Journal of Information & Optimization Sciences
ISSN 0252-2667 (Print), ISSN 2169-0103 (Online)
Vol. 45 (2024), No. 4, pp. 1199–1215
DOI : 10.47974/JIOS-1703

Critical success factors of blockchain technology adoption in banking and financial sector using diamond fuzzy AHP

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Abstract

Blockchain technology is creating significant interest among a wide range of industries in the world due to the continuing applications in the banking sector. Thus, the aim of this research is to introduce an outline for examining critical factors that affect the success of the adoption of Blockchain-technologies in the sector of Finance and arranges them using the fuzzy analytical hierarchy process technique. First, it identifies thirteen critical success factors under three categories: technological, organizational, and environmental, taking the assistance of the extensive literature review and expert-opinion. Then, these factors are given a ranking that is based on their relative weightage. It is concluded that top management attitude, organization readiness, government regulation, immutability, and disintermediation are the detrimental factors for widespread blockchain adoption. The findings of this study will empower the stakeholders in the financial sector to improve their performance using blockchain technologies.

Subject Classification: *Primary 93A30, Secondary 49K15.*

Keywords: *Blockchain, Critical success factors, Diamond fuzzy numbers, Financial institutions, Fuzzy numbers, Fuzzy AHP.*

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1. Introduction

Blockchain first became popular because of its use in cryptocurrency (hereon referred to as CC) like Bitcoin, which was conceptualized by Nakamoto (a pseudonym) [1] ,which later spread its way into other applications outside CC, chiefly on smart contracts(digital) and Distributed-ledger systems [2]. It is a revolutionary technology that is a distributed-ledger that has radically improved the clarity and confidentiality of transactions, simultaneously creating innovative avenues for growth while also reducing operations-related risks, as well as expense. This is a fundamental technological innovation that has very interesting application capability in the banking industry as it is resistant to modification or retrospective alteration which brings the required transparency in dealings as it offers transaction verification/ authentication in the peer-to-peer networks by using an agreement approach [3] [4]. The banking and financial sector is witnessing significant disruption through blockchain technology due to its encryption feature addressing security & safety concerns of digital transactions and eliminating third-party intermediations for faster executions at low cost [5]. It offers the opportunity for the financial sector to streamline international monetary transfers, automatic banking ledgers, digital/smart contracts, assets [6].

This technology is still in its budding stage; thus, availability of literature is limited. Thus, this paper attempts to make numerous significant contributions through finding and prioritizing those factors that can influence effective integration of blockchain-technology. This paper first examines theoretical background of earlier research work undertaken on factors that influence the integration of this technology in the banking, and financial sector. Then, highlights the research design and results of the study. Lastly, the conclusion, managerial implications, and limitations as well as future scope of research are discussed.

2. Literature review

2.1 *Blockchain-Technology*

Blockchain is a form of distributed ledger technology that works across a network ensuing cryptanalytic hash (like a digital fingerprint) function for data recording and verification. This network bears an incontrovertible data-chain, allowing agreement amongst parties that cannot be trusted, concerning the persistence of stored information [7]. Blockchain is a type of decentralized ledger comprised of blocks, that are

records, across several computers in a public or private network. Whenever any transaction occurs, it is saved as a block, and each new block is linked to the previous one containing all information from the previous block creating an irreversible chain. These blocks/records are perpetually connected in a chain-like manner, that cannot be altered by a single entity and are authenticated making the use of government-conventions [8] All the transactions in Blockchain, are apparent to all the involved parties and each one of them, can check the record of such transaction of its partners directly without the intermediaries' involvement [8]. The verification process using current encryption measures has the power to safeguard data on distribution-ledgers from mishandling. Altering prevailing blocks is impossible so, users have the access to complete activity track [9].

2.2 *Blockchain adoption Critical Success Factors*

Adoption of blockchain is still in a developing stage. Thus, it is important to analyse the aspects which affect adoption in an organization. Consequently, such factors that affect its successful adoption were found via thorough evaluation of available literature. These factors are categorized into three substantial categories: technological-factors, organizational-factors, and environmental-factors [10][11]. Table 1 categorizes, cites source, and describes supporting factors of every category, supporting inclusion of each as a vital factor for the successful blockchain integration.

2.2.1 Technological-factors

The availability and relevance of all technological solution features under specific circumstances comprised the technology-factor [12] The five attributes that have been considered in this study under the context of technological, that are compatibility, relative advantage, complexity, immutability, and disintermediation,

Immutability means transactions cannot be altered as these can be linked back to their beginnings [13] It is meticulously linked to traceability [14]. The managerial control over business transactions has depleted, or even eradicated [15] Consequentially, the probability of any misconduct, and compromising situation regarding personal information or misrepresentation has become limited [16] This technology has brought lucidity to business procedures as well as ethical codes of conduct, such as responsibility, truthfulness, and thoughtfulness. This leads to precise following of executive level services and correct asset values, of an

organization [17]. The perception regarding new technology of being intricate natured in terms of understanding is termed Complexity [18]. It signifies the need for specific skills related to blockchains that can make adoption smooth [19] .Another technology-related factor is compatibility which refers to the degree of alignment of the business objectives of organization and new technology [20]. Organizations like to adopt this technology when there's compatibility between their existing infrastructure and business operations, and blockchain [21]. The outcome of such incompatibility could be an expensive and time-taking process [22]. Furthermore, disintermediation is another critical factor which means that the central authority freedom provided by blockchain and its use of consensus-mechanism, reduces intermediaries and allows transactions to be quick and economical [23] [24]. Relative advantage refers to a stream of benefits that firms foresee in comparison to the upfront cost associated with moving to a technology that is new [25].The alleged benefits of such technology depends upon the nature, and type of innovation, as well as organization's expectation while adopting such technology [26]. Prerequisite adoption cost is inclusive, containing every transformation effort (monetary and nonmonetary) taken up by an organization to put in use and handle a new technology. With the maturity of technology with time, such costs could differ maturity [27] [28]

2.2.2 Organization factors

The organizational factors describe characteristics and resources of an organization, which have the power to either make adoption effortlessness or hamper it. Five Sub-factors are included in this study: top management support, training facilities, organizational readiness, organization size and availability of adequate funds.

Support of top management stands for the depth of top management capability of an organization to motivate its employees, for early adoption of blockchain-technology by giving them direction, fulfilling the demand for resources and necessities [29]. The accessibility to correct facilities for training deals with, problem of absence of knowledge as well as experience of emerging technologies and boosts the adaption of technologies among team members [30]. The degree to which organizations can acclimatize their structures, resources, culture, and processes, to the demands of the proposed reorganization determines the organization's readiness for transformation [31]. Organizational Readiness is calculated through the accessibility to adequate funds, experience, and knowledge regarding

technology adoption [32]. Another organization-related critical factor is organizational size which is described by items produced, the number of transactions performed, sales level, assets, and full-time workforce size [33] .Another vital fact when it comes to the adoption of this is the accessibility to adequate funds during the development process of blockchain [10].

2.2.3 Environmental factors

The environmental factors constitute of industry characteristics, the organization's external situation, support infrastructure status, and the ecosystem, (prevalent current regulations) [34]. The degree of pressure that a firm faces from direct competitors regarding adoption of innovation is described as competitive pressure [35]. It states the constant wish of organizations to express its capability to its stakeholders or investors

Table 1
Critical Success Factors

Categories	Factors	Source
Technological Factors	Immutability (T1)	Jansson & Petersen, 2017 [13]
	Disintermediation (T2)	Voshmgir, 2016 [24]; Alharby & Van, 2017 [23]
	Complexity (T3)	Nilashi et al., 2016 [19]; Drescher, 2017 [18]
	Compatibility (T4)	Wong et al., 2019 [21]; De Castro et al., 2020 [20]
	Relative advantage (T5)	Rogers, 2003 [25]; Carson et al., 2018 [26]
Organization Factors	Top management support (O1)	Queiroz & Wamba, 2019 [29]
	Organizational Readiness (O2)	Weiner, 2009 [31]; Post et al., 2018 [32]
	Organization Size (O3)	Bose and Luo, 2011 [33]
	Training facilities (O4)	Morkunas et al., 2019 [30]
	Availability of adequate funds (O5)	Kouhizadeh et al., 2021 [10]
Environmental Factors	Competitive Pressure (E1)	Angelis & da Silva, 2019 [36]
	Strategic Partners Pressure (E2)	Zhao et al., 2019 [37]
	Government regulation (E3)	Kawasmi et al. 2020 [38]

through adopting innovations to facilitate their competitive advantage growth and improvement [36]. Severe competition necessitates organizations to adopt innovative technology to enhance quality, decrease cost, and increase efficiency and effectiveness [29]. Pressure from strategic partners has also been evidenced as a major adoption factor of emerging technologies [37]. Further Government regulation is another critical factor, that can be expressed as laws proposed to control behavior of people. Cooperative and collaborative communication among stakeholders is further enhanced by well-framed laws, and lead to the efficient adoption/integration of such technology [38].

3. Study design

The primary goal of this paper is to delve into the essential factors/aspects that determine the success of adopting blockchain technology in the finance, and banking domains. To accomplish this aim, the study unfolded in two stages.

3.1 *Phase I: Critical success factor identification*

In this initial phase, a thorough examination of existing literature was carried out, drawing from diverse databases like Scopus, Google Scholar, Elsevier, and others using keywords like blockchain OR blockchain technology AND banking AND financial institutions AND critical success factors. Through this extensive review of literature, 17 critical success factors (CSF) were identified. Then, these factors were discussed with more than thirty industry specialists from the banking segment, financial institutions, as well as academia which were very meticulously linked with the implementation or integration of blockchain technology in the banking or financial sector across India. The team of selected experts had diverse backgrounds, such as vice president, managers, business core head of banking with payment, technical experts, and blockchain consultants along with experts from the academia. Based on opinions of thirty experts, about thirteen CSFs were finalized. Then in phase II, these finalized thirteen CSFs were analyzed.

3.2 *Phase II: Diamond fuzzy analytical hierarchy process*

An analytical technique that combines fuzzy set theory and hierarchical structure is called Fuzzy Analytical Hierarchical Process (FAHP). It aids in the comparison, of substitutes by digitalizing the

linguistic variables [39] [40]. Using qualitative or quantitative values, decision-makers can articulate their preferences toward each individual criterion as well as sub-criterion [41]. FAHP has been applied in previous studies to keep up with the fuzziness and imprecision of human thought [42]. This technique provides better exhibition of inaccuracy, vagueness, and intricacy and aids improved decisions. Consequently, this model characteristic is further effective and efficiently flexibly digitizes linguistic evaluations of the decision-makers making it better in comparison to other similar methodologies [43]. Fuzzy set concept was discussed in fuzzy theory, was proposed by Zadeh, in 1965(see [44]). According to Zadeh [44] the idea of a fuzzy set, gives a proper thought of take-off from the structure of a calculated system that matches in numerous regards the structure utilized on account of standard sets however is more normal than the last mentioned and, perhaps, may demonstrate to have a lot more extensive degree of pertinence, especially in the fields of example grouping and data handling. The standard AHP was established by Saaty in 1980 (See [45])which is used to produce the preference weights in the criteria, and alternatives. In real-world problems, human judgment involves ambiguity and vagueness, which standard AHP cannot handle. To overcome this deficiency and capture the decision-maker's uncertainty, basic AHP is extended to the fuzzy environment using Diamond Fuzzy Numbers in this paper. A Diamond Fuzzy Number (DFN), as shown in Figure 1, of a fuzzy set X is defined as:

$$\tilde{X}_D = (x_1, x_2, x_3, (a_\alpha, b_\alpha)); x_1 < x_2 < x_3,$$

and its membership function is given by,

$$\delta_{\tilde{X}_D}(p) = \begin{cases} 0, & \text{for } p < x_1 \\ \frac{(p-x_1)}{(x_2-x_1)}, & \text{for } x_1 \le p \le x_2 \\ \frac{(x_3-p)}{(x_3-x_2)}, & \text{for } x_2 \le p \le x_3 \\ a_\alpha - \text{Base} & \\ \frac{(x_1-p)}{(x_1-x_2)}, & \text{for } x_1 \le p \le x_2 \\ \frac{(p-x_3)}{(x_3-x_2)} & \text{for } x_2 \le p \le x_3 \\ 1, & p = b_\alpha \\ 0, & \text{otherwise} \end{cases}$$

where a_α is the base of the triangle x_1, b_α, x_2 and for the inverted reflection of the above triangle, i.e., $x_1 x_2 x_3$.

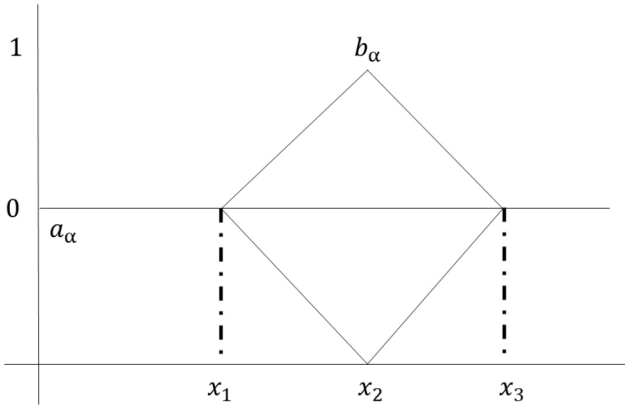


Figure 1

Graphical representation of Diamond Fuzzy Number

The conditions required for a DFN $\tilde{X}_D$:

- $\delta_{\tilde{X}_D}(p)$ is a continuous function, in the interval [0, 1]
- $\delta_{\tilde{X}_D}(p)$ is strictly increasing, and continuous function on [x_1, x_2]
- $\delta_{\tilde{X}_D}(p)$ is strictly decreasing, and continuous function on [x_2, x_3]

Addition & Subtraction of two Diamond Fuzzy Numbers: If $\tilde{X}_D = (a,b,c)$ and $\tilde{Y}_D = (d,e,f)$ are two DFNs then,

$$\tilde{X}_D + \tilde{Y}_D = (a+d, b+e, c+f)$$

$$\tilde{X}_D - \tilde{Y}_D = (a-d, b-e, c-f)$$

According to Kabir and Hasin (See [46]), decision-makers' unclear, or vague preferences cannot be presented through crisp values. Therefore, to overcome this deficiency of the AHP technique, the FAHP is suggested in this paper. Linguistic variables are used in FAHP for comparisons were made between the criteria and sub criteria in a pairwise manner, represented by diamond fuzzy numbers portrayed below in Table 2.

Table 2
Linguistic Preference Scale used in FAHP

Crisp Saaty Scale	Fuzzy Diamond Scale	Inverse Fuzzy Diamond Scale	Linguistic Scale Explanation
1	(1, 1, 1)	(1, 1, 1)	Equal preference of both i and j criteria
2	(1, 2, 3)	(1/3, 1/2, 1/1)	Intermediate value between 1 and 3
3	(2, 3, 4)	(1/4, 1/3, 1/2)	Criteria i is slightly more preferred over criteria j
4	(3, 4, 5)	(1/5, 1/4, 1/3)	An intermediate value between 3 and 5
5	(4, 5, 6)	(1/6, 1/5, 1/4)	Criteria i is important over criteria j
6	(5, 6, 7)	(1/7, 1/6, 1/5)	An intermediate value between 5 and 7
7	(6, 7, 8)	(1/8, 1/7, 1/6)	Criteria i is strongly important over criteria j
8	(7, 8, 9)	(1/9, 1/8, 1/7)	Intermediate value between 7 and 9
9	(9, 9, 9)	(1/9, 1/9, 1/9)	Criteria i is extremely important over criteria j

Algorithm

The way the FAHP model works can be described as follows [47].

1st Step: Identify the problem and prepare a hierarchical structure of the problem.

2nd Step: Prepare a pairwise comparison matrix for criteria and sub-criterions. For this purpose, the preferences of the selected individual investors are taken built on the linguistics scale.

3rd Step: Compute the fuzzy geometric mean value $(\tilde{x}_i)$ as

$$\tilde{x}_i = ((a_1 \otimes a_2 \otimes \ldots \otimes a_n)^{1/n}, (b_1 \otimes b_2 \otimes \ldots \otimes b_n)^{1/n}, (c_1 \otimes c_2 \otimes \ldots \otimes c_n)^{1/n})$$

where $a_k, b_k, c_k; k = 1, 2, \ldots, n$ are upper value, middle value, and lower values of the fuzzy scale for k^{th} criteria or sub-criteria.

Table 3

Fuzzy geometric mean values of CSFs

CSFs	Fuzzy Geometric Mean Value		
O1	5.278	6.0003	6.6939
O2	2.988	3.6171	4.238
O3	0.189	0.2253	0.2806
O4	0.721	0.9107	1.141
O5	0.36	0.4525	0.5867
E1	0.311	0.3835	0.4945
E2	0.28	0.3392	0.4265
E3	2.166	2.6441	3.1298
T1	1.75	2.1136	2.5044
T2	1.087	1.319	1.5964
T3	0.752	0.9754	1.2061
T4	0.565	0.6991	0.861
T5	0.493	0.6028	0.7462
Sum	16.94	20.283	23.905
	0.042	0.0493	0.059

4th Step: Determine the normalized fuzzy weights $(\tilde{w}_i)$ as:

$$\tilde{w}_i = \tilde{x}_i \otimes (\tilde{x}_1 \oplus \tilde{x}_2 \oplus \cdots \oplus \tilde{x}_n)^{-1}$$

Table 4

Normalized fuzzy weights of CSFs

CSFs	Normalized Fuzzy Weights		
O1	0.2208	0.296	0.3951
O2	0.125	0.178	0.2502
O3	0.0079	0.011	0.0166
O4	0.0302	0.045	0.0674
O5	0.0151	0.022	0.0346
E1	0.013	0.019	0.0292
E2	0.0117	0.017	0.0252
E3	0.0906	0.13	0.1848
T1	0.0732	0.104	0.1478
T2	0.0455	0.065	0.0942
T3	0.0315	0.048	0.0712
T4	0.0236	0.034	0.0508
T5	0.0206	0.03	0.044

5th Step: Defuzzify the fuzzy weights into crisp weights as:

$$w_i = (a_1, a_2, a_3) = \frac{(a_1 + a_2 + a_3)}{3}$$

Table 5

Crisp weights of CSFs

CSFs	Crisp Weights
O1	0.3039
O2	0.1845
O3	0.0119
O4	0.0475
O5	0.024
E1	0.0204
E2	0.0179
E3	0.1352
T1	0.1084
T2	0.0682
T3	0.0503
T4	0.0363
T5	0.0315
Sum	1.0399

6th Step: Finally, normalize the crisp weights $\tilde{w}_i$ using the following equation:

$$W_i = \frac{w_i}{\sum_{i=1}^{n} w_i}$$

Table 6

Normalized crips weights and ranks of CSFs

CSFs	Normalized Crisp Weights	Ranks
O1	0.2923	1
O2	0.1774	2
O3	0.0114	13
O4	0.0457	7
O5	0.0231	10
E1	0.0196	11
E2	0.0172	12
E3	0.13	3
T1	0.1042	4
T2	0.0656	5
T3	0.0483	6
T4	0.0349	8
T5	0.0303	9

Execute the above six steps to determine the normalized weights of both criteria and the sub-criteria. The sub-criteria, global weights can be determined by multiplying each sub-criterion local weight with the related

criterion weight. Table 3, 4, 5 and 6 shows the derived values of Step 3, 4, 5 and 6 respectively.

4. Results and Discussions

The significance and position of each factor is shown in Table 7. The ranks are given as per normalized crisp weights. The experts ranked the top management attitude and organization readiness which belong to organizational context as the most essential factors for achieving effective blockchain adoption/integration. In the context of the environment, only the Government Regulation is regarded as the noteworthy factor for blockchain adoption/integration. In the technological aspect, immutability and disintermediation are favorably ranked. On the flip side, the professionals don't believe that organization size has much impact for successful adoption of blockchain.

5. Conclusion

Blockchain technology has transformed not only the financial sector but almost every industry of the world be it law enforcement, ride-hailing, real estate, healthcare, supply chain, marketing, education, etc. It is considered one of the major disrupting technologies and a key representation of the Fourth Industrial Revolution. The main objective of this research was to realize the adoption of blockchain technology with reference to the financial services industry. This study analysed thirteen critical success factors shaping blockchain-technology adoption and clustered them into three categories: technology, organization, and environment. The fuzzy analytical hierarchy process (FAHP) technique was used to rank the success factors based on their relative weightage. Top management attitude, Organization readiness, Government Regulation, Immutability, and disintermediation are found to be top five pivotal factors for effective blockchain adoption.

6. Managerial implications

Pinpointing critical factors for blockchain success will empower the industry and governments to classify based on priority the strategic elements and accomplish effective blockchain integration and adoption. Adoption of blockchain technology can eliminate intermediaries ensuring fast, safe, and secured transactions. Real-time auditing using distributed

ledger technology can reduce dependency on auditing firms therefore saving time and cost [48]. Further, smart contracts execute pre-defined business steps and legally enforceable transactions minimizing litigation and financial distress [49] [50] [51]. Blockchain will permit transparent real-time execution of transfers of shares and help organizations reduce trading costs [52]. Blockchain alleviates the fraud potential in organizations by using an inimitable "timestamp" and keeping foolproof records for all transactions [17]. Blockchain can provide unmatched transparency which increases the profit prospects of investors by observing their transactions in real time [53] [54]. Blockchain may help in voting more fast, secure, precise, and accurate [55] [56]. Blockchain enables traceable and accurate asset transactions and aligns it with organization strategy ensuring real-time information access by every department [57].

7. Limitations of the study and future research scope

The present research has been limited based on constructs used, respondents, and tools used for analysis. The model we've presented could be a useful foundation for delving deeper into the essential aspects influencing the integration of various blockchain technologies, like cryptocurrencies, plus smart contracts. Also, moving forward, we propose conducting practical tests of our framework in specific areas like public health, last-mile delivery, and e-government. This will enhance the credibility of identifying the crucial factors that influence the efficient adoption plus integration of blockchain technologies in various applications.

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