_2), (B_4)</td></tr>
<tr><td colspan="2">(C): (C_4), (C_3), (C_2), (C_1)</td></tr>
<tr><td rowspan="3">F3: Sequence of perspective to rise to aspired/desired level in three FinTech innovation diffusion performance (from high to low, by gap value)</td><td>Initiation performance (Q_1)</td><td>(A), (B), (C)</td></tr>
<tr><td>Adoption performance (Q_2)</td><td>(B), (A), (C)</td></tr>
<tr><td>Routinization performance</td><td>(B), (A), (C)</td></tr>
<tr><td rowspan="6">F4: Sequence of criteria to rise to aspired/desired level within individual perspectives in the three FinTech innovation diffusion performance (from high to low, by gap value)</td><td colspan="2">Initiation performance</td></tr>
<tr><td colspan="2">(A): (A_4), (A_2), (A_3), (A_1)
(B): (B_1), (B_3), (B_4), (B_2)
(C): (C_2), (C_1), (C_4), (C_3)</td></tr>
<tr><td colspan="2">Adoption performance</td></tr>
<tr><td colspan="2">(A): (A_4), (A_1), (A_3), (A_2)
(B): (B_1), (B_3), (B_4), (B_2)
(C): (C_3), (C_4), (C_2), (C_1)</td></tr>
<tr><td colspan="2">Routinization performance</td></tr>
<tr><td colspan="2">(A): (A_1), (A_4), (A_3), (A_2)
(B): (B_1), (B_2), (B_4), (B_3)
(C): (C_3), (C_2), (C_4), (C_1)</td></tr>
</table>

of gap presented through the specialists' panel, these enhancement priority arrangements are comprehensive and unmatched, both in terms of individual and holistic viewpoints. For financial industry superintendents, realizing the TOE structure's enhancement priorities to measure the diffusion of FinTech innovation performance must be simpler than the gaps in these three phases.

5. Conclusions

As contemporary financial industry gradually seeks to enhance their performance in the activities of value chain via applying the FinTech, it becomes an important undertaking for financial industry to implement FinTech to improve effectiveness, processes, information sharing, and coordination with partners and support customer services. Therefore, it is significant to realize what factors effect FinTech innovation. Based on the theoretical viewpoints on the contexts and processes of innovation diffusion, we develop an integrated model to study the effect of 12 related factors on three stages of FinTech innovation. The empirical outcomes determined important factors shaping the implementation, and revealed their differential effects across dissimilar stages and in dissimilar surroundings. The paper makes three contributions to the literatures on FinTech innovation. Primary, we theorized three stages (initiation, adoption, routinization) in FinTech innovation, and combined the three-stage conceptualization through the technology organization-environment context. In prior researches, we presented the utility of the TOE issues for realizing single phases of FinTech diffusion, such as value, usage, and decisions of adoption across dissimilar financial industry. In the study, we extend the general literatures of IT diffusion via emphasizing the procedure of implementation and by evolving an integrated conceptual paradigm. Therefore, the external validity of the integrative model tested in the study is improved via other associated investigations. Our paper, nevertheless, only used to the TOE framework to study multiple phases in the procedure of FinTech diffusion. The dissimilar foci on dissimilar phases mean which they have different dependent variables. They are also according to dissimilar theories and tested in dissimilar businesses with dissimilar consequences. More approximately, most of the present studies in the literatures studied the diffusion of innovation with a "non-adoption versus adoption" focus. By contrast, our procedure-oriented method in the paper permitted us to inspect the "difference influences" of TOE factors along the three stages of the diffusion procedure. Next, we tested and theorized difference influences of the TOE issues across the implementation phases. Though previous studies have recognized such differential influences as a significant theoretical subject, the literatures lack empirical examination. To our knowledge, the study is the primary systematic research of the dissimilar influences in innovation implementation. Therefore, we develop an integrated model (combining rough numbers, DEMATEL, DANP, and modified VIKOR), which could be adopted for making evaluations according to specific priorities in FinTech innovation perspectives and factors. Finally, through theorizing the dynamic influences and evolving a systematic method to data collection in a multiple stages' framework, this paper spreads a FinTech innovation to the diffusion of innovation. Based on the professional outcomes, we reveal how the outcomes can offer direction to administrators by recognizing the main features for decision-making, which allow the investigation of optimal approaches for the enhancement of current FinTech innovation procedures in in Taiwan, greater China and the world.

The existence of certain limitations in the present approach, indicating that further study is necessary. First, the FinTech innovation estimation factors were filtered from review of previous literatures on technology–organization–environment (TOE) assessment. Therefore, it might have left out some impacts concerning the IT/IS implementation estimation procedure. Future study could use dissimilar techniques such as longitudinal investigations and interviews to recognize other factors. Second, it also can use extra multiple criteria methods (such as interval type-2 fuzzy TOPSIS, WINGS (Weighted Influence Non-linear Gauge System) approach, or BWM (Best Worst Method)) to assess these comparative weights of the impact on the FinTech innovation issue, and such consequences can then be connected with these outcomes of the research. Lastly, to proposal more unprejudiced data on the fitness of this FinTech innovation evaluation, forthcoming research could apply case studies of specific enactment estimations and therefore help confirm the viability of this common estimation structure for the financial industries and the FinTech innovation recommended herein.

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