Hybrid Decision Model for Evaluating Blockchain Business Strategy: A Bank’s Perspective

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Abstract: Banks attempt to invest in emerging financial technology (FinTech), such as blockchain, to enhance competitiveness. There is a great deal of literature on the technical and legal aspects of blockchain. However, there is little specific guidance on how banks can apply a holistic model to evaluate the blockchain-based business. This study proposes a hybrid decision model with confidence-weighted fuzzy assessments to address this valuable research topic. Supported by a group of seasoned experts, five major blockchain-based business models are evaluated for a domestic bank in Taiwan. The key findings contribute to understanding the importance of the involved factors and identifying the ideal business strategy for the bank. The result suggests that the most crucial dimension is policies and regulations, not the technical capability of banks.

Keywords: blockchain; banking; financial technology (FinTech); multiple criteria decision-making (MCDM); best-worst-method (BWM); modified VIKOR; fuzzy set theory

1. Introduction

Emerging technologies are attempting to bring about a new wave of impactful changes. FinTech (financial technology) provides traditional financial services by using technology so that financial institutions can provide more efficient and convenient services [1]. In 1982, Lamport et al. [2] developed a fault-tolerant algorithm applied to the decentralized peer-to-peer network communication system to solve the Byzantine Generals problem. Satoshi Nakamoto’s article “Bitcoin: A Peer-to-Peer Electronic Cash System” appeared during the 2008 financial crisis, applying this point of view with the concept of blockchain, thus created Bitcoin [3].

Blockchain is a data recording technology. Its main technical characteristics are (1) decentralization and (2) immutability, making it different from the general method of writing data into databases. The core concept is to jointly maintain a digital distributed ledger through an encrypted peer-to-peer network.

Blockchain technology also uses the “smart contract” to proceed in an event-driven approach [4]. After the agreed transaction terms are deployed on the blockchain platform when an event set by the contract occurs, the corresponding conditions will trigger the contract to execute predefined actions (e.g., transfer of assets or realization of a transaction).

The shared value system of blockchain has been adopted by digital forms of cryptocurrency, and blockchain technology is used as a medium for capital exchange in a distributed network. This is different from traditional systems for financial transactions. Transactions using cryptocurrency are recorded and tracked in a public digital ledger, and transactions are performed directly by the parties involved without an intermediary. PwC released its report “Time for trust: The trillion-dollar reason to rethink blockchain” in October 2020 [5].

It assessed the current use of blockchain technology and analyzed the possible impacts of blockchain on the global economy, including payment, financial services (e.g., digital currencies or cross-border remittances), and economic potential of USD 433 billion.
The global financial industry is facing tremendous changes in the competitive environment. Emerging technologies have continued to change customer preferences, and many challenges have emerged from the digital transformation process. Financial institutions need to redefine services and maintain competitiveness in this continuously changing environment—all challenging tasks. In its “2020 Global Blockchain Survey [6],” Deloitte interviewed nearly 1500 business executives from various industries in 14 countries and regions and found that 55% of respondents regarded blockchain as a top-five strategic priority.

Thus far, governments of various countries have not fully opened up to the idea of blockchain, making it difficult to establish a set of standards for the exchange of information in cross-national application scenarios. JPMorgan, in observation of global logistics blockchain applications, has pointed out that even though more than 500 international logistics and technology companies, including UPS, Fed, ExPENSKE, C.H.Robinson, and SAP, have joined the alliance, the application is still at the Proof of Concept (POC) stage. In Taiwan, the Life Insurance Association R.O.C. (LIA-ROC) and life insurance companies have jointly promoted a platform that will develop electronic insurance policy passbooks, rapid insurance claims, and insurance crime prevention. Financial Information Service Co. (FISC) released the Financial Blockchain Confirmation Service in 2018 [7], though to date, there are no large-scale commercial applications.

It can be seen that the bottleneck in blockchain applications is not only limited by how businesses judge blockchain’s commercial value but also how global regulations view risk related to blockchain. In addition, from the perspective of financial industry governance, many countries have regulations that require user information and transaction records to be physically stored in that country. However, these regulations deviate from the characteristics of blockchain’s decentralized architecture. In practice, the application limits the ability of the blockchain to distribute data to nodes for verification.

A report from the UN [8] suggested that the supervisory authority should leverage new technologies to supervise financial institutions. Relying on the inspection management attitude of global governments and the Bank for International Settlements (BCBS) [9] concerning the blockchain’s legal compliance technology and supervision technology, effective and constant change of markets, and complying with complex financial regulations having issues that the financial industry needs to pay attention to in the future. Blockchain is fused from the technologies of various fields [10], which integrated information security, economic models, and mathematical calculations; the most important innovation is the breakthrough of consensus algorithms.

After weighing the advantages and disadvantages of blockchain, the financial industry remains aware of the potential of blockchain and believes that it can simplify business processes for financial institutions and improve cost structure [11]. Nevertheless, most prominent European and American financial institutions remain relatively conservative and cautious. However, there are many successful cases of smaller financial institutions actively embracing blockchain.

The application of blockchain systems in global financial transactions continues to evolve and important milestones, such as ICO (initial coin offerings), STO (security token offerings), DeFi (decentralized finance), and NFT (non-fungible token), have emerged. Moreover, to commercialize blockchain applications, implementations have gradually moved from a completely open and free operating environment (public chain) to a moderately controlled environment (private chain or consortium chain).

This evolution shows that the international perspective on the blockchain is still about seeking best practice strategies. For instance, the R3 alliance [12] aims to establish a blockchain platform spanning Europe and Asia, allowing its members to develop a blockchain-based transnational financing system with consistent protocols. Additionally, the Hyperledger alliance [13], established in 2015, was jointly established to maintain an open, decentralized ledger technology platform. Compared with the establishment of R3,
Hyperledger has stronger technological implications, and its goal is to allow members to cooperate and participate in an open platform.

Moreover, other than JPMorgan issuing JPM Coin, Quorum technology (supported by JPMorgan) is one of the three standard frameworks for enterprise blockchain [14]. On the other side, MasterCard and Visa are also developing blockchain and decentralized ledger technologies, including authorization, processing, and security issues in blockchain transactions. Combining traditional payment systems with blockchain can ensure decentralization and account security.

Financial institutions must go through trusted third parties or financial intermediaries to deliver value in financial transactions. At the same time, strict financial regulations, high levels of supervision, and restrictions on licensed industries make the entry barriers for competitors higher. From the above, we may infer in this research that the crucial value of blockchain technology for financial industry applications include:

1. **Trust**: Establishes trust among diverse fields; transactions that are cleared can be traced and are immutable. The commercial ecosystem can implement cross-business system exchange and aim to reduce costs, shorten transaction settlement time, and accelerate cash flow while also establishing a reliable basis of network data;

2. **Sharing**: A blockchain is a form of open-source code. The encrypted decentralized network makes it easy for anyone to provide innovative application services. Sharing distributed ledgers creates a shared-value system;

3. **Reliability**: Distributed ledgers with time stamps are difficult to tamper with, and decentralized architecture helps lower the risk of system failures significantly.

As for the financial industry’s investment in blockchain, whether one was to focus solely on technological development and ignore the commercial value or only see the commercial value but fail to explore the technical implications, either would cause an imbalance in the financial industry’s blockchain strategy. One of the critical challenges of the financial system is managing risk, such as credit risk and liquidity risk, through self-regulation mechanisms [15]. Therefore, the following suggestions are put forward as references for the financial industry’s blockchain layout: commercial value evaluation, operating cost estimation, and cross-field talent cultivation.

Based on the blockchain’s trust infrastructure, much cross-scientific research focuses on the impact of cryptocurrencies on traditional economic or commercial structures [16]. At the same time, most of the current blockchain-related research focuses on its regulatory and technical aspects. There are relatively few studies on integrating multi-level considerations and on assisting the financial industry in formulating strategies for the introduction of blockchain [17]. As a promising technologies, blockchain continues to attract surging attention [18–20]. However, most existing literature on blockchain focuses on discussing technological issues. There is insufficient research on how organizations can effectively adopt and implement it into their business operations [21]. Only a few studies, such as Du et al. [21] and Kimani et al. [22], examined the strategies related to how organizations adopt blockchain.

To fill this research gap, we managed to collect domain experts’ knowledge to form a hybrid decision model for supporting financial companies’ blockchain business strategy. This study is positioned as an industrial application, and it is hoped that the findings may contribute to the long-term competitiveness of the banking sector. In practice, this research has the following purposes:

1. It attempts to identify the crucial factors (criteria) for the banking sector to evaluate its long-term competitiveness regarding the blockchain business strategy selection;

2. This study hopes to explore the relative importance and the contextual relations among those crucial factors. It may bring in-depth understanding to this complicated problem;

3. The constructed model aims to identify the best alternative among a group of plausible blockchain businesses for a bank to illustrate the proposed novel approach.
The present study attempts to establish a strategic evaluation decision model for the selection of blockchain business applications for the banking industry. Additionally, through industry surveys and expert opinions, it will summarize essential blockchain business application strategies and then use an innovative decision model to assist a bank in choosing its blockchain business strategy.

This research is divided into the following sections: The second section describes the development of blockchain and the problems that may arise from the adoption of blockchain into financial sectors. The third section explains the proposed research model. The fourth section discusses the analytical results. The fifth section describes findings and major contributions, management implications, research limitations, and the direction of future research.

2. Literature Review and Recent Developments

The business applications of blockchain have gained growing interest recently. Chris- tidis and Devetsikiotis [23] found that blockchain can enable different industries to accelerate sharing services and resources and complete various encryption verifications, saving time-consuming workflows. Aitzhan and Svetinovic [24] verified that blockchain can complete transactions without entrusting a third party while still taking security and privacy into account. Additionally, Li et al. [25] systematically examine the weaknesses of popular blockchain systems and propose ways to improve them. However, in finance, only a handful of papers mentioned blockchain strategy and business developments.

Research on supply chains conducted by Lohmer et al. [26] pointed out that blockchain technology has advantages, including the decentralized nature of data storage, data validation, immutability, and transparency. It plays the crucial role of an intermediary before establishing a solid trust relationship between institutions or enterprises. Given these advantages, many industries embed the blockchain in a specific context to improve operation efficiency [27]. The business potential and benefits of blockchain in finance are evident.

2.1. Key Aspects for the Banking Sector to Evaluate Blockchain Businesses

The introduction of blockchain technology is an innovative move for banks. However, since the financial sector is highly regulated, banks must endure strict supervision to meet different authorities’ requirements. Therefore, one of the key concerns will be the banks’ policy and regulation aspects to adopt blockchain businesses. The other crucial aspects, including technology, organization, and environment, are commonly observed for a business/organization to consider while adopting innovative technologies [28–30]. The four aspects are briefly discussed in the following subsections.

2.1.1. Policies and Regulations

(1) Financial Supervision and Regulations

Due to technological innovation and the expansion of overall financial supervision, FinTech has provided consumers with a better product and user experience, enabling FinTech to impact the conventional financial industry [31,32] significantly. However, sometimes disruptive or excessive FinTech innovations might lead to economic crises [33]. Therefore, to provide sustainable FinTech services, banks should comply with various financial supervision and regulations while developing blockchain-based businesses.

(2) Government Licenses

Blockchain entails integrating cross-domain technologies while providing numerous opportunities for competition and cooperation between financial institutions and FinTech companies. On one side, traditional financial institutions belong to a highly regulated industry, and to conduct business, they must obtain government business licenses and comply with self-discipline standards. On the other side, financial supervision agencies often apply differentiated flexible supervision and licensing restrictions for FinTech companies to foster [34]. Thus, banks must either acquire government licenses or collaborate with
licensed FinTech companies to develop innovative solutions, and government licenses are essential in most cases.

(3) Conflicting Risk among Regulations

Financial supervision agencies, financial institutions, and FinTech companies all face issues of achieving a balance in terms of laws and regulations without conflicting with each other. Examples include data sharing without violating relevant laws and regulations (e.g., General Data Protection Regulation, GDPR) while smoothly introducing innovative services [35,36]. New business models brought by blockchain must evaluate the associated potential conflicting risk.

2.1.2. External Market

(1) Market Potential

The “Blockchain Market Scale” report, published by Fortune Business Insights in October 2020 [37], pointed out that after long-term analysis of the application of blockchain technology in the government, healthcare, financial, and insurance industries, and other fields, it is expected that the global blockchain market size will reach USD 69.04 billion by 2027. Its compound annual growth rate will reach 56.1% within the forecast period. Thus, the market potential of blockchain applications is attractive to the banking sector. However, early movers still need to expand the blockchain ecosystem and promote their products and services, to boost market growth [38]. Therefore, to make a substantial investment, banks usually incline to choose the field with the highest market potential.

(2) Competitors’ Actions and Market Trend

In the FinTech era, financial institutions adopt new technologies to seize business opportunities, making the delayed reactions of lagging competitors unprofitable. Blockchain-based business models have gained growing interest in the financial industry, and most banks are paying close attention to their competitors’ actions. Additionally, when the market trend changes, such as the COVID-19 pandemic in 2020, it may significantly impact the global industry, accelerating the change of users’ behavior from offline to online [39]. It also compels more financial institutions to invest in this direction [38,40]. Blockchain-based digital payment is in line with this trend.

(3) Cooperative Alliances

Since one of the critical advantages of blockchain is sharing, it enables various companies to ally without revealing their business secrets or confidential data to their partners. Additionally, most blockchain-based business models require participation from external partners to form an ecosystem. Strengthening cooperation with strategic partners will help achieve resource sharing, enable operational complementarity, enhance competitiveness, and improve profitability and innovation capabilities [41]. Additionally, successful innovations require stakeholders’ participation and cooperation in the alliance and establishing common operating processes and technical standards. [42]. Therefore, the success of blockchain-based businesses would hinge upon the willingness and capability of its corporative alliance.

2.1.3. Technological Capabilities

(1) Application Scenario Deconstruction Capability

Financial services using blockchain as infrastructure are likely to reshape their existing business models [43]. Sometimes, technological innovations are embodied by destructive solutions that have already been used in different scenarios [44]. Examples that might be applicable to adopt blockchain are, but not limited to, the following: point-to-point verifiable electronic voting, medical record management, identity management systems, access control systems, intellectual property protection, and supply chain management. Financial institutions need to have the capability to deconstruct application scenarios to analyze current bottlenecks and confirm the possible advantages of adopting blockchain [45].
(2) Cybersecurity

Cybersecurity is essential to the financial services of banks. Once a bank decides to adopt blockchain-based technology, it will be inevitable to extend its centralized system to a decentralized network. The more extensive the blockchain network, the higher the threat of hacking and data corruption that a bank will face [31].

For instance, recently, hackers use malware and other methods to defraud the private key and access the user’s digital property. In the point-to-point network layer, hackers often initiate many continuous and useless transactions to the blockchain, causing the entire network service to be temporarily interrupted or suspended. For instance, the world’s largest crowdfunding platform Dao, Cryptocurrency exchange Bitfinex, Japanese Bitcoin exchange BITPoint, and other institutions have all been attacked and suffered significant losses. Banks should explore and take preventive measures to strengthen cybersecurity before launching their blockchain-based services [46].

(3) ID Authentication

There are mainly three authentication methods to verify user identity in a conventional financial system: knowledge-based, token-based, and biological characteristics-based [47,48]. Knowledge-based authentication is performed mainly by requesting users to enter a password or personal identification number (PIN) to verify their identity. On the other hand, counterparty-enabled authentication is executed through the use of a physical credential (e.g., a chip card). The third one, biometric technology based on individual uniqueness (i.e., biological characteristics), has successfully provided a secure and usable user identity verification method [49]. Biometrics are now widely used in online transactions where physical payment transactions can only be completed after user identity verification [50]. However, those methods mainly work on a centralized system; users have to reveal their identity to access their financial services.

Compared with the abovementioned methods, personal data is encrypted with a private key in a blockchain network. Users with autonomous digital IDs can control their data and decide which information to share with the service providers, thereby protecting their privacy. This characteristic is appealing to the users/participants of a financial ecosystem wary about their data privacy.

(4) System Reliability

The trust mechanism of the financial system is undergoing another stage of transformation. Blockchain, however, directly improves reliability during the system design phase. The crucial technical characteristics of blockchain are that it is decentralized and incorruptible.

Decentralization, as mentioned earlier, is the core feature of blockchain. The operation of blockchain is based on the concept of a “distributed database” that offers transparency with pseudonymity and operates without relying on a central organization. The purpose is to allow multiple nodes to be part of the consensus protocol for peer-to-peer transmission. Thus, a decentralized system is usually superior compared with a centralized system regarding reliability.

Incorruptibility means that every piece of data in the blockchain is irreversible; when the data is verified, it will be permanently recorded in the block. A hash algorithm is utilized to ensure the integrity of data. If the key is not obtained, the computational logic cannot be easily found, thus significantly reducing the probability of data tampering [43].

2.1.4. Management and Finance

(1) Top Management Support

Top management support is critical for a business to pursue technological innovations [51–54]. A high level of support from top management for specific technology can ensure long-term commitment and adequate resource allocation, overcoming obstacles and reducing resistance to changes [55,56].

In the adoption of blockchain, top management support is even more critical because the blockchain-based services usually involve additional regulatory requirements, higher
complexity, and the acquisition and integration of new resources [57–59]. An empirical study found that top management’s support reinforced the employees’ devotion to creating feasible blockchain business models [60]. The support from top management is indispensable while devising blockchain-based innovations.

(2) Financial Consideration

International Data Corporation (IDC) released an analysis of the “Worldwide Semiannual Blockchain Spending Guide” in 2019 [61], showing that global spending on blockchain solutions is expected to reach USD 15.9 billion by 2023. During the five years from 2018 to 2023, blockchain investment’s compound annual growth rate is expected to get 60.2%. In 2023, global corporate spending on blockchain solutions might reach USD 15.9 billion, of which about 30% belongs to the banking industry.

Though the required investment of implementing blockchain is high, the main barriers to adopting blockchain would be conversion costs and network effects [62]. Conversion cost refers to the labor and budget required to transition from any existing system to a blockchain-based one. Their current systems bind all banking service providers, and the extension or integration of blockchain-based solutions must gauge the implementation, maintenance, and conversion costs.

(3) Operational Risk

Adopting FinTech solutions, such as blockchain, can improve banks’ efficiency; however, it may also affect the banks’ business by increasing their operational risks [63]. For the banking sector, operational risk mainly refers to the potential for loss due to failure or dysfunction in system reliability and integrity; the associated risks include scalability, security, reversibility, and interoperability [64].

(4) New Business Revenue

Blockchain-based platforms have enticing features to banks, such as higher barriers for data corruption and building trust from heterogeneous business partners [64,65]. Nevertheless, considering the hefty investment in various resources to develop blockchain-based applications, it is crucial to yield substantial and sustainable revenue is crucial for banks.

2.2. Mainstream Blockchain Business Models for Banks

The 2016 World Economic Forum (WEF) report entitled “The future of financial infrastructure” [66] stated that trade financing, compliance with laws and regulations, cross-border payments, asset remortgage, etc., are suitable for blockchain applications. A study by the International Monetary Fund (IMF) in 2017 [67] revealed similar findings. In 2019, the IDC reported that blockchain applications would be primarily concentrated in cross-border payment and trade finance. In this study, we concluded from previous reports to identify four mainstream blockchain business models for banks: (1) payment, (2) cross-border trade, (3) supply chain finance, and (4) insurance claims. The four business models based on blockchain are briefly discussed in the following.

Conventional payment network has many intermediate links, resulting in untransparent rules, long processing time, high handling fees, and exchange rate losses, resulting in inefficiency in the transfer of funds. Several emerging payment services based on blockchain are gaining attention (e.g., Ripple, Stellar, PundiX, and Alchemy Pay).

Cross-border trade must comply with international trade regulations, and the overall transaction process is complicated. There are many manual interventions during the process, and there is a risk of being easily tampered with.

Supply Chain Finance involves banks and many companies, usually centered on core companies (mainly multinational or large corporates). Suppose the other participants can leverage the credit of core companies; it can help upstream companies take more orders and promote downstream companies’ sales capabilities. It can improve the whole supply chain ecosystem’s operating efficiency. The insurance claim is the certification data obtained by the third notary institution so that the insurance contract can pay compensation based on
the claim conditions and supporting evidence. Usually, the claim settlement’s processing
time is lengthy, a large number of documents are required to process back and forth, and it
is common to cause many disputes.

The abovementioned four models may take the advantages of blockchain to transform
or create new business for banks. Additionally, the present study attempts to apply a
hybrid MCDM approach to help banks make a systematic evaluation.

2.3. Applications of MCDM Methods in Business Evaluation

Most real-world problems require considering multiple conflicting factors [68], and it
would be difficult for DM(s) to make a circumspect decision while evaluating a new busi-
ness. The present study addresses a challenging topic for banks—evaluating blockchain-
based business models, covering multiple aspects with complexity. Therefore, we adopt
the MCDM approach to support decision aids in this work.

The mainstream MCDM methods, such as Analytic Hierarchy and Network Processes
(AHP/ANP) [69], Decision-Making Trial and Evaluation Laboratory (DEMATEL) [70,71],
DEMATEL-based ANP (DANP) [68,72], Technique for Order Preference by Similarity to
Ideal Solution (TOPSIS), and VIKOR [73], all have been extensively applied in various
business evaluations. Examples are the analyses of corporate governance [74], corporate
social responsibility (CSR) [75], business process information management [76], and many
others. The MCDM methods have bridged the gap between academic research and practical
business applications.

3. Hybrid Decision Model with Fuzzy Assessment

In this study, we propose a novel hybrid decision-making approach for the banking
sector. This hybrid approach comprises three parts: (1) a pairwise comparison BWM weight-
ing system, (2) an aggregation function, and (3) confidence-weighted fuzzy assessments.
The hybrid model is illustrated in Figure 1.

Figure 1. The proposed hybrid model.

The first one adopts Best-Worst Method (BWM), proposed by Rezaei in 2015 [77].
Compared with the other mainstream MCDM methods, such as the prevailing analytic
network processes (ANP) [69], BWM has the advantage of soliciting fewer pairwise com-
parisons to derive the final weightings. Based on our discussions with experts during
the preliminary stage, this approach may help mitigate their decision fatigue while filling
the questionnaires.

The next one is a semi-linear aggregation function, termed the modified VIKOR. Its
key benefit, but not limited to, is the capability to consider the importance of the highest
weighted performance gap for selecting an alternative. This mechanism may serve as a
sensitivity analysis for the decision model. The details will be explained in Section 3.2.

Since this research topic is an emerging issue, it relies on domain experts’ knowledge
on forming assessments for plausible alternatives. As a baseline, we applied a crisp
assessment, ranges from 1 (worst) to 10 (best). Next, we incorporate two types of fuzzy assessment techniques: (1) conventional fuzzy assessment using the fuzzy triangular membership function and (2) confidence-weighted fuzzy assessment.

3.1. Best-Worst Method

Proposed by Rezaei [77], BWM attempts to resolve the lengthy pairwise comparisons required by the other mainstream MCDM methods (e.g., ANP). The original BWM considers criteria directly, which ignores the dimensional layer. In practice, MCDM problems often have hierarchical structures, as suggested by Saaty [69]. Therefore, this study follows this idea and decomposes the classical BWM into a two-layer system. In other words, under each dimension, we presume the existence of multiple criteria, and the whole model comprises several critical dimensions. This model assumes the independent relationship among its dimensions and criteria. It is the trade-off to exchange for fewer comparisons required from experts.

At the dimensional layer, we assume that there are \( k \) dimensions (\( D_1 \) to \( D_k \)) and \( q \) feasible alternatives (\( a_1 \) to \( a_q \)). Each decision-maker (DM) should identify the most important dimension (i.e., the best, \( D_B \)) and indicate the relative importance of \( D_B \) to the other dimensions, ranges from 1 (equally important) to 9 (extremely important). This step will form a Best-to-Others vector: \( V_{BO} = (w_{D_B 1}, \cdots, w_{D_B k}) \), where \( w_{D_B j} \) denotes the relative importance of \( D_B \) over \( D_j \). Similarly, by identifying the least important dimension (i.e., the worst, \( D_W \)), an Others-to-Worst vector can be obtained (\( V_{OW} = (w_{D 1 W}, \cdots, w_{D_k W})^T \)). Thus, by referring to Rezaei [77], we may obtain the optimal weight of each dimension by solving the min–max problem, shown in Equation (1):

\[
\min \max_j \left\{ \left| \frac{w_{D_B j}}{w_{D_B 1}} - \frac{w_{D_B j}}{w_{D_B k}} \right| \right\} \\
\text{s.t.} \\
\sum_{j=1}^{k} w_{D j} = 1 \\
\text{for all } w_{D j} \geq 0.
\]

(1)

The min–max problem can be transformed into solving the following minimization problem in Equation (2):

\[
\min \varepsilon \\
\text{s.t.} \\
\left| \frac{w_{D_B j}}{w_{D_B 1}} - \frac{w_{D_B j}}{w_{D_B k}} \right| \leq \varepsilon \\
\left| \frac{w_{D j}}{w_{D 1 W}} - \frac{w_{D j}}{w_{D_k W}} \right| \leq \varepsilon \\
\sum_{j=1}^{k} w_{D j} = 1 \text{ and } w_{D j} \geq 0 \text{ for all } j.
\]

(2)

Follow the same procedures, the relative importance of each criterion under each dimension can be obtained. The relative importance of each criterion under each dimension is shown in Equation (3), termed as the local weights (\( W^L \)):

\[
W^L = \left( \left( w_{D_1 C_1 1}, \cdots, w_{D_1 C_{m_1 1}} \right), \cdots, \left( w_{D_j C_1 1}, \cdots, w_{D_j C_{m_j 1}} \right), \cdots, \left( w_{D_k C_1 1}, \cdots, w_{D_k C_{m_k 1}} \right) \right).
\]

(3)

In Equation (3), \( \left( w_{D_j 1} C_1, \cdots, w_{D_j m_j} C_{m_j} \right) \) denotes the relative importance of each criterion (from \( C_1 \) to \( C_{m_j} \)) under dimension \( j \), for \( j = 1, \cdots, k \). Additionally, \( \sum_{j=1}^{k} w_{D j 1} = 1 \). Finally, the relative importance of each criterion can be obtained by multiplying the dimensional weight with the associated local weights, which is called the global weight for each criterion in Equation (4):
\[ W^G = \left( w_1^D \times \left( w_{D_1}^{C_1}, \ldots, w_{D_i}^{C_i} \right), \ldots, w_j^D \times \left( w_{D_1}^{C_1}, \ldots, w_{D_j}^{C_j} \right), w_k^D \times \left( w_{D_1}^{C_1}, \ldots, w_{D_k}^{C_k} \right) \right). \]  

Since \( \sum_{j=1}^{k} w_j^D = 1 \) and \( \sum_{q=1}^{m_i} w_j^{D_i} = 1 \), the summation of all the global weights equals to one.

3.2. Modified VIKOR Aggregation Function

The modified VIKOR has a difference compared with the conventional one—it adopts the ideal and the worst levels, not the highest and lowest performance levels of the available alternatives, to calculate the ranking result. This modification can avoid the potential ranking reversal problem [73]. In this regard, the modified VIKOR synthesizes the weighted average performance gap and the associated highest performance gap of each alternative to calculate the compromised score. The details are as follows:

Again, let us assume that we have \( q \) alternatives and \( l > 1 \) (i.e., \( \eta \) and \( \lambda \)) alternative on the \( \eta \)-th criterion is defined as \( P_{\eta i} \). The weights of the criteria are obtained by the BWM in this model; we rename the global weights from Equation (4) to \( W^G = (w_1, \ldots, w_\eta, \ldots, w_l) \) and \( \sum_{\eta=1}^{\theta} w_\eta = 1 \). Then, by defining the \( L_p \)-matrix, we may aggregate all the weighted performance gaps for the \( i \)-th alternative as in Equation (5):

\[ L_p = \left\{ \sum_{\eta=1}^{l} \left[ w_\eta \left( \left| p_{\eta i}^{\text{Ideal}} - p_{\eta i} \right| / \left| p_{\eta i}^{\text{Ideal}} - p_{\eta i}^{\text{Worst}} \right| \right) \right] \right\}^{Z}, \text{ for } 1 \leq Z < \infty \text{ and } i = 1, \ldots, q. \]  

In here, we set the ideal and worst performance levels as 10 and 0 (i.e., \( p_{\eta i}^{\text{Ideal}} = 10 \) and \( p_{\eta i}^{\text{Worst}} = 0 \)) for all criteria. According to Opiricovic and Tzeng [73], while \( Z = 1 \) and \( Z \approx \infty \), the \( L_p \)-matrix can yield two indices for the \( i \)-th alternative: \( S_i = \sum_{\eta=1}^{l} w_\eta \left( \left| 10 - P_{\eta i} \right| / 10 \right) \left| 1 \right. \), where \( S_i \) and \( R_i \) denote the weighted performance gap and the maximal performance gap, respectively. The final ranking can be determined by calculating the compromised index \( Q_i \) in Equation (6), the lower the better:

\[ Q_i = \lambda \times S_i + (1 - \lambda) \times R_i, \text{ for } i = 1, \ldots, q \text{ and } 0 < \lambda \leq 1 \]  

Though there is no strict requirement regarding the value of \( \lambda \), in most VIKOR-based applications, its common value is above 70%. In the present study, we attempt to set different values of \( \lambda \) as a sensitivity analysis.

3.3. Confidence-Weighted Fuzzy Assessment

The blockchain business strategy is an emerging topic in the banking sector. Since there is still plenty of uncertainty regarding its outlook, even domain experts would encounter difficulties or lack of complete confidence while making assessments. We extend the conventional fuzzy assessment into the confidence-weighted fuzzy assessment [30] to model this challenging issue.

First, we follow the definition of a fuzzy number and use the triangular fuzzy membership function to depict the performance of the \( i \)-th alternative on the \( \eta \)-th criterion. The full performance scale ranges from 0 to 10, and we adopted a 3-level semantic scale to denote “low (L),” “moderate (M),” and “high (H).” Thus, once an expert’s confidence regarding the assessment of the \( i \)-th alternative on the \( \eta \)-th criterion is low, its confidence-weighted performance will be: \( \tilde{P}_{\eta i}^k = p_k(\text{Conf}) \otimes \tilde{l}^k \), where \( p_k(\text{Conf}) \) indicates the confidence level \( 0 < p(\text{Conf}) \leq 100\% \) and \( \tilde{l}^k \) is the semantic value of “low (L)” of the \( k \)-th expert.
4. Results and Discussions

This study referred to several FinTech or blockchain industrial reports [5–7,10] and consulted domain experts to identify four blockchain business models: (1) payment, (2) cross-border trade, (3) supply chain finance, and (4) insurance claims for banks. Besides, during our discussions with experts, they suggested dividing the banks’ business models into two types: leading and participatory ones. The critical difference between the leading and participatory types is the first to take more risk and responsibility to initiate a blockchain business alliance to exchange for superior competitiveness in the future. However, since the environment is competitive and dynamic, banks would have to gauge their strengths and capability compared with the others.

As suggested by the senior analysts from the PwC consultancy in Taipei, they recommended applying the hybrid decision model for the E.Sun bank [78] to evaluate blockchain businesses. Not only because the E.Sun bank is reputable in its operational performance, but also its capability in developing FinTech applications. E.Sun is a domestic bank, which has 139 branches in Taiwan. Though the E.Sun bank is not among the top three financial institutions in terms of scale; it has received the top performance ranking award from the Taiwan Banking Bureau several times.

Since we adopted E.Sun bank to illustrate the hybrid approach, we further delved into the four blockchain business models in two types (i.e., eight potential alternatives) for its initial evaluation. After analyzing the current business environment, we excluded leading cross-border trade and supply chain finance because Cathy Financial Holdings [79] and First Financial Holding [80] have launched their leading type of blockchain ecosystems in those two fields. The two financial holding companies are both larger in scale compared with the E.Sun bank. Besides, several insurance companies have either joined an alliance or initiated their service platforms based on blockchain. We were considering that the E.Sun bank does not involve the insurance business; therefore, we also excluded the leading insurance claims. Therefore, this study kept the following five alternatives for the E.Sun bank.

- Leading Payment (A);
- Participatory Payment (B);
- Participatory Cross-Border Trade (C);
- Participatory Supply Chain Finance (D);
- Participatory Insurance Claims (E).

The present study reviewed recent research in this field and counseled a group of PwC senior consultants who have expertise in FinTech. The decision model’s evaluation framework is shown in Table 1, and the associated discussions can be found in Section 2.2.

| Dimensions                  | Criteria                                      | References            |
|-----------------------------|-----------------------------------------------|-----------------------|
| Policies and Regulations    | Financial Supervision and Regulations (C1)    | [31–33]               |
|                            | Government Licenses (C2)                      | [34]                  |
|                            | Conflicting Risk among Regulations (C3)       | [35,36]               |
| External Market             | Market Potential (C4)                         | [37,38]               |
|                            | Competitors’ Actions and Market Trend (C5)    | [38–40]               |
|                            | Cooperative Alliances (C6)                    | [41,42]               |
| Technological Capabilities  | Application Scenario Deconstruction Capability (C7) | [43–45] |
|                            | Cybersecurity (C8)                            | [31,46]               |
|                            | ID Authentication (C9)                        | [47–50]               |
|                            | System Reliability (C10)                      | [43]                  |
| Management and Finance      | Top Management Support (C11)                  | [51–60]               |
|                            | Financial Consideration (C12)                 | [61,62]               |
|                            | Operational Risk (C13)                        | [63,64]               |
|                            | New Business Revenue (C14)                    | [64,65]               |
The investigations involve multiple domain experts in three stages, shown in Figure 2. We conducted the Delphi survey from four PwC senior consultants to finalize the 14 criteria and identified the five blockchain business alternatives in the initial stage. In the second stage, based on the dimensions and criteria listed in Table 1, we collected the BWM questionnaires from 10 experts: five senior PwC consultants, three from a blockchain-based FinTech company (an official partner of the R3 and Hyperledger alliances), and two senior IT heads from the banking sector in Taiwan. They all have more than 15 years of experience in banking or FinTech related works. In the final stage, we collected the crisp and fuzzy evaluations from the five PwC consultants.

![Figure 2. Three stages of the research.](image)

The Delphi method (Stage 1) determined the BWM model’s framework, including its four dimensions and 14 criteria. In Stage 2, the BWM questionnaires collected from the ten experts (in Appendix A) all passed the consistency checks, and the local weights ($W^L$) and global weights, refer to Equations (1)–(4) are reported in Table 2. From Table 2, we may learn that the most crucial dimension is $D_1$ (Policies and Regulations), which accounts for 33.57%. On the contrary, from the experts’ perspective, $D_3$ (Technological Capabilities) is the least important, echoes our discussions in section one: the business concern deserves more attention. The relative importance of each dimension and criterion is shown in Figure 3.

| Dimensional Weights | Criteria | Local Weights | Global Weights |
|---------------------|----------|---------------|----------------|
| Policies and Regulations ($D_1$) ($w_1^D = 33.57\%$) | Financial Supervision and Regulations ($C_1$) | 43.30% | 14.54% |
|  | Government Licenses ($C_2$) | 36.20% | 12.15% |
|  | Conflicting Risk among Regulations ($C_3$) | 20.50% | 6.88% |
| External Market ($D_2$) ($w_2^D = 28.67\%$) | Market Potential ($C_4$) | 38.60% | 11.07% |
|  | Competitors’ Actions and Market Trend ($C_5$) | 31.87% | 9.14% |
|  | Cooperative Alliances ($C_6$) | 29.53% | 8.47% |
| Technological Capabilities ($D_3$) ($w_3^D = 16.65\%$) | Application Scenario Deconstruction Capability ($C_7$) | 35.25% | 5.87% |
|  | Cybersecurity ($C_8$) | 24.21% | 4.03% |
|  | ID Authentication ($C_9$) | 17.95% | 2.99% |
|  | System Reliability ($C_{10}$) | 22.58% | 3.76% |
| Management and Finance ($D_4$) ($w_4^D = 21.10\%$) | Top Management Support ($C_{11}$) | 37.21% | 7.85% |
|  | Financial Consideration ($C_{12}$) | 21.80% | 4.60% |
|  | Operational Risk ($C_{13}$) | 22.09% | 4.66% |
|  | New Business Revenue ($C_{14}$) | 18.90% | 3.99% |
The top three criteria of the BWM model are: Financial Supervision and Regulations ($C_1$), Government Licenses ($C_2$), and Market Potential ($C_4$), and their importance are 14.54%, 12.15%, and 11.07%, respectively. We may infer that in the context of blockchain business developments, “technological capability” might not be decisive, which could be outsourced to a third-party solution provider. The critical concerns of banks are mainly in regulations and market environment while evaluating blockchain-based businesses.

In the next, with the experts’ judgments, both in crisp and fuzzy assessments, on the five blockchain business alternatives ($A$, $B$, $C$, $D$, and $E$), we adopted the modified VIKOR (refer to Section 3.2) to aggregate their final performance scores. The crisp assessment ranges from 0 (worst) to 10 (best); the fuzzy one is categorized into three scales: low (L), moderate (M), and high (H) to cover the same spectrum (i.e., 0 to 10).

Although the fuzzy assessment provides an intuitive way to express experts’ opinions, the experts’ confidence in each assessment might vary. Therefore, we requested the experts to denote their semantic scales and reveal their confidence in each judgment to resolve this issue. The five PwC experts’ fuzzy semantic scales are summarized in Table 3, and the associated triangular fuzzy membership function is illustrated in Figure 4. For instance, refer to Figure 4, one expert’s fuzzy semantic scales for L, M, and H are: (0.0, 0.0, 0.5), (0.4, 0.6, 0.7), and (0.7, 1.0, 1.0), respectively. If this expert’s assessment on the attractiveness of alternative $E$ regarding $C_4$ is moderate (M) and his confidence is 85%, then we may defuzzify this performance assessment as follows: $85\% \times \left[ 0.4 + \frac{0.6 - 0.4 + 0.7 - 0.4}{3} \right] \times 10 = 4.82$.

Table 3. The five PwC experts’ fuzzy semantic scales (triangular fuzzy membership function).

| PwC Expert 1 | Low ($L_l, L_m, L_r$) | Moderate ($M_l, M_m, M_r$) | High ($H_l, H_m, H_r$) |
|--------------|-----------------------|---------------------------|-----------------------|
| PwC Expert 2 | (0.0, 0.0, 0.5)      | (0.4, 0.5, 0.7)            | (0.7, 1.0, 1.0)       |
| PwC Expert 3 | (0.0, 0.0, 0.5)      | (0.4, 0.5, 0.8)            | (0.7, 1.0, 1.0)       |
| PwC Expert 4 | (0.0, 0.0, 0.5)      | (0.4, 0.5, 0.8)            | (0.7, 1.0, 1.0)       |
| PwC Expert 5 | (0.0, 0.0, 0.5)      | (0.4, 0.7, 0.8)            | (0.7, 1.0, 1.0)       |

Each fuzzy semantic scale will multiply 10 to be in line with the crisp performance spectrum.

Figure 3. BWM weights of the dimensions and criteria.

Figure 4. Triangular fuzzy membership function.
The final performance ranking results applying the modified VIKOR are reported in Table 4, using both the conventional and confidence-based fuzzy assessments. By setting different values of $\lambda$, refer to Equation (6), the top choice is the same: Leading Payment ($A$). However, the two assessments reveal a minor difference. The conventional fuzzy assessment-based ranking is: $A \succ B \succ C \succ E \succ D$, but the confidence-based fuzzy is: $A \succ C \succ B \succ E \succ D$. The results are summarized in Table 4.

### Table 4. BWM + VIKOR in two types of fuzzy assessments.

| Criteria | Weights | Conventional Fuzzy Assessment | Global | Weights | Confidence-Based Fuzzy Assessment |
|----------|---------|-------------------------------|--------|---------|-----------------------------------|
| $C_1$    | 14.54%  | 16.00% 22.00% 24.00% 25.33% | $A$    | 14.54% 36.10% 36.30% 31.60% 40.77% | $A$ \succ C \succ B \succ E \succ D |
| $C_2$    | 12.15%  | 22.67% 10.00% 28.00% 25.33% | $B$    | 12.15% 37.60% 18.63% 34.30% 47.17% | $A$ \succ C \succ B \succ E \succ D |
| $C_3$    | 6.88%   | 28.67% 15.33% 20.00% 31.33% | $C$    | 6.88% 46.60% 14.57% 46.67% 53.17% | $A$ \succ C \succ B \succ E \succ D |
| $C_4$    | 11.07%  | 15.33% 22.67% 28.67% 37.33% | $D$    | 11.07% 32.10% 57.60% 46.53% 45.57% | $A$ \succ C \succ B \succ E \succ D |
| $C_5$    | 9.14%   | 22.00% 29.33% 52.00% 44.67% | $E$    | 9.14% 42.30% 50.67% 57.13% 63.60% | $A$ \succ C \succ B \succ E \succ D |
| $C_6$    | 8.47%   | 36.67% 16.67% 23.33% 32.00% | $S$    | 8.47% 50.13% 37.83% 43.50% 47.73% | $A$ \succ C \succ B \succ E \succ D |
| $C_7$    | 5.87%   | 10.00% 42.67% 34.67% 28.67% | $R$    | 5.87% 30.70% 59.83% 52.17% 49.53% | $A$ \succ C \succ B \succ E \succ D |
| $C_8$    | 4.03%   | 22.67% 21.33% 15.33% 30.00% | $\lambda = 0.9$ | 4.03% 34.57% 44.50% 46.41% 49.43% | $A$ \succ C \succ B \succ E \succ D |
| $C_9$    | 2.99%   | 15.33% 15.33% 15.33% 39.33% | $\lambda = 1.0$ | 2.99% 34.27% 30.83% 32.10% 49.67% | $A$ \succ C \succ B \succ E \succ D |
| $C_{10}$ | 3.76%   | 22.67% 15.33% 15.33% 39.33% | $\lambda = 0.8$ | 3.76% 34.27% 30.83% 32.10% 49.67% | $A$ \succ C \succ B \succ E \succ D |
| $C_{11}$ | 7.85%   | 30.00% 30.00% 22.00% 30.00% | $\eta = 0.9$ | 7.85% 47.57% 46.53% 40.13% 45.93% | $A$ \succ C \succ B \succ E \succ D |
| $C_{12}$ | 4.60%   | 35.33% 28.00% 28.00% 42.67% | $\eta = 1.0$ | 4.60% 50.87% 44.50% 46.37% 56.73% | $A$ \succ C \succ B \succ E \succ D |
| $C_{13}$ | 4.66%   | 37.33% 36.00% 42.67% 45.33% | $\eta = 2.99$ | 4.66% 51.53% 55.13% 59.97% 64.93% | $A$ \succ C \succ B \succ E \succ D |
| $C_{14}$ | 3.99%   | 44.67% 58.00% 67.33% 75.33% | $\eta = 3.99$ | 3.99% 56.80% 70.37% 74.03% 80.57% | $A$ \succ C \succ B \succ E \succ D |

The final ranking is based on the aggregated performance gap index $Q$, the smaller the better.

In Table 4, we report $\left| p_{\text{ideal}}^{\text{ideal}} - p_{\text{ideal}}^{\text{ideal}} - p_{\text{Worst}}^{\text{Worst}} \right| = (10 - P_{i}) / 10$ for each alternative (on each criterion). Additionally, while $\lambda = 1.0$, $Q = S$(refer to Equation (6)). Therefore, by setting $\lambda = 1.0$, $0.9$, and $0.8$, the two types of fuzzy assessments all reveal stable ranking results. This can be regarded as a sensitivity analysis, which suggests the robustness of the analytics. All the raw data of assessments are reported in Appendix B.

Furthermore, we collected the crisp performance evaluation and applied the simple additive weighting (SAW) aggregator with the BWM weightings. We summarized the ranking results using two aggregators (SAW and modified VIKOR) and three types of assessment in Table 5. All the rankings show that alternative A (Leading Payment) is the best option for the E.Sun bank to develop its blockchain-based business model. Additionally, if the E.Sun bank has available (additional) resources it may follow the suggested ranking to pursue the next blockchain business. Once the experts’ confidence level is considered, the second option will be Participatory Cross-Border Trade (C). This hybrid approach reveals a systematic and transparent model for the E.Sun bank to evaluate its blockchain business strategy with a priority.

### Table 5. Rankings of BWM + three types of assessments and two aggregators (SAW and VIKOR).

| Crisp Assessment | Conventional Fuzzy | Confidence-Based Fuzzy |
|------------------|--------------------|------------------------|
| SAW              | $A \succ B \succ C \succ E \succ D$ | $A \succ C \succ B \succ E \succ D$ |
| VIKOR = 1.0      | $A \succ B \succ C \succ E \succ D$ | $A \succ C \succ B \succ E \succ D$ |
| VIKOR = 0.9      | $A \succ B \succ C \succ E \succ D$ | $A \succ C \succ B \succ E \succ D$ |
| VIKOR = 0.8      | $A \succ B \succ C \succ E \succ D$ | $A \succ C \succ B \succ E \succ D$ |

Leading Payment (A) is the best option for the E.Sun bank to develop its blockchain-based business model.
Global giants and rigid transaction processes have dominated the conventional payment sector, which has caused redundant middle layers, untransparent trading rules, and inefficient operations. A domestic bank (such as the E.Sun bank in Taiwan) may leverage its local networking to construct an alliance using blockchain technology. Once its payment ecosystem could offer users more convenient and efficient services, the leading bank would strengthen its market positioning, and thus solicit more users and participants. In a highly regulated and competitive banking market, applying new technologies—such as blockchain—to revolutionize existing systems is a complicated and challenging task. The proposed hybrid model offers a holistic evaluation approach for decision aids.

5. Concluding Remarks

To conclude, this study focuses on the business evaluation of disruptive innovation technology for the banking sector: blockchain. Several key features, such as building trust and forming ecosystems with reliability, have enormous potential to transform the financial industry. Additionally, many blockchain business models are heading toward large-scale applications around the globe. In this context, conventional financial institutions are anxious at competing against each other and the emerging FinTech companies.

However, considering limited resources and various constraints, banks would need a systematic framework to guide their business strategy. The present study bridges the gap by proposing a hybrid MCDM model with supports from seasoned experts. The primary contributions of this research are as follows:

(1) Clarify essential factors for banks to evaluate blockchain-based businesses;
(2) Identity the relative importance of each criterion to selecting blockchain business model;
(3) Take the E.Sun bank as an example to illustrate how to prioritize its blockchain business strategy;
(4) Propose a novel confidence-based fuzzy assessment to transform domain experts’ knowledge into performance figures.

The findings align with our expectations: Financial Supervision and Regulations (C1) and Government Licenses (C2) are the most critical criteria for banks. Moreover, since banks may outsource or acquire FinTech solutions, technological capability is less critical to the external market, internal management, and financial aspects while evaluating new blockchain business.

Though this study has obtained insightful findings on the evaluation of blockchain business strategy, it still has certain limitations. First, the BWM weighting model assumes independence among the criteria, which might not be precise. Future research may adopt a nonlinear method to capture the synergy effect among factors (criteria). Second, the hybrid MCDM model hinges upon experts’ experience and knowledge, and we only have limited domain experts involved in this study (Figure 2). Thus, the ranking result could be regarded as a case study. Future research may seek more domain experts’ participation. Third, we do not have existing packages for the experts to gauge the plausible expenditure of each alternative (i.e., associated with financial consideration). Experts made their evaluations mainly based on their understanding and estimations in this field.

Besides, due to the importance of policy and regulations, a circumspect government should lay an adaptable foundation for fostering FinTech innovations. As technologies progress, conventional supervision and regulations might be insufficient to monitor financial markets and protect users effectively. For instance, the anonymity of cryptocurrency trading might impede anti-money laundering (AML) among the financial networks. Those concerns bring another influential research topic: RegTech (regulation technology), which is another crucial subject for banks to address.
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Appendix A

The BWM questionnaires from the ten domain experts are organized in Tables A1 and A2, to show BO and OW vectors for the dimensions and criteria, respectively.

Table A1. BWM’s BO and OW vectors of dimensions.

| Expert   | Best       | Best-to-Others | Worst     | Others-to-Worst |
|----------|------------|----------------|-----------|-----------------|
| D_1      | D_2        | D_3            | D_4       | D_1             | D_2   | D_3  | D_4  |
| Expert 1 | D_4        | 1              | 2         | 3              | 3     | 1/3  | 1/2  | 1/2  | 1    |
| Expert 2 | D_2        | 3              | 1         | 8              | 2     | 1/5  | 1/8  | 1    | 1/7  |
| Expert 3 | D_4        | 4              | 3         | 2              | 1     | 1    | 1/2  | 1/3  | 1/4  |
| Expert 4 | D_1        | 1              | 3         | 1              | 2     | 1/3  | 1    | 1/2  | 1    |
| Expert 5 | D_1        | 1              | 1         | 9              | 2     | 1/9  | 1/7  | 1    | 1/2  |
| Expert 6 | D_1        | 1              | 2         | 1              | 3     | 1/4  | 1/2  | 1/3  | 1    |
| Expert 7 | D_3        | 1              | 1         | 2              | 3     | 1/3  | 1/2  | 1    | 1    |
| Expert 8 | D_3        | 2              | 4         | 1              | 3     | 1/3  | 1    | 1/5  | 1/4  |
| Expert 9 | D_1        | 1              | 2         | 3              | 3     | 1/3  | 1/2  | 1    | 1    |
| Expert 10| D_1        | 1              | 2         | 2              | 1     | 1/3  | 1/2  | 1    | 1/2  |
Table A2. BWM’s BO and OW vectors of criteria.

| Expert  | $D_1$ | $D_2$ | $D_3$ | $D_4$ | $D_5$ | $D_6$ | $D_7$ | $D_8$ | $D_9$ | $D_{10}$ | $D_{11}$ | $D_{12}$ | $D_{13}$ | $D_{14}$ |
|---------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|---------|---------|---------|---------|
| Expert 1 | C1 1 2 3 | C2 1/3 1/2 1 | C3 1/3 1/2 1 | C4 2 1 3 | C5 1/2 1/3 1 | C6 1 2 4 2 | C7 3 1 4 2 | C8 1/2 1/4 1 | C9 1/3 1/3 1 | C10 1/5 1/4 1 | C11 1 2 3 9 | C12 1/4 1/3 1/2 | C13 1/4 1/3 1/2 | C14 1/4 1/3 1/2 |
| Expert 2 | C1 1 2 3 | C2 1/3 1/2 1 | C3 1/3 1/2 1 | C4 3 1 2 | C5 1/3 1/2 1 | C6 1 2 4 2 | C7 3 1 4 2 | C8 1/2 1/4 1 | C9 1/3 1/3 1 | C10 1/5 1/4 1 | C11 1 2 3 9 | C12 1/4 1/3 1/2 | C13 1/4 1/3 1/2 | C14 1/4 1/3 1/2 |
| Expert 3 | C1 1 2 3 | C2 1/3 1/2 1 | C3 1/3 1/2 1 | C4 7 1 1 | C5 1/3 1/2 1 | C6 1 2 4 2 | C7 3 1 4 2 | C8 1/2 1/4 1 | C9 1/3 1/3 1 | C10 1/5 1/4 1 | C11 1 2 3 9 | C12 1/4 1/3 1/2 | C13 1/4 1/3 1/2 | C14 1/4 1/3 1/2 |
| Expert 4 | C1 1 2 3 | C2 1/3 1/2 1 | C3 1/3 1/2 1 | C4 7 1 1 | C5 1/3 1/2 1 | C6 1 2 4 2 | C7 3 1 4 2 | C8 1/2 1/4 1 | C9 1/3 1/3 1 | C10 1/5 1/4 1 | C11 1 2 3 9 | C12 1/4 1/3 1/2 | C13 1/4 1/3 1/2 | C14 1/4 1/3 1/2 |
| Expert 5 | C1 1 2 3 | C2 1/3 1/2 1 | C3 1/3 1/2 1 | C4 1 1/3 1 | C5 1/3 1/2 1 | C6 1 2 4 2 | C7 3 1 4 2 | C8 1/2 1/4 1 | C9 1/3 1/3 1 | C10 1/5 1/4 1 | C11 1 2 3 9 | C12 1/4 1/3 1/2 | C13 1/4 1/3 1/2 | C14 1/4 1/3 1/2 |
| Expert 6 | C1 1 2 3 | C2 1/3 1/2 1 | C3 1/3 1/2 1 | C4 1 1/3 1 | C5 1/3 1/2 1 | C6 1 2 4 2 | C7 3 1 4 2 | C8 1/2 1/4 1 | C9 1/3 1/3 1 | C10 1/5 1/4 1 | C11 1 2 3 9 | C12 1/4 1/3 1/2 | C13 1/4 1/3 1/2 | C14 1/4 1/3 1/2 |
| Expert 7 | C1 1 2 3 | C2 1/3 1/2 1 | C3 1/3 1/2 1 | C4 1 1/3 1 | C5 1/3 1/2 1 | C6 1 2 4 2 | C7 3 1 4 2 | C8 1/2 1/4 1 | C9 1/3 1/3 1 | C10 1/5 1/4 1 | C11 1 2 3 9 | C12 1/4 1/3 1/2 | C13 1/4 1/3 1/2 | C14 1/4 1/3 1/2 |
| Expert 8 | C1 1 2 3 | C2 1/3 1/2 1 | C3 1/3 1/2 1 | C4 1 1/3 1 | C5 1/3 1/2 1 | C6 1 2 4 2 | C7 3 1 4 2 | C8 1/2 1/4 1 | C9 1/3 1/3 1 | C10 1/5 1/4 1 | C11 1 2 3 9 | C12 1/4 1/3 1/2 | C13 1/4 1/3 1/2 | C14 1/4 1/3 1/2 |
| Expert 9 | C1 1 2 3 | C2 1/3 1/2 1 | C3 1/3 1/2 1 | C4 1 1/3 1 | C5 1/3 1/2 1 | C6 1 2 4 2 | C7 3 1 4 2 | C8 1/2 1/4 1 | C9 1/3 1/3 1 | C10 1/5 1/4 1 | C11 1 2 3 9 | C12 1/4 1/3 1/2 | C13 1/4 1/3 1/2 | C14 1/4 1/3 1/2 |
| Expert 10| C1 1 2 3 | C2 1/3 1/2 1 | C3 1/3 1/2 1 | C4 1 1/3 1 | C5 1/3 1/2 1 | C6 1 2 4 2 | C7 3 1 4 2 | C8 1/2 1/4 1 | C9 1/3 1/3 1 | C10 1/5 1/4 1 | C11 1 2 3 9 | C12 1/4 1/3 1/2 | C13 1/4 1/3 1/2 | C14 1/4 1/3 1/2 |
Appendix B

The five PwC experts’ crisp evaluations for the five alternatives are reported in Tables A3–A7. Additionally, their confidence fuzzy evaluations for the five alternatives (A, B, C, D, E) are in Tables A8–A12, respectively.

Table A3. Crisp evaluations for Leading Payment (A).

| C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 | C11 | C12 | C13 | C14 |
|----|----|----|----|----|----|----|----|----|-----|-----|-----|-----|-----|
| PwC_1 10 | 6 | 9 | 10 | 8 | 6 | 10 | 10 | 9 | 10 | 9 | 4 | 4 | 4 |
| PwC_2 7 | 9 | 5 | 9 | 7 | 8 | 8 | 7 | 8 | 7 | 8 | 6 | 6 | 9 |
| PwC_3 7 | 7 | 7 | 10 | 7 | 8 | 10 | 10 | 8 | 10 | 1 | 4 | 10 | 10 |
| PwC_4 10 | 10 | 8 | 9 | 6 | 4 | 8 | 10 | 10 | 10 | 9 | 6 | 9 | 2 |
| PwC_5 7 | 8 | 4 | 5 | 4 | 6 | 8 | 4 | 4 | 4 | 4 | 4 | 4 | 5 |

Table A4. Crisp evaluations for Participatory Payment (B).

| C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 | C11 | C12 | C13 | C14 |
|----|----|----|----|----|----|----|----|----|-----|-----|-----|-----|-----|
| PwC_1 10 | 8 | 8 | 9 | 6 | 8 | 7 | 8 | 8 | 9 | 8 | 4 | 3 | 3 |
| PwC_2 8 | 7 | 6 | 7 | 7 | 7 | 7 | 8 | 7 | 7 | 8 | 7 | 6 | 6 |
| PwC_3 10 | 10 | 8 | 8 | 5 | 10 | 5 | 6 | 10 | 10 | 10 | 7 | 5 | 5 |
| PwC_4 7 | 7 | 5 | 9 | 5 | 6 | 4 | 10 | 10 | 10 | 4 | 5 | 8 | 3 |
| PwC_5 5 | 6 | 2 | 6 | 7 | 8 | 4 | 5 | 6 | 5 | 6 | 6 | 4 | 4 |

Table A5. Crisp evaluations for Participatory Cross-Border Trade (C).

| C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 | C11 | C12 | C13 | C14 |
|----|----|----|----|----|----|----|----|----|-----|-----|-----|-----|-----|
| PwC_1 9 | 8 | 9 | 9 | 6 | 7 | 5 | 10 | 10 | 9 | 9 | 8 | 3 | 3 |
| PwC_2 8 | 7 | 6 | 7 | 7 | 7 | 7 | 8 | 7 | 7 | 8 | 7 | 6 | 6 |
| PwC_3 10 | 10 | 5 | 7 | 6 | 10 | 5 | 8 | 10 | 10 | 10 | 6 | 5 | 5 |
| PwC_4 9 | 8 | 7 | 6 | 4 | 5 | 7 | 9 | 9 | 9 | 6 | 5 | 5 | 4 |
| PwC_5 7 | 8 | 4 | 6 | 7 | 7 | 5 | 6 | 5 | 5 | 5 | 6 | 6 | 3 |

Table A6. Crisp evaluations for Participatory Supply Chain Finance (D).

| C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 | C11 | C12 | C13 | C14 |
|----|----|----|----|----|----|----|----|----|-----|-----|-----|-----|-----|
| PwC_1 8 | 5 | 5 | 7 | 4 | 9 | 6 | 7 | 9 | 8 | 9 | 6 | 4 | 4 |
| PwC_2 6 | 7 | 6 | 7 | 6 | 6 | 7 | 8 | 7 | 7 | 8 | 7 | 5 | 5 |
| PwC_3 8 | 5 | 5 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 5 | 5 | 3 |
| PwC_4 7 | 7 | 7 | 9 | 3 | 3 | 5 | 4 | 4 | 4 | 3 | 2 | 4 | 5 |
| PwC_5 8 | 9 | 6 | 5 | 4 | 7 | 5 | 5 | 4 | 6 | 5 | 6 | 7 | 4 |

Table A7. Crisp evaluations for Participatory Insurance Claims (E).

| C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 | C11 | C12 | C13 | C14 |
|----|----|----|----|----|----|----|----|----|-----|-----|-----|-----|-----|
| PwC_1 9 | 5 | 6 | 8 | 4 | 9 | 6 | 9 | 10 | 10 | 9 | 6 | 3 | 4 |
| PwC_2 8 | 7 | 7 | 6 | 7 | 7 | 7 | 7 | 8 | 7 | 8 | 7 | 6 | 6 |
| PwC_3 10 | 10 | 8 | 8 | 10 | 10 | 10 | 8 | 10 | 8 | 10 | 8 | 10 | 3 |
| PwC_4 9 | 9 | 8 | 3 | 2 | 2 | 5 | 4 | 3 | 3 | 4 | 3 | 3 | 4 |
| PwC_5 4 | 4 | 3 | 4 | 5 | 7 | 4 | 4 | 3 | 4 | 5 | 5 | 4 | 3 |
Table A8. Confidence-weighted fuzzy evaluations (PwC_1).

| Alternatives | C₁ | C₂ | C₃ | C₄ | C₅ | C₆ | C₇ | C₈ | C₉ | C₁₀ | C₁₁ | C₁₂ | C₁₃ | C₁₄ |
|--------------|----|----|----|----|----|----|----|----|----|-----|-----|-----|-----|-----|
| A Fuzzy      | H  | M  | H  | H  | H  | M  | H  | H  | H  | H   | H   | H   | L   | L   |
| (%)         | 95 | 90 | 90 | 95 | 85 | 90 | 95 | 95 | 90  | 95  | 90  | 90  | 90  | 90  |
| B Fuzzy      | H  | H  | H  | H  | M  | H  | H  | H  | H  | H   | H   | H   | L   | L   |
| (%)         | 95 | 85 | 90 | 90 | 95 | 85 | 95 | 95 | 90  | 95  | 90  | 85  | 85  | 85  |
| C Fuzzy      | H  | H  | H  | M  | M  | M  | H  | H  | H  | H   | H   | H   | L   | L   |
| (%)         | 90 | 85 | 90 | 90 | 95 | 85 | 95 | 95 | 90  | 95  | 90  | 85  | 85  | 85  |
| D Fuzzy      | H  | M  | M  | L  | M  | M  | H  | M  | H  | H   | H   | M   | L   | L   |
| (%)         | 85 | 85 | 95 | 90 | 90 | 95 | 90 | 90 | 85  | 90  | 90  | 85  | 85  | 85  |
| E Fuzzy      | H  | M  | M  | H  | M  | M  | H  | H  | H  | H   | M   | L   | L   | L   |
| (%)         | 90 | 85 | 85 | 90 | 90 | 90 | 90 | 95 | 95  | 90  | 90  | 85  | 85  | 85  |

Table A9. Confidence-weighted fuzzy evaluations (PwC_2).

| Alternatives | C₁ | C₂ | C₃ | C₄ | C₅ | C₆ | C₇ | C₈ | C₉ | C₁₀ | C₁₁ | C₁₂ | C₁₃ | C₁₄ |
|--------------|----|----|----|----|----|----|----|----|----|-----|-----|-----|-----|-----|
| A Fuzzy      | H  | M  | M  | H  | H  | H  | H  | H  | H  | H   | M   | M   | H   | H   |
| (%)         | 60 | 80 | 70 | 70 | 60 | 70 | 70 | 90 | 70  | 90  | 70  | 80  | 80  | 80  |
| B Fuzzy      | H  | H  | H  | M  | H  | H  | H  | H  | H  | H   | H   | H   | H   | M   |
| (%)         | 70 | 60 | 60 | 80 | 70 | 60 | 60 | 70 | 60  | 60  | 70  | 60  | 60  | 80  |
| C Fuzzy      | H  | H  | M  | H  | H  | H  | H  | H  | H  | H   | H   | H   | M   | H   |
| (%)         | 70 | 60 | 60 | 80 | 60 | 60 | 60 | 70 | 60  | 60  | 70  | 60  | 60  | 60  |
| D Fuzzy      | H  | M  | M  | M  | M  | M  | H  | M  | H  | H   | H   | H   | H   | L   |
| (%)         | 80 | 60 | 80 | 80 | 80 | 80 | 80 | 60 | 70  | 60  | 60  | 70  | 60  | 90  |
| E Fuzzy      | H  | H  | H  | M  | H  | H  | H  | H  | H  | H   | H   | H   | H   | M   |
| (%)         | 70 | 60 | 60 | 80 | 60 | 60 | 60 | 70 | 60  | 60  | 70  | 60  | 60  | 80  |

Table A10. Confidence-weighted fuzzy evaluations (PwC_3).

| Alternatives | C₁ | C₂ | C₃ | C₄ | C₅ | C₆ | C₇ | C₈ | C₉ | C₁₀ | C₁₁ | C₁₂ | C₁₃ | C₁₄ |
|--------------|----|----|----|----|----|----|----|----|----|-----|-----|-----|-----|-----|
| A Fuzzy      | M  | M  | M  | H  | H  | H  | H  | H  | H  | M   | L   | M   | H   | H   |
| (%)         | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 80 | 90  | 60  | 75  | 90  | 90  | 90  |
| B Fuzzy      | H  | H  | H  | M  | H  | M  | M  | H  | H  | H   | M   | M   | M   | M   |
| (%)         | 90 | 90 | 80 | 80 | 90 | 80 | 80 | 85 | 90  | 90  | 90  | 80  | 80  | 80  |
| C Fuzzy      | H  | M  | M  | M  | M  | M  | M  | H  | H  | H   | M   | M   | M   | M   |
| (%)         | 90 | 90 | 80 | 80 | 90 | 80 | 80 | 80 | 90  | 90  | 90  | 85  | 80  | 80  |
| D Fuzzy      | H  | M  | M  | H  | H  | H  | H  | H  | H  | H   | H   | M   | L   | L   |
| (%)         | 80 | 80 | 80 | 90 | 90 | 90 | 90 | 90 | 90  | 90  | 90  | 80  | 80  | 85  |
| E Fuzzy      | H  | H  | H  | H  | H  | H  | H  | H  | H  | H   | H   | H   | M   | L   |
| (%)         | 90 | 90 | 90 | 80 | 90 | 90 | 80 | 90 | 80  | 80  | 80  | 85  | 80  | 85  |

Table A11. Confidence-weighted fuzzy evaluations (PwC_4).

| Alternatives | C₁ | C₂ | C₃ | C₄ | C₅ | C₆ | C₇ | C₈ | C₉ | C₁₀ | C₁₁ | C₁₂ | C₁₃ | C₁₄ |
|--------------|----|----|----|----|----|----|----|----|----|-----|-----|-----|-----|-----|
| A Fuzzy      | H  | H  | H  | H  | M  | L  | H  | H  | H  | H   | H   | M   | L   | L   |
| (%)         | 90 | 90 | 70 | 80 | 80 | 80 | 70 | 90 | 90  | 90  | 80  | 80  | 80  | 60  |
| B Fuzzy      | M  | M  | M  | H  | M  | M  | L  | H  | H  | H   | L   | M   | H   | L   |
| (%)         | 90 | 90 | 70 | 80 | 70 | 80 | 80 | 90 | 90  | 90  | 80  | 70  | 70  | 70  |
| C Fuzzy      | H  | H  | M  | M  | L  | M  | M  | H  | H  | H   | M   | M   | M   | L   |
| (%)         | 80 | 70 | 90 | 80 | 80 | 70 | 90 | 80 | 80  | 80  | 70  | 70  | 70  | 80  |
| D Fuzzy      | M  | M  | M  | L  | L  | M  | L  | L  | L   | L   | L   | L   | L   | M   |
| (%)         | 90 | 90 | 90 | 80 | 70 | 70 | 70 | 80 | 80  | 70  | 60  | 60  | 80  | 70  |
| E Fuzzy      | H  | H  | H  | L  | L  | L  | M  | L  | L   | L   | L   | L   | L   | L   |
| (%)         | 80 | 80 | 70 | 70 | 60 | 60 | 70 | 80 | 70  | 80  | 70  | 70  | 70  | 80  |
Table A12. Confidence-weighted fuzzy evaluations (PwC_5).

| Alternatives | C_1 | C_2 | C_3 | C_4 | C_5 | C_6 | C_7 | C_8 | C_9 | C_10 | C_11 | C_12 | C_13 | C_14 |
|--------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| A  Fuzzy     | H   | H   | M   | M   | M   | M   | H   | M   | M   | M   | M   | M   | M   | M   |
| (%)         | 50  | 60  | 50  | 60  | 50  | 70  | 60  | 50  | 50  | 50  | 50  | 50  | 50  | 60  |
| B  Fuzzy     | M   | M   | L   | M   | H   | H   | M   | M   | M   | M   | M   | M   | M   | M   |
| (%)         | 60  | 70  | 60  | 70  | 50  | 60  | 50  | 60  | 70  | 60  | 60  | 60  | 70  | 50  |
| C  Fuzzy     | H   | H   | M   | M   | H   | M   | M   | M   | M   | M   | L   | M   | M   | L   |
| (%)         | 50  | 60  | 50  | 50  | 50  | 60  | 50  | 50  | 60  | 70  | 60  | 60  | 70  | 50  |
| D  Fuzzy     | H   | H   | M   | M   | M   | H   | M   | L   | M   | M   | M   | M   | M   | H   |
| (%)         | 60  | 70  | 60  | 50  | 50  | 60  | 60  | 60  | 80  | 70  | 60  | 70  | 50  | 80  |
| E  Fuzzy     | M   | M   | L   | M   | M   | M   | M   | L   | M   | M   | M   | M   | M   | M   |
| (%)         | 50  | 50  | 70  | 50  | 60  | 80  | 50  | 50  | 70  | 50  | 60  | 60  | 50  | 70  |

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