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Exploring the critical factors affecting the adoption of blockchain: Taiwan's banking industry

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Abstract

As an emerging technology, blockchain has recently gained attention in both academic and economic fields, but its adoption is not yet widespread in the banking sector in Taiwan. As academics have paid scant attention to this topic, this study determines the critical factors affecting blockchain adoption from the organizational perspective in the banking industry. We propose hybrid methods to fill the gap in the literature. First, we apply the technology-organization-environment framework as the basis and combine relevant factors as a framework to identify the relevant evaluation factors. Second, we propose a hybrid method that integrates the decision-making trial and evaluation laboratory (DEMATEL) with the evaluation based on distance from average solution (EDAS) approach and employs DEMATEL to measure the importance of the factors and alternatives to blockchain as ranked by the EDAS method. According to the ranking results, we identify the best preference among alternatives to blockchain. The results suggest that organizational and technological aspects are the main considerations to enhance and promote the effectiveness of blockchain adoption. This study suggests valuable strategies for stimulating blockchain adoption in the banking sector in Taiwan.

Keywords: Blockchain, Key factors, TOE framework, DEMATEL, EDAS

Introduction

Blockchain is emerging as a technological revolution that will impact the way the financial industry executes its operations in the future (Zheng et al. 2018; Ali et al. 2020). It offers significant potential for providing innovative technologies to the banking industry that can massively impact the banking industry and also society (Chang et al. 2020). Indeed, blockchain in the banking domain has been implemented as an open distributed ledger that records the transactions between two parties (Zhang et al. 2020). It consists of the chain of data blocks in which each has a set of transactions related to the others (Chen and Bellavitis 2020). Moreover, blockchain can provide quicker payments, lower costs for banks, increase the number of financial transactions with added security, and increase performance.

Despite the benefits of blockchain, there are some difficulties and obstacles regarding its adoption for the banking sector (Xu et al. 2019; Chang et al. 2020; Mishra and Kaushik 2021). Moreover, the adoption of blockchain in organizations is still in its infancy and studies in this area are limited (AlShamsi et al. 2022). First, most prior studies focused on technological factors affecting blockchain adoption. Second, the majority of the existing literature on the adoption of blockchain focuses on supply chains and ignores business adoption of blockchain, especially in the banking sector. Moreover, most previous studies on organizational decisions on blockchain adoption have concentrated on structural equation modeling (SEM) to examine the relationships among adoption factors.

Apart from the above-mentioned literature, depending on the type of blockchain, it can often not be verified and validated automatically but requires human thinking and collaboration (Coita et al. 2019; Mohammad and Islam 2022). The most appropriate personnel change their operational style to fit the scenario (Spence 2018). This human factor influences the method of applying blockchain technologies for such content that cannot easily be classified as wrong or right (Yi et al. 2020). However, in all these studies, there is no specific human factor that is considered for the adoption of blockchain. Therefore, identifying the key factors affecting the blockchain adoption is a multifaceted problem.

The multiple-criteria decision-making (MCDM) technique could be a convenient way to identify the critical factors affecting an organization's adoption of blockchain (Xiao et al. 2023). The decision-making trial and evaluation laboratory (DEMATEL) method solves various types of MCDM problems (Hu et al. 2021; Meng et al. 2021; Si et al. 2018). This approach recognizes the complex relationships among factors and measures their importance (Hsu and Yeh 2017, 2018). To the best of our knowledge, no previous studies have examined blockchain adoption using DEMATEL. Moreover, evaluation based on the distance from the average solution (EDAS) is a new MCDM method (Keshavarz Ghorabaee et al. 2015). With the benefit of simplicity and faster computation, previous studies have utilized the EDAS method (Dhanalakshmi et al. 2020; Mishra et al. 2020).

This study seeks to fill the gap in the literature by identifying the critical factors affecting adoption of blockchain in the banking sector in Taiwan. First, it reviews the literature related to blockchain to uncover the relevant evaluation factors. Second, it proposes a hybrid method connecting the DEMATEL and EDAS approaches. Hence, DEMATEL is used to measure the importance of the factors. It then ranks and determines the best alternative obtained by the EDAS. Finally, to validate the effectiveness of the proposed approach, comparative experiments are conducted for the banking sector in Taiwan. The findings provide valuable information for the banking sector to expand adoption of blockchain in Taiwan.

The remainder of this paper is organized as follows. "Literature review" section reviews the literature on blockchain. "Method" section describes the proposed approach. "Conclusions" section reports the empirical results and discusses the managerial implications. Finally, conclusions and future directions are presented.

Literature review

Blockchain

A blockchain is a digital, decentralized (distributed) ledger, cryptographic security protocol, and consensus mechanism (Niranjanamurthy et al. 2019; Antal et al. 2021). The distributed ledger ensures that the entry of new data creates a block that is not stored in a single location but is continually copied and distributed to different nodes across the network, making it accessible and traceable by participants in the network (Yoo 2017; Lewis et al. 2017; Mori 2016).

Blockchain introduces a decentralized ledger and stores the complete transaction history in a bank across dozens of controlled-access computers, which replicates the breadcrumb trail of banking activities (Butt et al. 2019; Uddin et al. 2021; Bellucci et al. 2022). It is not possible to delete or change the activity history. Blockchain performs many of the core workflows in finance and banking from records keeping and cybersecurity to currencies, debts, and equity management (Bellucci et al. 2022).

This technology is obviously a powerful decentralized technology that is revolutionizing the banking sector (Liu et al. 2021; Zheng et al. 2018; Zhang et al. 2020). Since its data cannot be tampered with, blockchain ensures immutability and security and can change the way banks build their banking infrastructure (Zheng et al. 2018; Chang et al 2020). This technology also has the potential to change the financial sector in the long term as numerous business models could emerge, while many others would become superfluous (Sun et al. 2016). Therefore, the financial industry is the sector that will benefit the most from blockchain.

Previous studies on blockchain revolve primarily around Bitcoin and cryptocurrencies (Guo and Liang 2016; Nerurkar et al. 2021; Zheng and Lu 2021; Xu et al. 2022). In addition, they focus on technical aspects. For example, technical issues related to scalability (Khan et al. 2021), security, and privacy (Mohanta et al. 2019; Butt et al. 2019; Taylor et al. 2020) have been examined. Other studies focus on the impact of blockchain in the banking industry. Topics include the penetration of Bitcoin in the context of retail banking and new technology-enabled central banks (Dashkevich et al. 2020). Moreover, Ahluwalia et al. (2020) propose a framework for how banks can start-up and accelerate blockchain innovations from the perspective of transaction cost economics. However, these studies do not consider banks' adoption of blockchain; most research is experimental in nature and empirical data about the potentials does not exist as the aforementioned research primarily concentrates on concepts and frameworks.

Related literature on the factors influencing blockchain adoption

With blockchain as an emerging technology, studies on its adoption in banking remain fairly small. For example, Kawasmi et al. (2020) investigate blockchain adoption in the global banking industry via a literature review and identify three categories of adoption factors: supporting, hindering, and circumstantial. Saheb and Mamaghani (2021) qualitatively confirm that technological, organizational, and environmental factors have more significant impacts on adopting blockchain for the banking sector. Ozturan et al. (2019) assess the level of technology readiness of the banking industry. Kulkarni and Patil (2020) apply the technology-organization-environment (TOE) framework and partial least squares (PLS)-SEM to examine the drivers and hurdles of blockchain adoption in banking services. In summary, despite the attention blockchain has received, there remains a lack of consensus on decisions related to its adoption and evaluation in the banking sector.

AlShamsi et al. (2022) conducted a comprehensive literature review on the organizational adoption of blockchain. Their results confirmed that TOE is widely used as a framework used for theoretical perspective on blockchain adoption. Their results also revealed that supply chain management is the main domain in which blockchain applications were adopted. Furthermore, existing studies have examined the adoption of blockchain technologies through the lens of the organizational level.

Furthermore, during the last three years, initial research that quantitatively and qualitatively explores blockchain adoption has evolved and derived first results on the distinct criteria affecting intra-firm adoption. The majority of qualitative studies employed explorative approaches to generate knowledge on this new field of research; recent work applied quantitative methods based on large empiric samples. These empirical studies either applied firm-centered adoption models such as Tornatzky and Fleischer's (1990) TOE framework (e.g., Clohessy and Acton 2019), the diffusion of innovation (DOI) theory (e.g., Ullah et al. 2020) or user-centered decision frameworks, such as the unified theory of acceptance and usage of technology (UTAUT) (e.g., Wamba and Queiroz 2019) or the technology acceptance model (TAM) (e.g., Pantouw and Aruan 2019) to examine organizational decision-making. These models contrast not only in terms of the dependent and independent variables but also in the underlying units of analysis. While some constructs examine the action of adoption (Orji et al. 2020), others merely investigate the intention to adopt blockchain technology (Yadav et al. 2020). In addition, the dimensions affecting adoption decisions differ significantly. Research employing user-centered models emphasizes the impact of individual decision-maker characteristics on the adoption decision (Saurabh and Dey 2021). Relevant studies based on the key theories, their components, and studies investigating blockchain adoption are presented in Table 1.

1. Based on the aforementioned studies, we draw the following conclusions: despite the diverse factors affecting blockchain adoption among the findings of previous studies, the results confirmed that the TOE was the most common model for studying blockchain adoption on the organizational level.
2. Most previous studies demonstrate the importance of technological factors affecting blockchain adoption. However, no specific human factors are considered in terms of the adoption of blockchain.
3. The relevant studies on blockchain focus on the supply chains and ignore the business adoption of blockchain, especially in the banking sector.
4. Most previous studies organizational adoption decisions on blockchain concentrate on the TOE and applied SEM to examine the relationships among the adoption factors.

Table 1 Previous studies on blockchain adoption

References	Method	Country/region	Contexts	Framework
Clohessy and Acton (2019)	Multiple-case study	Ireland	N/A	TOE
Lee et al. (2019)	Regression analysis	USA	Academia	UTAUT
Queiroz and Wamba (2019)	PLS-SEM	USA and India	Logistics and supply chain management	TAM and UTAUT
Singh et al. (2019)	Not specified	Not specified	Finance	TAM
Yang (2019)	Survey and interviews	Taiwan	Maritime shipping	TAM
Wamba and Queiroz (2019)	PLS-SEM	Brazil	Supply chain management	UTAUT
Albayati et al. (2020)	Path analysis	Not specified	Finance	TAM
Karamchandani et al. (2020)	SEM	India	Supply chain management	TAM and DOI
Muhamad et al. (2020)	SEM	Malaysia	Intelligence community	TAM and TRI
Nuryyev et al. (2020)	SEM	Taiwan	Tourism and hospitality	TAM
Orji et al. (2020)	Analytic network process (ANP)	Nigeria	Logistics	TOE
Rijanto (2020)	Case study	Indonesia	Agriculture	TOE
Ullah et al. (2020)	PLS-SEM	Developed countries	Energy	TAM and DOI
Wahab et al. (2020)	Not specified	Malaysia	Warehouse industry	UTAUT
Yadav et al. (2020)	DEMATEL	India	Agriculture supply chain	
Aketch et al. (2021)	SEM	Kenya	Finance	TAM and IDT
Alazab et al. (2021)	SEM	Australia	Supply chain management	UTAUT, TTF, and ISS
Ajwani-Ramchandani et al. (2021)	In-depth longitudinal case study	Malaysia	Supply chain management	TOE
Fernando et al. (2021)	SEM	Malaysia	Manufacturing	TOE
Kamble et al. (2021)	SEM- Bayesian network	India	Supply chain management	TAM and TOE
Kouhizadeh et al. (2021)	DEMATEL	Not specified	Supply chain management	TOE
Queiroz et al. (2021)	PLS-SEM	Brazil	Supply chain management	UTAUT
Toufaily et al. (2021)	Semi-structured interviews	Middle East and North Africa	N/A	DOI and TOE
Saurabh and Dey (2021)	Conjoint analysis	India	Agri-food supply chain	
Ullah et al. (2021)	PLS-SEM	Malaysia	Education	TAM and DOI

Factors for evaluating blockchain adoption

Previous studies on blockchain adoption have focused on the TOE framework, which offers a valuable analytical basis for assessing the acceptance of different types of IT innovation in organizations (Arpaci et al. 2012). This model is specifically found to be useful at the organizational level of information technology (IT) adoption. Overall, based on numerous studies on the adoption of information systems (IS), the TOE model has been successfully applied in various contexts. Other studies have criticized the fact that the major constructs and variables in the TOE framework are not concise and differ from context to context (Wang et al. 2010; Yeh and Chen 2018). Moreover, the flexibility of the model allows for the incorporation of other theories or variables (Lian et al. 2014).

Human factors are also critical in the adoption of any new IT innovation. These factors should be considered carefully when making the decision on adopting new IT/IS (Tekic and Koroteev 2019). Staff who have sufficient innovation knowledge or technology capability can help organizations to successfully adopt an innovative technology. The sufficient technical expertise available in such organizations will have more propensity to adopt IS if they possess staff with more knowledge of ISs (Yi et al. 2020). Moreover, the human, organization and technology-fit (HOT-fit) framework (Yusof et al. 2008) overlaps with the TOE by considering the organizational and technological dimensions during a firm's decision to implement new innovations and also uniquely considers the human dimension (Schiavone et al. 2021; Xu and Lu 2022; Ahmetoglu et al. 2022).

In addition, information security awareness and compliance have far-reaching impacts on the long-term success of technological innovations (Schneider, et al. 2020). Given the security features of blockchain, the adoption of the technology can be regarded as a behavior of protecting oneself from the consequences and security issues in digital transactions (Shi et al. 2020; Feng et al. 2019). Given the lack of understanding of the organizational perception of blockchain benefits and limited research on its adoption (Chod et al. 2020; Adel and Younis 2021; Garg et al. 2021), this study also explores whether banking organizations are willing to use blockchain from security issues.

Moreover, standards uncertainty negatively influences blockchain adoption (Lu 2019; Uddin et al. 2021). Finally, few studies have reported that governments have not laid down specific regulations on blockchain for the banking industry (Zheng and Lu 2021; Nelaturu et al. 2022). Therefore, the importance of environmental factors and the government's role is not conducive to the focus of this study, that is, the banking industry.

Thus, we adopt the technological and organizational factors of the TOE framework with human and security factors as the four dimensions of our research framework. The factors for evaluating the blockchain adoption process are described below.

Technology dimension (T) Technological factors covers features of the technology itself that influences the adoption of blockchain (Lu et al. 2013; Guo and Liang 2016). The technology component consists of relative advantage, compatibility, complexity and system integration (Lu et al. 2013; Xu et al. 2019; Hanna et al. 2020; Hsu and Yeh 2017; Aboelmaged 2014).

Organization dimension (O) Organizational factors include the firms' characteristics and resources available that affect the adoption of blockchain (Lu et al. 2013; Guo and Liang 2016). Several studies support this finding with respect to blockchain adoption with factors such as adequate resources, firm size, and top management support considered potential influences (Rawash 2021; Lian et al. 2014; Lu et al. 2013; Hanna et al. 2020; Xu et al. 2019).

Human components (H) Human factors refer to staff who have sufficient innovation knowledge or technological capabilities when adopting and implementing blockchain (Adel and Younis 2021; Mohammad Saif and Islam 2022). These include system users, IT personnel, system consultants, and project leaders (Mohammad et al. 2022; Xu and Lu 2022; Nong and Ha 2021; Spence 2018; Adel and Younis 2021; Schneider et al. 2020).

Security dimension (S) Security refers to the level of procedures in place to protect information and a system from unauthorized access or any other security events (Sarfaraz et al. 2021; Shi et al. 2020; Sebastião and Godinho 2021; Fang et al. 2022). We investigate the related security of blockchain, such as client information, internal information, system protection, and backup mechanism (Sarfaraz et al. 2021; Shi et al. 2020; Benatia et al. 2016; Taylor et al. 2020; Liu and Ye 2010; Lu 2021; Liu et al. 2010; Feng et al. 2019).

This study proposes using technological and organizational factors in the TOE framework with human and security factors as the framework for influencing blockchain

Table 2 Exploring the critical factors affecting the adoption of blockchain in the banking industry

Dimension/criteria	Descriptions	References
Technology (T)		
Relative advantage (T1)	It is the degree to which using the blockchain is perceived to make one better off than otherwise	Lu et al. (2013); Xu et al. (2019)
Compatibility (T2)	The degree to which the blockchain is perceived to be consistent with internal organizational and information systems environment	Lu et al. (2013); Xu et al. (2019); Hanna et al. (2020)
Complexity (T3)	The degree to which using the blockchain is perceived to be a difficult task	Lu et al. (2013); Hsu and Yeh (2017)
System integration (T4)	The blockchain reduces incompatibility between legacy systems and enhances the responsiveness of information systems	Xu et al. (2019); Aboelmaged (2014)
Organization (O)		
Adequate resources (O1)	The capabilities that an organization possesses for future needs or dynamic changes	Rawash (2021); Lian et al. (2014)
Firm size (O2)	Large firms typically have the resources necessary to experiment, pilot, and decide what blockchain they require	Lu et al. (2013); Hanna et al. (2020)
Top management support (O3)	Top management can provide vision, support, and a commitment to create a positive effect on the blockchain adoption process	Xu et al. (2019)
Human (H)		
System user (H3)	The system user has sufficient knowledge and the adequate skills to adopt blockchain technology	Mohammad et al. (2022)
IT personnel (H1)	The IT personnel are able to execute their tasks well and demonstrate a sound understanding of the organizations' needs	Xu and Lu (2022); Nong and Ha (2021)
System consult (H3)	The system consult has the ability to be good consultants and provide world-class support	Spence (2018); Nong and Ha (2021)
Project leader (H4)	The project leader has to be good leader and an undertaking to keep up to date with new techniques and technology	Adel and Younis (2021); Schneider et al. (2022)
Security (S)		
Client information (S1)	The degree that Blockchain deals with integrity and confidentiality of the client information	Shi et al. (2020)
Internal information (S2)	The degree to which the blockchain is deemed secure for exchanging data and conducting online transactions	Benatia et al. (2016); Taylor et al. (2020)
System protection (S3)	The degree available in blockchain that helps protect the system and personal files	Liu and Ye (2021); Lu (2021)
Backup mechanism (S4)	The degree of creating a copy of the data and recovery in case original data is lost or corrupted	Liu et al. (2021); Feng et al. (2019)

adoption in the banking industry. Consequently, we present four factors in terms of technology, organization, human, and security, including the four dimensions and 15 criteria presented in Table 2.

Research gap

The key factors affecting the blockchain adoption is a multifaceted problem. However, previous studies focus on technical aspects. Others focus on the impact of blockchain in the banking industry. Topics include the penetration of Bitcoin in the context of retail banking. Moreover, these studies do not examine banks' blockchain adoption and most research primarily concentrates on concepts and frameworks. Finally, no specific human factor is considered in the adoption of blockchain. Thus, to the best of our knowledge, our focus on blockchain adoption determinants is one of the few attempts to factor in the application of TOE theory.

Moreover, this study aims to fill the gap in the literature by identifying the critical factors affecting blockchain adoption in the banking sector. We propose a hybrid evaluation model for blockchain adoption using the hybrid of the DEMATEL and EDAS approaches. First, the former is used to measure the importance of the factors. It then ranks and determines the best alternative obtained by the latter. Finally, to validate the effectiveness of the proposed approach, Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) is used as the benchmark.

Method

The main contribution of this study is the identification of the critical factors affecting the banking sector's blockchain adoption. We therefore propose the hybrid DEMATEL and EDAS methods. First, we use DEMATEL to measure the importance of the factors. Second, we incorporate these weights into the EDAS method to rank and determine the best alternative presented to the decision maker. The details of the proposed approach are delineated as follows.

Proposed approach

Previous studies have underlined the lack of applications that integrate the DEMATEL and EDAS methods that influence blockchain adoption. The procedures of this hybrid MCDM model are illustrated in Fig. 1. In the first stage, we employ the TOE framework as the basis for model development and combine it with other relevant factors affecting blockchain adoption. Ultimately, the evaluation factors are derived from the following four aspects: technology, organization, human, and security. The second stage determines the relative weights of dimension and criteria via the DEMATEL method and then prioritizes the blockchain alternatives using the EDAS technique. Finally, to verify the feasibility of the proposed approach, we include four alternatives to blockchain for Taiwan's banking sector.

In the DEMATEL method, we use a numerical scale between 1 and 5, which assigns weights for evaluation factors. The overall priority weights of dimensions and criteria

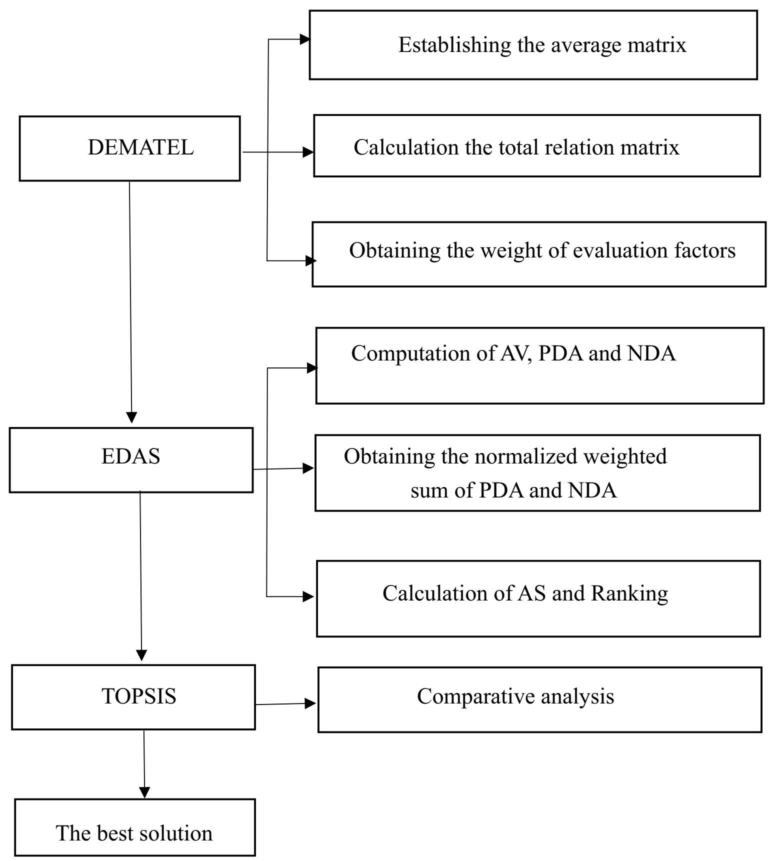

Fig. 1 Framework for the proposed approach

are then calculated. Lastly, the respondents are asked to provide a set of values from 1 to 5 to rate each alternative with respect to each criterion. Each alternative is compared with the criteria, and the alternatives are then ranked as determined by the EDAS method. To demonstrate the proposed approach, we conduct comparative experiments. Specifically, the TOPSIS technique was employed as the benchmark. An empirical case study helps identify the key factors affecting blockchain adoption. These methods are delineated in each of the following sub-sections.

DEMATEL method

The DEMATEL method is based on graph theory (i.e., digraph) which enables analysis and solution of problems via the visualization method. These graphs are more helpful than undirected graphs because they can reveal the directed relationships of sub-systems (Gabus and Fontela 1972; Vafadarnikjoo et al. 2022; Alzahrani et al. 2022; Wu et al. 2022). DEMATEL is a useful approach for analyzing the interdependent relationships among related variables in cause-and-effect groups. It reveals the degree of interaction between variables to determine the weights of individual factors in the related structural model. The method has been applied to identify the critical factors (Hu et al. 2021; Kou et al. 2021; Hsu and Yeh 2017, 2018; Si et al. 2018).

Blockchain adoption is a complex problem involving several causal relationships among factors. Therefore, we employ DEMATEL to identify the key factors that affect blockchain adoption. The processes of the DEMATEL method are discussed as follows (Hsu and Yeh 2017, 2018; Si et al. 2018; Zhang and Su 2019; Gayathri et al. 2021).

Step 1: establishing the average matrix.

This method evaluates the following direct-influence matrix $\boldsymbol{A}$. This is performed by experts who provide the degree to which factor i affects factor j, denoted as x_{ij}^{k}. Hence, $\boldsymbol{X}^{1}$, $\boldsymbol{X}^{2}$,.., $\boldsymbol{X}^{\mathrm{h}}$ are the matrices of H experts. Moreover, the element of $\boldsymbol{X}^{\mathrm{k}}$ is an integer based on the scale range. The diagonal elements of each matrix $\boldsymbol{X}^{\mathrm{k}}$ are zero. The provided scores generate an n × n non-negative average matrix $\boldsymbol{A}$, where:

$$A_{ij} = \frac{1}{h}\sum_{k=1}^{h} X_{ij} \tag{1}$$

The matrix $\boldsymbol{A} = [a_{ij}]_{n\times n}$ with $1 \le k \le H$ is also referred to as the initial direct-relation matrix.

Step 2: normalizing the direct-influence matrix.

The normalized direct-relation matrix $\boldsymbol{S}$ can be obtained using Eqs. (2) and (3):

$$\boldsymbol{S} = m \cdot \boldsymbol{A} \tag{2}$$

$$m = \min\left[\frac{1}{\max\limits_{i}\sum\limits_{j=1}^{n}|a_{ij}|}, \frac{1}{\max\limits_{j}\sum\limits_{i=1}^{n}|a_{ij}|}\right] \tag{3}$$

Step 3: calculating the total direct-influence matrix.

The total direct-influence matrix $\boldsymbol{T}$ *can be obtained from Equation (4):*

$$\boldsymbol{T} = \boldsymbol{S}(I - \boldsymbol{S})^{-1} \tag{4}$$

Step 4: obtaining the sum of rows and columns.

Equations (5) and (6) are used to calculate the sums of rows and columns in matrix **T**, respectively.

$$R = [R_i]_{n\times 1} = \left[\sum_{j=1}^{n} t_{ij}\right]_{n\times 1} \tag{5}$$

$$D = [D_j]_{1\times n} = \left[\sum_{i=1}^{n} t_{ij}\right]_{1\times n} \tag{6}$$

here, R denotes both direct and indirect effects of factor i on the other factors. Similarly,D_j indicates both direct and indirect effects that factor j has received from others.

Step 5: identifying the cause-and-effect groups.

$(D_i - R_i)$ depicts the net influence level of a factor. Generally, when it is positive, then factor i belongs to the cause group. Conversely, if it is negative, then factor i belongs to the effect group. Similarly, $(D_i + R_i)$ is a measurable index of the influences by and on other factors and reveals the importance of factors.

Step 6: calculating the importance of the factors.

The weighted normalized value $(D_i + R_i)$ is calculated as follows:

$$W_i = \frac{D_i + R_i}{\sum_{i=1}^{n} \sum_{j=1}^{n} (D_i + R_i)}, \tag{7}$$

where i, j = 1, 2,..., n.

EDAS method

Keshavarz Ghorabaee et al. (2015) propose EDAS for the classification of inventory. Compared with the TOPSIS method, the merit of the EDAS method is that a unique optimal solution does not exist for the decision maker. The method is only based on the distance from the average solution (AV), which is a much easier task. Previous studies compare this with other methods such as TOPSIS (Hwang and Yoon 1981) and Vise Kriterijumska Optimizacija I Kompromisno Resenje (VIKOR) (Opricovic 1998), indicating the validity of the EDAS method. To select the most appropriate alternative, we use the EDAS method. The processes of the method can be summarized as follows (Keshavarz Ghorabaee et al. 2015; Dhanalakshmi et al. 2020; Mishra et al. 2020; Wei et al. 2021; Biswas and Pamucar 2023).

Step 1: the criteria and alternatives are available for the decision problem.

Step 2: generating the decision matrix X.

This method evaluates decision matrix X, which refers to n alternatives and m criteria, presented by Eq. (8):

$$X = \left[X_{ij}\right] n \times m = \begin{bmatrix} x_{11} & x_{11} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2m} \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ x_{n1} & x_{n2} & \ldots & x_{nm} \end{bmatrix} \tag{8}$$

here, X_{ij} is the preference for the i^{th} alternative with respect to the j^{th} criterion.

Step 3: obtaining the average solution to all criteria.

$$AV_j = \frac{\sum_{i=1}^{n} x_{ij}}{n} \tag{9}$$

Step 4: calculating the positive distance from average (PDA) and the negative distance from average (NDA).

$$PDA_j = \frac{max\left(0, \left(x_{ij} - AV_j\right)\right)}{AV_j} \tag{10}$$

$$NDA_j = \frac{max\left(0, \left(AV_j - x_{ij}\right)\right)}{AV_j} \tag{11}$$

Step 5: obtaining the weighted summation of PDA and NDA.

$$SP_i = \sum_{j=1}^{m} w_j PDA_{ij} \tag{12}$$

$$SN_i = \sum_{j=1}^{m} w_j NDA_{ij} \tag{13}$$

Step 6: calculating the Normalization for *SPi* and *SNi*.

$$NSP_i = \frac{SP_i}{Max_i(SN_i)} \tag{14}$$

$$NSN_i = 1 - \frac{SN_i}{Max_i(SN_i)} \tag{15}$$

Step 7: summing the appraisal score (AS).

$$AS_i = \frac{1}{2}(NSP_i + NSN_i) \tag{16}$$

here, $0 \leq ASi \leq 1$.

Step 8: ranking the alternatives.

The alternatives are ranked in descending order of appraisal score (*ASi*) calculated using Eq. (16).

Results and discussion

Demographics profile of respondents

To achieve our research goal, data were collected through an online survey conducted from January to February 2020. All participants have good knowledge of the topic of blockchain technologies in banking. Of the initial 60 questionnaires, 56 usable responses were obtained, a response rate of 93.3%. In addition, we excluded data with obviously unreasonable results, such as repeated selection of the same response option for all items, as well as data with large missing values. The majority of the respondents were male (54%) (female = 46%). The largest age group was between 41 and 50 years (36%), followed by 31 and 40 years (29%), while 18% were aged over 51. The majority (93%) of the respondents had a bachelor's degree. Blockchain adoption is a complicated process; the respondents include the departments of management, operations, and IT/IS in banking. The detailed demographic information is presented in Table 3.

Determining weights of criteria based on DEMATEL

The following section presents an empirical study using the DEMATEL method to calculate the relative importance of the evaluation factors that affect blockchain adoption of the banking sector. Referring to the factors affecting blockchain adoption from the

Table 3 Demographic characteristic of respondents (sample $N = 56$)

Variable	Classification	Frequency	Percentage (%)
Gender	Male	30	54
	Female	26	46
Age	Below 30	10	18
	31–40	16	29
	41–50	20	36
	51–60	10	18
Education level	Junior college	4	7
	Bachelor degree	29	52
	Above Master	23	41
Department	Management	7	13
	Operations	29	52
	IT/IS	20	36
Experience (years)	Below 5	8	14
	5–10	19	34
	11–15	7	13
	16–20	10	18
	21–25	5	9
	Above 25	7	13

relevant literature, four dimensions are identified for further evaluation. The total-influence matrix for the dimensions by DEMATEL, obtained based on the survey results of the aforementioned respondents, is presented in Table 4.

The values of $(R + C)$ and $(R - C)$ of the dimension level are calculated from the total-influence matrix; the results are reported in Table 5. The normalized values of $(\mathrm{D} + \mathrm{R})$ can explain the importance of the selected criteria using Eq. (7).

This procedure is similarly applied to the criteria level. From Table 6, we see the local and global weights of the factors affecting blockchain adoption.

Regarding different dimensions, the highest weight is Security (S) (0.2550), followed by Technology (T) (0.2533), Human (H) (0.2482), and Organization (O) (0.2434). Similar results were obtained for the global priority of various evaluation criteria. Adequate

Table 4 The total-influence matrix for the dimensions

	T	O	H	S
T	7.4511	7.4792	7.5578	8.0332
O	7.3002	6.8799	7.1932	7.6040
H	7.5237	7.3307	7.1536	7.8276
S	7.5115	7.2822	7.3539	7.5476

Table 5 Degree of total influence for the dimensions

	Row sum (D)	Column sum (R)	D + R	D − R	Weight
T	30.5213	29.7864	60.3077	0.7348	0.2533
O	28.9772	28.9720	57.9492	0.0052	0.2434
H	29.8355	29.2584	59.0940	0.5771	0.2482
S	29.6951	31.0123	60.7074	− 1.3171	0.2550

Table 6 The overall weights of adoption factors

Dimension	Weight	Rank	Criteria	Local weight	Rank	Global weight	Rank
Technology (T)	0.2533	2	Relative advantage (T1)	0.2462	3	0.0624	10
			Compatibility (T2)	0.2479	2	0.0628	9
			Complexity (T3)	0.2461	4	0.0623	11
			System integration (T4)	0.2598	1	0.0658	4
Organization (O)	0.2434	4	Adequate resources (O1)	0.3423	1	0.0833	1
			Firm size (O2)	0.3267	3	0.0795	3
			Top management support (O3)	0.3310	2	0.0806	2
Human (H)	0.2482	3	System user (H1)	0.2455	4	0.0609	15
			IT personnel (H2)	0.2582	1	0.0641	8
			System consult (H3)	0.2471	3	0.0613	14
			Project leader (H4)	0.2492	2	0.0619	13
Security (S)	0.2550	1	Client information (S1)	0.2523	1	0.0643	5
			Internal Information (S2)	0.2520	3	0.0643	7
			System protection (S3)	0.2522	2	0.0643	6
			Backup mechanism (S4)	0.2435	4	0.0621	12

resources (O1) has the highest weight (0.0833), followed by Top management support (O3) (0.0806), Firm size (O2) (0.0795), and System integration (T4) (0.0658). Therefore, more attention should be paid to these four criteria for blockchain adoption.

Among these four evaluation criteria, the first-, second-, and third- highest evaluation criteria are in Organization (O), whereas the fourth evaluation criterion is in Technology (T). The results suggest that organizational and technological aspects are the main considerations for enhancing and promoting the effectiveness of blockchain adoption.

Ranking of alternatives based on EDAS

After measuring the weights of the criteria, the next step is to rank the four alternatives ("bank confirmation (A)," "settlement of insurance claim (B)," "trade finance (C)," and "mobile wallets (D)") to blockchain using the EDAS method. The results of the average solutions of the alternatives for the selected criteria are listedselected criteria appear in Table 7.

The next step involves determining the positive distance from the average *(PDA*) and negative distance from the average (*NDA*) for each alternative using Eqs. (10) and (11), respectively. The results are presented in Tables 8 and 9, respectively. In particular, PDA and NDA are determined as follows:

$$\mathrm{PDA}_{\mathrm{T1}} = \frac{\mathrm{MAX}(0,(3.8-3.805)}{3.805} = \frac{0}{3.805} = 0$$

$$\mathrm{NDA}_{\mathrm{T1}} = \frac{\mathrm{MAX}(0,(3.805-3.8)}{3.805} = \frac{0.005}{3.805} = 0.001$$

Using Eqs. (12) and (13), we obtain the weighted sum of PDA and NDA, as reported in Tables 10 and 11, respectively. Here, $\mathrm{SP_A}$ and $\mathrm{SN_A}$ are determined as follows:

Table 7 Results of the evaluation of the alternatives based on selected criteria

Criteria	Alternative				AV
	A	B	B	D	
Relative advantage (T1)	3.800	3.700	3.770	3.950	3.805
Compatibility (T2)	3.750	3.390	3.460	3.820	3.605
Complexity (T3)	3.460	3.210	3.210	3.610	3.373
System integration (T4)	3.730	3.460	3.460	3.630	3.570
Adequate resources (O1)	3.550	3.460	3.480	3.800	3.573
Firm size (O2)	3.630	3.570	3.520	3.700	3.605
Top management support (O3)	3.790	3.630	3.630	3.910	3.740
System user (H1)	3.710	3.590	3.500	3.820	3.655
IT personnel (H2)	3.790	3.520	3.550	3.880	3.685
System consult (H3)	3.700	3.390	3.380	3.500	3.493
Project leader (H4)	3.910	3.660	3.520	3.820	3.728
Client information (S1)	4.180	3.820	3.930	4.270	4.050
Internal information (S2)	4.130	3.790	3.930	4.160	4.003
System protection (S3)	4.020	3.770	3.820	4.130	3.935
Backup mechanism (S4)	3.710	3.540	3.550	3.820	3.655

Table 8 The positive distance from the average (PDA)

Criteria	A	B	B	D
Relative advantage (T1)	0	0	0	0.038
Compatibility (T2)	0.040	0	0	0.060
Complexity (T3)	0.026	0	0	0.070
System integration (T4)	0.045	0	0	0.017
Adequate resources (O1)	0	0	0	0.064
Firm size (O2)	0.007	0	0	0.026
Top management support (O3)	0.013	0	0	0.045
System user (H1)	0.015	0	0	0.045
IT personnel (H2)	0.028	0	0	0.053
System consult (H3)	0.059	0	0	0.002
Project leader (H4)	0.049	0	0	0.025
Client information (S1)	0.032	0	0	0.054
Internal information (S2)	0.032	0	0	0.039
System protection (S3)	0.022	0	0	0.050
Backup mechanism (S4)	0.015	0	0	0.045

$$\begin{aligned}\mathrm{SP_A} = {} & 0 + 0.003 + 0.002 + 0.003 + 0 + 0.001 + 0.001 + 0.001 \\ & + 0.002 + 0.004 + 0.003 + 0.002 + 0.002 + 0.001 + 0.001 = 0.025\end{aligned}$$

$$\mathrm{SN_A} = 0 + 0 + 0 + 0 + 0.001 + 0 + 0 + 0 + 0 + 0 + 0 + 0 + 0 + 0 + 0 = 0.001$$

The normalized weighted sums of PDA and NDA obtained using Eqs. (14) and (15) are presented in Tables 10 and 11, respectively. Equation (16) is used to calculate the appraisal score $\mathrm{AS_i}$ of the selected alternative, as presented in Table 12.

An example is presented as follows:

Table 9 The negative distance from average (NDA)

Criteria	A	B	B	D
Relative advantage (T1)	0.001	0.028	0.009	0
Compatibility (T2)	0	0.060	0.040	0
Complexity (T3)	0	0.048	0.048	0
System integration (T4)	0	0.031	0.031	0
Adequate resources (O1)	0.006	0.031	0.026	0
Firm size (O2)	0	0.010	0.024	0
Top management support (O3)	0	0.029	0.029	0
System user (H1)	0	0.018	0.042	0
IT personnel (H2)	0	0.045	0.037	0
System consult (H3)	0	0.029	0.032	0
Project leader (H4)	0	0.018	0.056	0
Client information (S1)	0	0.057	0.030	0
Internal information (S2)	0	0.053	0.018	0
System protection (S3)	0	0.042	0.029	0
Backup mechanism (S4)	0	0.031	0.029	0

$$\mathrm{NSP_A} = \frac{0.025}{\mathrm{MAX}(0.025, 0, 0, 0.043)} = \frac{0.025}{0.043} = 0.581$$

$$\mathrm{NSN_A} = 1 - \frac{0.001}{\mathrm{MAX}(0.001, 0.035, 0.032, 0)} = 1 - \frac{0.001}{0.035} = 0.971$$

$$\mathrm{AS_A} = \frac{0.581 + 0.971}{2} = 0.776$$

The preference order of the four alternatives to blockchain D > A > B > C. Thus, the best-ranked alternative is D.

Table 10 The weight sums of PDA

Criteria	A	B	B	D
Relative advantage (T1)	0	0	0	0.002
Compatibility (T2)	0.003	0	0	0.004
Complexity (T3)	0.002	0	0	0.004
System integration (T4)	0.003	0	0	0.001
Adequate resources (O1)	0	0	0	0.005
Firm size (O2)	0.001	0	0	0.002
Top management support (O3)	0.001	0	0	0.004
System user (H1)	0.001	0	0	0.003
IT personnel (H2)	0.002	0	0	0.003
System consult (H3)	0.004	0	0	0.000
Project leader (H4)	0.003	0	0	0.002
Client information (S1)	0.002	0	0	0.003
Internal information (S2)	0.002	0	0	0.003
System protection (S3)	0.001	0	0	0.003
Backup mechanism (S4)	0.001	0	0	0.003
SP	0.025	0	0	0.043

Table 11 The weighted sums of NDA

Criteria	A	B	B	D
Relative advantage (T1)	0	0.002	0.001	0
Compatibility (T2)	0	0.004	0.003	0
Complexity (T3)	0	0.003	0.003	0
System integration (T4)	0	0.002	0.002	0
Adequate resources (O1)	0.001	0.003	0.002	0
Firm size (O2)	0	0.001	0.002	0
Top management support (O3)	0	0.002	0.002	0
System user (H1)	0	0.001	0.003	0
IT personnel (H2)	0	0.003	0.002	0
System consult (H3)	0	0.002	0.002	0
Project leader (H4)	0	0.001	0.003	0
Client information (S1)	0	0.004	0.002	0
Internal information (S2)	0	0.003	0.001	0
System protection (S3)	0	0.003	0.002	0
Backup mechanism (S4)	0	0.002	0.002	0
SN	0.001	0.035	0.032	0

Table 12 Normalized weighted sums, appraisal scores, and ranking of alternatives

Alternative	SP_i	SN_i	NSP_i	NSN_i	AS_i	Ranking
A	0.025	0.001	0.581	0.971	0.776	2
B	0	0.035	0	0	0	4
C	0	0.032	0	0.085	0.042	3
D	0.043	0	1.000	1.000	1.000	1

TOPSIS method results

For the validity of ranking results, comparative experiments are conducted using the TOPSIS method. The distance to the positive ideal solution ($\boldsymbol{S}_i^+$), the distance to the negative ideal solution ($\boldsymbol{S}_i^-$) and the relative proximity of each alternative to the ideal solution (C_i^*) were calculated. The results are presented in Table 13.

The results reveal that D has the highest C_i^* value, indicating that it is the best alternative. Moreover, the ordering results of the TOPSIS method are consistent with those of the proposed methods.

Results and findings

Blockchain is an innovative technology used in the financial sector. This study seeks to enrich the current understanding of blockchain adoption for the banking industry from the organizational perspective. The proposed framework can be used by banks for a more effective adoption of alternatives to blockchain. Considering that blockchain adoption is an MCDM problem, we therefore propose the hybrid DEMATEL and EDAS methods. Additionally, the TOE framework is modified to include two additional factors that hinder the adoption of blockchain. Therefore, the proposed model considers technology, organization, human, and security factors.

Table 13 Ranking of the alternatives according to the TOPSIS method

Alternatives	S_i^+	S_i^-	C_i^*	Ranking
A	0.0864	0.1506	0.6354	2
B	0.2003	0.0287	0.1251	4
C	0.1963	0.0290	0.1289	3
D	0.0428	0.1982	0.8224	1

The influential weights of the dimensions based on DEMATEL are displayed in Table 6. It reveals that "Security" is the most important factor, with an overall weighting of 25.50%, followed by "Technology," with a weighting of 25.33%. The least important factor is "Organization," with a weighting of 24.34%. This indicates that the banking sector gives priority to "Security" when considering blockchain adoption, meaning blockchain is a security issue rather than an organizational one. The ranking results for the alternatives considered by the EDAS are listed in Table 12. Finally, the effectiveness of our proposed approach was validated and verified by experiments with the TOPSIS method. According to Table 13, the EDAS approach is consistent with the TOPSIS method in terms of ranking. Based on the above analysis, the best-ranked alternative is denoted as D.

Discussion

This study takes an important step toward filling the gap in the literature by identifying the most important factors influencing blockchain adoption in the banking sector in Taiwan. The results of this quantitative study offer several interesting insights into banking professionals' perceptions. First, according to our DEMATEL results, "Security" is the most important dimension for evaluating blockchain adoption with an influence weight of 0.2550. It is notable that "Security" is the most important issue in the context of a distributed environment (Antal et al. 2021; Taylor et al. 2020; Mohanta et al. 2019), and the blockchain technology within the banking environment is certainly no exception. This is particularly true for the banking sector because banking data require a more secure environment for storage and retrieval. Therefore, Taiwan's banking sector must ensure an adequate level of security. This is because implementation of blockchain is heavily reliant on the support of internet and other communication technologies; guaranteeing the security of information flows is an important concern in adoption decisions.

Second, "Technology" is the second most important factor, with an influence weight of 0.2533. This finding echoes the results obtained in previous studies, where technology is demonstrated to be a key factor in overcoming resistance to changes caused by new technology adoption and diffusion. Similar to the findings in studies of new technology adoption in other industries (Chang et al. 2020; Dicuonzo et al. 2021), we find that a firm's ability to convert new technology into core capabilities is essential and that technology integration is the most significant factor when evaluating blockchain adoption in the banking industry.

Third, we find that the human dimension reflects the importance of IS human resources and staffs' IS knowledge in developing blockchain in the banking sector. This study revealed a need to provide training to the system user, IT personnel, system consultant, and project leader with respect to the average perceived technical competence of IS staff banking. In this regard, as with different categories of personnel, levels, and different scope of blockchain in banking, each has supervisory functions and responsibilities. (Mohammad et al. 2022; Xu and Lu 2022). This assists in adopting blockchain that would fulfill banking practitioners' needs and work processes by providing sufficient knowledge to both IS and the banking field. Therefore, the human factor should be carefully assessed before a decision to adopt blockchain is made.

Finally, the EDAS method in Table 11 reveals the results and final ranking of alternatives. According to the results, the ranking of alternatives is in relation to declining values; therefore, alternative D (mobile wallets) represents the best solution, while other alternatives occupy positions as they are listed in the model. It is important to emphasize that alternative C (trade finance) has a value close to zero and is a bad solution. As a result, alternatives D, A, and B are the top three alternatives, and C (trade finance) is the worst. Moreover, the TOPSIS method confirmed that the proposed method is an effective and efficient decision-making tool for selecting appropriate alternatives. In the banking setting, using blockchain will make mobile wallets even more secure by providing features such as "multi-signature" to verify a purchase. This technology can also improve the speed, usage, and reduce fees for worldwide payments. Thus, managers in the banking sector should promote mobile wallets with blockchain as the first alternative. Moreover, while the goal is to achieve complete digitalization, achieving this target is likely to take some time, assuming it can be fully accomplished. The adoption of blockchain technology in alternative C (trade finance) has been slow.

Conclusions

Blockchain has developed rapidly in recent years and is being widely used; however little is known about the factors influencing organizational adoption by the banking sector. Previous studies on the topic of blockchain adoption mostly ignore or do not include information security of users and human resources. Additionally, identifying the critical factors affecting blockchain adoption is an MCDM problem. Therefore, we propose hybrid DEMATEL and EDAS methods to fill the gap in the literature. DEMATEL was applied to confirm the interrelationships among the evaluation factors, measure their importance, and prioritize the alternatives obtained by the EDAS approach. To illustrate and validate the proposed method, we present an empirical study of Taiwan's banking sector.

The main contributions of this study are as follows: (1) we propose a TOE framework that encompasses technology and organization and integrates human and security factors to supplement the framework that identifies the influences of blockchain adoption. The results can be used as a reference for the banking sector. (2) The DEMATEL method was employed to clarify the relationships among the evaluation factors and determine their relative weights. (3) Comparative experiments were conducted to demonstrate the effectiveness of the proposed approach. These indicate that the EDAS approach is consistent with the TOPSIS method in terms of ranking. In particular, alternative D had the highest priority.

Finally, our study provides a valuable reference for the banking sector to understand blockchain adoption and is a useful reference for theoretical and practical implications.

Theoretical implications

Existing studies have examined organizational adoption of blockchain. However, to date, no studies have incorporated the human factor into this framework. We applied an innovative and multifaceted evaluation framework for the case of blockchain adoption.

This study also clarifies the main factors influencing blockchain adoption in the banking sector. Thus, this study can serve as a fundamental reference with regard to examining the adoption of other new technologies in the banking sector.

Our focus on blockchain adoption determinants is, to the best of our knowledge, one of the few attempts to factor in the application field of the TOE theory. We applied an innovative approach and extend the application field of the TOE theory to the study of blockchain in the banking sector. Considering that blockchain adoption is an MCDM problem, we therefore propose the hybrid DEMATEL and EDAS methods. Additionally, the TOE framework was modified to include two additional factors that hinder the adoption of blockchain. Therefore, the proposed model considers technology, organization, human, and security factors.

The above findings extend the application field of the TOE theory to the study of blockchain in the banking sector. This research demonstrates that two aspects of the TOE model (organizational and technological) are critical factors to implement the new technology. Hence, researchers must select variables and specify relationships within the TOE framework. Additionally, previous studies use multiple regression analysis for the TOE framework. The current study employed hybrid MCDM to the TOE framework to identify the key factors for adopting blockchain. Finally, this study fills the gap in the literature by applying a hybrid MCDM method to understand whether the banking sector will adopt blockchain.

Managerial and practical implications

This study also offers several valuable insights for banking practitioners and suggests how to adopt blockchain. First, owing to limited resources, the widespread adoption of blockchain would produce a significant influence on the banking sector. As previously stated, we present four factors in terms of technology, organization, human, and security to provide valuable contributions to the banking sector.

Second, the results indicate that security and technology are the top two major factors that may strongly influence decisions on blockchain adoption. This implies that these two factors should be considered when adopting blockchain technology. Security (C1) is considered the most important criterion for blockchain adoption. From this perspective, the subcategories differ in importance as follows: client information, system protection, and internal information. The criteria of technology also acts as the second important factor of blockchain adoption. Under this perspective, system integration and compatibility are the most important sub-criteria.

Finally, the ranking of alternatives is in relation to declining values; therefore, alternative D (mobile wallets) represents the best solution, while other alternatives occupy positions as they are listed in the model. It is important to emphasize that alternative C (trade finance) has a value close to zero and is a bad solution. These results suggest where the banking sector should focus their resources to improve the use of blockchain, highlighting the need to leverage certain characteristics of blockchain to increase its adoption by the banking sector.

Limitations and future research

The results indicate that the proposed approach is a good alternative solution for the banking sector to design a service strategy to boost blockchain adoption. However, this study has some limitations that can be used as a start point for further research. In terms of how this study can contribute to future research on dark side effects, first, even though an ample range of literature was examined to develop the underlying review, and the screening criteria employed were developed in an inclusive way, literature of interest that has not been included may exist. Second, the evaluation criteria are based on the TOE framework, which excludes some possible variables. Additional research should incorporate other theories, such as TAM, to further identify other factors. Third, a limitation of this study is its small sample size. Future research should collect more samples for more accurate estimates. Fourth, we retained only 12 evaluation criteria to structure the blockchain adoption model. However, there are numerous risks associated with the use of blockchain technology in the banking sector. Security factors include client information, internal information, system protection, and backup mechanisms. Future studies may incorporate different risks such as legal incoherence and transaction price mismatch risks to make different decisions. Fifth, future research should investigate how blockchain adoption structures vary across organizational contexts. Finally, different MCDM approaches such as analytic hierarchy process (AHP) and analytical network process (ANP) can be applied to identify other possible factors influencing blockchain adoption. In addition, we aimed to determine the weights of the factors and the choice of alternatives using the proposed approach. Nevertheless, these methods can be applied and need to be analyzed as there are clear differences between methods that do not require accurate information and techniques that can lead to the outcomes of ineffective adaptations. Follow-up researchers may further incorporate the other MCDM methods for the proposed approach.

Abbreviations

AS	Appraisal score
AV	Average solution
AHP	Analytic hierarchy process (AHP)
ANP	Analytical network process (ANP)
DEMATEL	Decision-making trial and evaluation laboratory
DOI	Diffusion of innovation
EDAS	Evaluation based on distance from average solution
IT/IS	Information technology/information system
MCDM	Multiple-criteria decision-making
NDA	Negative distance from average
PDA	Positive distance from average
PLS-SEM	Partial least squares structural equation modeling
SEM	Structural equation modeling
TAM	Technology acceptance model

TOE	Technology-organization-environment
TOPSIS	Technique for order preference by the similarity to ideal solution
UTAUT	Unified theory of acceptance and usage of technology
VIKOR	Vise Kriterijumska Optimizacija I Kompromisno Resenje

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References

Aboelmaged MG (2014) Predicting e-readiness at firm-level: an analysis of technological, organizational and environmental (TOE) effects on e-maintenance readiness in manufacturing firms. Int J Inf Manag 34(5):639–651
Adel H, Younis RAA (2021) Interplay among blockchain technology adoption strategy, e-supply chain management diffusion, entrepreneurial orientation and human resources information system in banking. Int J Emerg Mark. https://doi.org/10.1108/IJOEM-02-2021-0165
Ahluwalia S, Mahto RV, Guerrero M (2020) Blockchain technology and start-up financing: a transaction cost economics perspective. Technol Forecast Soc Change 151:119854
Ahmetoglu S, Che Cob Z, Ali NA (2022) A Systematic review of internet of things adoption in organizations: taxonomy, benefits, challenges and critical factors. Appl Sci 12(9):4117
Ajwani-Ramchandani R, Figueira S, de Oliveira RT, Jha S, Ramchandani A, Schuricht L (2021) Towards a circular economy for packaging waste by using new technologies: the case of large multinationals in emerging economies. J Clean Prod 281:125139
Aketch S, Mwambia F, Baimwera B (2021) Effects of blockchain technology on performance of financial markets in Kenya. J Int Financial Manag Account 6(1):1–15
Alazab M, Alhyari S, Awajan A, Abdallah AB (2021) Blockchain technology in supply chain management: an empirical study of the factors affecting user adoption/acceptance. Clust Comput 24(1):83–101
Albayati H, Kim SK, Rho JJ (2020) Accepting financial transactions using blockchain technology and cryptocurrency: a customer perspective approach. Technol Soc 62:101320
Ali O, Ally M, Dwivedi Y (2020) The state of play of blockchain technology in the financial services sector: a systematic literature review. Int J Inf Manag 54:102199
AlShamsi M, Al-Emran M, Shaalan K (2022) A systematic review on blockchain adoption. Appl Sci 12(9):4245
Alzahrani AI, Al-Samarraie H, Eldenfria A, Dodoo JE, Alalwan N (2022) Users' intention to continue using mhealth services: a DEMATEL approach during the COVID-19 Pandemic. Technol Soc 68:101862
Antal C, Cioara T, Anghel I, Antal M, Salomie I (2021) Distributed ledger technology review and decentralized applications development guidelines. Future Internet 13(3):62
Arpaci I, Yardimci YC, Ozkan S, Turetken O (2012) Organizational adoption of information technologies: a literature review. Int J eBusiness eGovernment Stud 4(2):37–50
Bellucci M, Bianchi DC, Manetti G (2022) Blockchain in accounting practice and research: systematic literature review. Meditari Account Res 30(7):121–146
Benatia I, Laouar MR, Bendjenna H, Eom SB (2016) Implementing a cloud-based decision support system in a private cloud: the infrastructure and the deployment process. Int J Decis Support Syst Technol 8(1):25–42
Biswas S, Pamucar D (2023) A modified EDAS model for comparison of mobile wallet service providers in India. Financ Innov 9(1):1–31
Butt TA, Iqbal R, Salah K, Aloqaily M, Jararweh Y (2019) Privacy management in social internet of vehicles: review, challenges and blockchain based solutions. IEEE Access 7:79694–79713
Chang V, Baudier P, Zhang H, Xu Q, Zhang J, Arami M (2020) How blockchain can impact financial services—the overview, challenges and recommendations from expert interviewees. Technol Forecast Soc Change 158:120166
Chen Y, Bellavitis C (2020) Blockchain disruption and decentralized finance: the rise of decentralized business models. J Bus Ventur Insights 13:e00151
Chod J, Trichakis N, Tsoukalas G, Aspegren HM, Weber M (2020) On the financing benefits of supply chain transparency and blockchain adoption. Manag Sci 66(10):4378–4396

Clohessy T, Acton T (2019) Investigating the influence of organizational factors on blockchain adoption: an innovation theory perspective. Ind Manag Data Syst 119(7):1457–1491
Coita DC, Abrudan MM, Matei MC (2019) Effects of the blockchain technology on human resources and marketing: an exploratory study. In: Kavoura A, Kefallonitis E, Giovanis A (eds) Strategic innovative marketing and tourism. Springer, Cham, pp 683–691
Dashkevich N, Counsell S, Destefanis G (2020) Blockchain application for central banks: a systematic mapping study. IEEE Access 8:139918–139952
Dhanalakshmi CS, Madhu P, Karthick A, Mathew M, Kumar RV (2020) A comprehensive MCDM-based approach using TOPSIS and EDAS as an auxiliary tool for pyrolysis material selection and its application. Biomass Convers. Biorefin 1–16
Dicuonzo G, Donofrio F, Fusco A, Dell'Atti V (2021) Blockchain technology: opportunities and challenges for small and large banks during COVID-19. Int J Innov Technol Manag 18(04):2140001–2140025
Fang F, Ventre C, Basios M, Kanthan L, Martinez-Rego D, Wu F, Li L (2022) Cryptocurrency trading: a comprehensive survey. Financ Innov 8(1):1–59
Feng Q, He D, Zeadally S, Khan MK, Kumar N (2019) A survey on privacy protection in blockchain system. J Netw Comput Appl 126:45–58
Fernando Y, Rozuar NHM, Mergeresa F (2021) The blockchain-enabled technology and carbon performance: insights from early adopters. Technol Soc 64:101507
Gabus A, Fontela E (1972) World problems, an invitation to further thought within the framework of DEMATEL. Battelle Geneva Research Center, Geneva
Garg P, Gupta B, Chauhan AK, Sivarajah U, Gupta US, Modgil S (2021) Measuring the perceived benefits of implementing blockchain technology in the banking sector. Technol Forecast Soc Change. https://doi.org/10.1016/j.techfore.2020.120407
Gayathri C, Kamala V, Gajanand MS, Yamini S (2021) Analysis of operational and financial performance of ports: an integrated fuzzy DEMATEL-TOPSIS approach. Benchmark Int J 29(3):1046–1066
Ghorabaee MK, Zavadskas EK, Olfat L, Turskis Z (2015) Multi-criteria inventory classification using a new method of evaluation based on distance from average solution (EDAS). Informatica 26(3):435–451
Guo Y, Liang C (2016) Blockchain Application and Outlook in the Banking Industry. Financ Innov 2(1):1–12
Hanna H, Haroun MH, Gohar N (2020) Developing a framework for block chain adoption using TOE model. J Bus Retail Manag Res 15(1):15–22
Hsu CW, Yeh CC (2017) Understanding the factors affecting the adoption of the Internet of Things. Technol Anal Strateg Manag 29(9):1089–1102
Hsu CW, Yeh CC (2018) Understanding the critical factors for successful M-commerce adoption. Int J Mob Commun 16(1):50–62
Hu KH, Hsu MF, Chen FH, Liu MZ (2021) Identifying the key factors of subsidiary supervision and management using an innovative hybrid architecture in a big data environment. Financ Innov 7(1):1–27
Hwang CL, Yoon KP (1981) Multiple attribute decision making: methods and applications. Springer-Verlag, New York
Kamble SS, Gunasekaran A, Kumar V, Belhadi A, Foropon C (2021) A machine learning based approach for predicting blockchain adoption in supply chain. Technol Forecast Soc Change 163:120465
Karamchandani A, Srivastava SK, Srivastava RK (2020) Perception-based model for analyzing the impact of enterprise blockchain adoption on SCM in the Indian service industry. Int J Inf Manag 52:102019
Kawasmi Z, Gyasi EA, Dadd D (2020) Blockchain adoption model for the global banking industry. J Int Technol Inf Manag 28(4):112–154
Khan D, Jung LT, Hashmani MA (2021) Systematic literature review of challenges in blockchain scalability. Appl Sci 11(20):9372
Kou G, Olgu Akdeniz Ö, Dinçer H, Yüksel S (2021) Fintech investments in European banks: a hybrid IT2 fuzzy multidimensional decision-making approach. Financ Innov 7(1):39
Kouhizadeh M, Saberi S, Sarkis J (2021) Blockchain technology and the sustainable supply chain: theoretically exploring adoption barriers. Int J Prod Econ 231:107831
Kulkarni M, Patil K (2020) Block chain technology adoption for banking services-model based on technology-organization-environment theory. In: Proceedings of the international conference on innovative computing & communications (ICICC), DOI: https://doi.org/10.2139/ssrn.3563101
Lee CC, Kriscenski JC, Lim HS (2019) An empirical study of behavioral intention to use blockchain technology. J Int Bus Stud 14(1)
Lewis R, McPartland J, Ranjan R (2017) Blockchain and financial market innovation. Econ Perspect 41(7):1–17
Lian JW, Yen DC, Wang YT (2014) An exploratory study to understand the critical factors affecting the decision to adopt cloud computing in Taiwan hospital. Int J Inf Manag 34(1):28–36
Liu N, Ye Z (2021) Empirical research on the blockchain adoption-based on TAM. Appl Econ 53(37):4263–4275
Liu W, Sun Y, Yüksel S, Dinçer H (2021) Consensus-based multidimensional due diligence of fintech-enhanced green energy investment projects. Financ Innov 7(1):1–31
Lu Y (2019) The blockchain: state-of-the-art and research challenges. J Ind Inform Integr 15:80–90
Lu MT, Lin SW, Tzeng GH (2013) Improving RFID adoption in Taiwan's healthcare industry based on a DEMATEL technique with a hybrid MCDM model. Decis Support Syst 56:259–269
Lu Y (2021) Implementing blockchain in information systems: a review. Enterp Inf Syst: 1–32.
Meng Y, Wu H, Zhao W, Chen W, Dinçer H, Yüksel S (2021) A hybrid heterogeneous Pythagorean fuzzy group decision modelling for crowdfunding development process pathways of Fintech-based clean energy investment projects. Financ Innov 7(1):1–34
Mishra L, Kaushik V (2021) Application of blockchain in dealing with sustainability issues and challenges of financial sector. J Sustain Financ Invest. https://doi.org/10.1080/20430795.2021.1940805
Mishra AR, Mardani A, Rani P, Zavadskas EK (2020) A novel EDAS approach on intuitionistic fuzzy set for assessment of health-care waste disposal technology using new parametric divergence measures. J Clean Prod 272:122807

Mohammad Saif AN, Islam MA. (2022) Blockchain in human resource management: a systematic review and bibliometric analysis. Technol Anal Strateg Manag 1–16

Mohanta BK, Jena D, Panda SS, Sobhanayak S (2019) Blockchain technology: a survey on applications and security privacy challenges. Internet Things 8:100107

Mori T (2016) Financial technology: blockchain and securities settlement. J Secur Oper Custody 8(3):208–227

Muhamad WNW, Razali NAM, Wook M, Ishak KK, Zainudin NM, Hasbullah NA, Ramli S (2020) Evaluation of blockchain-based data sharing acceptance among intelligence community. Int J Adv Comput Sci Appl. https://doi.org/10.14569/IJACSA.2020.0111270

Nelaturu K, Du H, Le DP (2022) A review of blockchain in fintech: taxonomy, challenges, and future directions. Cryptography 6(2):18

Nerurkar P, Patel D, Busnel Y, Ludinard R, Kumari S, Khan MK (2021) Dissecting bitcoin blockchain: empirical analysis of bitcoin network (2009–2020). J Netw Comput Appl 177:102940

Niranjanamurthy M, Nithya BN, Jagannatha SJCC (2019) Analysis of blockchain technology: pros, cons and swot. Cluster Comput 22(6):14743–14757

Nong NMT, Ha DS (2021) Application of MCDM methods to qualified personnel selection in distribution science: case of logistics companies. J Distrib Sci 19(8):25–35

Nuryyev G, Wang YP, Achyldurdyyeva J, Jaw BS, Yeh YS, Lin HT, Wu LF (2020) Blockchain technology adoption behavior and sustainability of the business in tourism and hospitality SMEs: an empirical study. Sustainability 12(3):1256

Opricovic S (1998) Multicriteria optimization of civil engineering systems. Fac Civ Eng 2(1):5–21

Orji IJ, Kusi-Sarpong S, Huang S, Vazquez-Brust D (2020) Evaluating the factors that influence blockchain adoption in the freight logistics industry. Transp Res e: Logist Transp Rev 141:102025

Ozturan M, Atasu I, Soydan H (2019) Assessment of blockchain technology readiness level of banking industry: case of Turkey. Int J Bus Manag 4(12):1–13

Pantouw RT, Aruan DTH (2019) Influence of game design and playability toward continuance intention using TAM framework. IPTEK J Proc Ser (5):307–315

Queiroz MM, Wamba SF (2019) Blockchain adoption challenges in supply chain: an empirical investigation of the main drivers in India and the USA. Int J Inf Manag 46:70–82

Queiroz MM, Fosso Wamba S, De Bourmont M, Telles R (2021) Blockchain adoption in operations and supply chain management: empirical evidence from an emerging economy. Int J Prod Res 59(20):6087–6103

Rawash HN (2021) E-commerce adopting TOE model by SMEs in Jordan. Multicult Educ 7(3):118–123

Rijanto A (2020) Business financing and blockchain technology adoption in agroindustry. J Sci Technol Policy Manag 12:215–235

Saheb T, Mamaghani FH (2021) Exploring the barriers and organizational values of blockchain adoption in the banking industry. J High Technol Manag Res 32(2):100417

Sarfaraz A, Chakrabortty RK, Essam DL (2021) A tree structure-based improved blockchain framework for a secure online bidding system. Comput Secur 102:102147

Saurabh S, Dey K (2021) Blockchain technology adoption, architecture, and sustainable agri-food supply chains. J Clean Prod 284:124731

Schiavone F, Leone D, Caporuscio A, Kumar A (2021) Revealing the role of intellectual capital in digitalized health networks. A mesolevel analysis for building and monitoring a KPI dashboard. Technol Forecast Soc Change 175:121325

Schneider S, Leyer M, Tate M (2020) The transformational impact of blockchain technology on business models and ecosystems: a symbiosis of human and technology agents. IEEE Trans Eng Manag 67(4):1184–1195

Sebastião H, Godinho P (2021) Forecasting and trading cryptocurrencies with machine learning under changing market conditions. Financ Innov 5(1):1–14

Shi S, He D, Li L, Kumar N, Khan MK, Choo KKR (2020) Applications of blockchain in ensuring the security and privacy of electronic health record systems: a survey. Comput Secur. https://doi.org/10.1016/j.cose.2020.101966

Si SL, You XY, Liu HC, Zhang P (2018) DEMATEL technique: a systematic review of the state-of-the-art literature on methodologies and applications. Math Probl Eng 2018:1–33

Singh H, Jain G, Munjal A, Rakesh S (2019) Blockchain technology in corporate governance: disrupting chain reaction or not? Corp Gov 20:67–86

Spence A (2018) Blockchain and the chief human resources officer: transforming the HR function and the market for skills, talent, and training. Blockchain Research Institute, Mountain View, CA, USA: 23

Sun J, Yan J, Zhang KZ (2016) Blockchain-based sharing services: what blockchain technology can contribute to smart cities. Financ Innov 2(1):1–9

Taylor PJ, Dargahi T, Dehghantanha A, Parizi RM, Choo KKR (2020) A systematic literature review of blockchain cyber security. Digit Commun Netw 6(2):147–156

Tekic Z, Koroteev D (2019) From disruptively digital to proudly analog: a holistic typology of digital transformation strategies. Bus Horiz 62(6):683–693

Tornatzky LG, Fleischer M (1990) The processes of technological innovation. Lexington Books, Lexington, pp 152–154

Toufaily E, Zalan T, Dhaou SB (2021) A framework of blockchain technology adoption: an investigation of challenges and expected value. Inf Manag 58(3):103444

Uddin MA, Stranieri A, Gondal I, Balasubramanian V (2021) A survey on the adoption of blockchain in IoT: challenges and solutions. Blockchain Res Appl. https://doi.org/10.1016/j.bcra.2021.100006

Ullah N, Alnumay WS, Al-Rahmi WM, Alzahrani AI, Al-Samarraie H (2020) Modeling cost saving and innovativeness for blockchain technology adoption by energy management. Energies 13(18):4783

Ullah N, Al-Rahmi WM, Alzahrani AI, Alfarraj O, Alblehai FM (2021) Blockchain technology adoption in smart learning environments. Sustainability 13(4):1801

Vafadarnikjoo A, Tavana M, Chalvatzis K, Botelho T (2022) A socio-economic and environmental vulnerability assessment model with causal relationships in electric power supply chains. Soc Econ Plann Sci 80:101156

Wahab SN, Loo YM, Say CS (2020) Antecedents of blockchain technology application among Malaysian warehouse industry. Int J Logist Syst Manag 37(3):427–444
Wamba SF, Queiroz MM (2019) The role of social influence in blockchain adoption: the Brazilian supply chain case. IFAC-PapersOnLine 52(13):1715–1720
Wang YM, Wang YS, Yang YF (2010) Understanding the determinants of RFID adoption in the manufacturing industry. Technol Forecast Soc Change 77(5):803–815
Wei G, Wei C, Guo Y (2021) EDAS method for probabilistic linguistic multiple attribute group decision making and their application to green supplier selection. Soft Comput 25(14):9045–9053
Wu X, Dinçer H, Yüksel S (2022) Analysis of crowdfunding platforms for microgrid project investors via a q-rung orthopair fuzzy hybrid decision-making approach. Financ Innov 8:52
Xiao H, Zhang Y, Kou G, Zhang S, Branke J (2023) Ranking and selection for pairwise comparison. Nav Res Logist 70(3):229–302
Xu J, Lu W (2022) Developing a human-organization-technology fit model for information technology adoption in organizations. Technol Soc. https://doi.org/10.1016/j.techsoc.2022.102010
Xu M, Chen X, Kou G (2019) A systematic review of blockchain. Financ Innov 5(1):1–14
Xu W, Hu D, Lang KR, Zhao JL (2022) Blockchain and digital finance. Financ Innovation 8(1):1–4
Yadav VS, Singh AR, Raut RD, Govindarajan UH (2020) Blockchain technology adoption barriers in the Indian agricultural supply chain: an integrated approach. Resour Conserv Recycl 161:104877
Yang CS (2019) Maritime shipping digitalization: Blockchain-based technology applications, future improvements, and intention to use. Transp Res e: Logist Transp Rev 131:108–117
Yeh CC, Chen YF (2018) Critical success factors for adoption of 3D printing. Technol Forecast Soc Change 132:209–216
Yi CSS, Yung E, Fong C, Tripathi S (2020) Benefits and use of blockchain technology to human resources management: a critical review. Int J Hum Resour Stud 10:131–140
Yoo S (2017) Blockchain based financial case analysis and its implications. Asia Pac J Innov Entrepreneurship 11(3):312–321
Yusof MM, Kuljis J, Papazafeiropoulou A, Stergioulas LK (2008) An evaluation framework for health information systems: human, organization and technology-fit factors (HOT-fit). Int J Med Inf 77(6):386–398
Zhang X, Su J (2019) A combined fuzzy DEMATEL and TOPSIS approach for estimating participants in knowledge-intensive crowdsourcing. Comput Educ 137:106085
Zhang L, Xie Y, Zheng Y, Xue W, Zheng X, Xu X (2020) The challenges and countermeasures of blockchain in finance and economics. Syst Res Behav Sci 37(4):691–698
Zheng XR, Lu Y (2021) Blockchain technology—recent research and future trend. Enterp Inf Syst. https://doi.org/10.1504/IJWGS.2018.095647
Zheng Z, Xie S, Dai HN, Chen X, Wang H (2018) Blockchain challenges and opportunities: a survey. Int J Web Grid Serv 14(4):352–375

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