Evaluating Barriers to Blockchain Adoption in the Insurance Sector using Interval-Valued Intuitionistic Fuzzy TOPSIS

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Abstract: - In this work, we suggest studying the barriers that prevent from using blockchain technology and smart contracts in the insurance sector. It is possible to improve many services, by introducing "Fintech" information technologies which will ensure maximum transparency and speed. The goal of our paper is to answer two main questions: What obstacles stand in the way of the successful use of blockchain technology throughout the insurance sector? Which of them are the most notable obstacles that require decision-makers consideration?. We opt for an analysis of the barriers to blockchain adoption using fuzzy logic for the following reasons. In many realistic situations, it is difficult to gather the exact assessment data; the assessment is based mainly on the decision makers' knowledge and their experiences using linguistic terms or sentences in a natural or artificial language. The idea is to transform the linguistic variables into fuzzy sets using appropriate membership functions. In other words, fuzzy logic allows a better representation of the uncertainty and subjectivity of decision-makers. In our study, we analyze the answers of twenty experts, - highly skilled professionals with advanced knowledge acquired through education and experience-, about the most significant barriers to blockchain adoption in an interval-valued intuitionistic fuzzy environment. Then, by making use of decision-making tools such as IVIF TOPSIS, we make a ranking of barriers according to their importance to find the most important factors that influence the adoption of blockchain technology. This study's goal is to propose a model for identifying and tracking the crucial elements that influence managers' decisions on whether to adopt a financial technology like blockchain in their businesses or not. In the end, we conclude with some recommendations and suggestions to overcome the most important barriers and face future challenges.

Key-Words: - Blockchain, insurance, interval-valued intuitionistic fuzzy logic, decision making, TOPSIS method, simulations.

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1 Introduction

Thousands of companies around the world are very excited about blockchain technology, they are actively thinking about the possible applications of this technology that can improve their products or services, [1]. Others think that this new technology is facing many challenges that should be studied and solved to benefit from this powerful tool without illusions, [2]. Actually, no one can predict what and when blockchain technology is going to change businesses.

The emerging potential of this technology motivates us to study the barriers to blockchain adoption in the insurance sector, as an important field in the financial industry. The concept is to consult managers and professionals with extensive experience who are knowledgeable about the key factors that may encourage or discourage the adoption of blockchain technology. The answers given by experts are in the form of linguistic terms explaining their evaluation of each barrier. Thus, to have a convenient interpretation of this survey, we consider uncertainties by making use of an intuitionistic interval-valued fuzzy approach, [3]. Then, we opt for the TOPSIS method, which aggregates the various answers of all experts to rank the most important barriers.

Blockchain, as a new technology of data transmission, is revolutionizing various aspects of the insurance industry, [4]. By providing a secure and transparent ledger system, it ensures the integrity of policyholder data and reduces fraudulent activities, [5]. Smart contracts automate claims processing, speeding up settlements and enhancing customer satisfaction, [6]. Blockchain's decentralized nature enables seamless data sharing among insurers, reinsurers, and other stakeholders, leading to more accurate risk assessment and improved underwriting processes, [7]. With optimized operations, enhanced data security, and increased trust, blockchain plays a crucial role in transforming the insurance sector, benefiting both insurers and policyholders, [8].

The Blockchain adoption in insurance is analyzed in this paper, through decision-making tools. We opt for interval-valued intuitionistic fuzzy TOPSIS, which evaluates alternatives by comparing them to an ideal solution and an anti-ideal solution and then assigns scores to rank the options based on their proximity to the ideal, [9]. It is an extension of the traditional TOPSIS method, considering the hesitancy and non-membership degrees in assessing alternatives. This additional information provides a better understanding of vague and imprecise data.

The goal of our research is to evaluate whether insurance companies are ready or not to adopt blockchain technology, by selecting the main barriers and determining the importance of each one by using MCDM methods in an intuitionistic interval-valued fuzzy environment.

The paper will be structured as follows. The first section will review the most significant obstacles to blockchain technology in the insurance industry. The second part presents the environment and tools required in our study. For this purpose, we explain intuitionistic interval-valued fuzzy logic and multi-criteria decision-making tools such as the TOPSIS method. Then, we present in detail the proposed methodology, followed by our case study. The outcomes of the application are presented in the last section, along with interpretation and results analysis. Finally, we offer some suggestions for overcoming adoption-related obstacles for blockchain technology.

2 Barriers to Blockchain Adoption in Insurance

To evaluate whether blockchain technology is adapted to the Moroccan insurance sector, we have chosen to analyze the reasons that may not encourage companies to switch to smart insurance based on blockchain technology.

To answer this question, we survey twenty experts in the insurance sector and blockchain. In our work, we mean by experts, in finance or blockchain, highly skilled professionals with advanced knowledge in their respective domains. We asked directors in the financial sector who had compelling backgrounds and extensive expertise in the insurance industry, such as many directors in the largest insurance firms in Morocco. For Blockchain and IT experts, we considered experienced professionals and researchers in those fields, who could provide consistent answers to our investigation. Their insights contribute to well-informed decision-making, shaping strategies in finance or blockchain-related industries.

The answers are collected and then transformed into fuzzy sets reflecting uncertainties and hesitation degrees for a better analysis. Each expert is supposed to evaluate the importance of each criterion on a specific scale, through linguistic variable that reflects his point of view.

In the following paragraphs, we make a literature review on the most important barriers to justify the main criteria selected in our study.

EFFICIENCY: To adopt a new technology or not, we need to make sure of its efficiency or its added value in improving the existing process. The power of blockchain is that it is a distributed ledger, shared by everyone but does not belong to anyone. Technically, all participants agree on a set of rules called "consensus" and work by this agreement, [10]. Indeed, many customers have lost trust in many financial institutions; this technology can be the proof of a new period of full transparency. It will enable organizations to focus on more important things, such as improving their services and creating new products. [11], as for smart contracts combined with blockchain, they are very efficient for making processes faster, Actually, actions are automatically executed if the terms of the virtual contract are fulfilled without any intermediary. No manual verification is required, as long as oracles are efficient in verifying the related conditions.

In other words, trust, transparency, and rapidity are the characteristics that may add more efficiency to insurance products based on blockchain. But, every expert can evaluate the efficiency of this technology from his perspective.

COST: The cost of the project of integrating fintech in the insurance sector is important, the financial situation of the company and the budget dedicated to innovation play a role in encouraging the adoption or not of fintech. We all know that, like any new project, it can be costly at the beginning as an initial investment but after that, costs will reduce significantly. It depends if the company is ready to spend or invest money in a new experience or not.

The implementation of blockchain technology can be costly due to several factors. Firstly, the development and deployment of blockchain solutions require specialized technical expertise. Additionally, the infrastructure required to support a blockchain network, including servers, nodes, and storage, can be expensive to set up and maintain, let alone the high consumption of energy, [12]. Adding to this, we need a huge budget to train employees and initiate them to fintech or even recruit new skills, which leads us to the next criteria.

SKILLS AVAILABILITY: There is still a lack of skills related to blockchain and a lack of a masters or thesis on this topic. But, it is possible to make efforts to train employees and adapt them to this new technology, [13]. No one can deny that blockchain promises very attractive applications, but this attractiveness should not push organizations to integrate this tool without really understanding it, [14]. The number of people who master this technology is quite low, adding IoT into the mix, the qualified human capital may not be enough. That’s why we should try to understand the core of this technology and train people in this field, to avoid potential financial loss. It will also be interesting to develop more developer-friendly APIs for developers because the current interfaces are not easy to use, [15]. Last but not least, preparing the human capital with relevant skills is an important factor before using fintech in the insurance sector.

SECURITY: The structure of the blockchain demonstrates that it is made of encrypted and immutable code blocks. A great number of servers or nodes are storing the same amount of data at the same time instead of a centralized entity, [16]. This is a strong point because it means that to hack a blockchain, you have to hack so many servers at the same moment, which is almost impossible. Even if some gaps should be filled such as the "51% attack", which means that the majority may attack the network to manipulate and take control of the blockchain. But, generally, security remains one of the main advantages of blockchain technology, [17].

UNTESTED TECHNOLOGY: We all know that Blockchain technology is still in its early stages, which means that it is still not sufficiently tested. But, governments, global banks, and international organizations - who are very interested in blockchain applications- are risk-averse, and may not be ready to put their sensitive data in an unreliable system. These institutions are quite slow to innovate and need to rely on a system tested and approved for a long period. For insurance companies, the fact that this technology has not yet been tested by many big organizations may be discouraging, but others may consider it a challenge to be among the leaders, [18].

INNOVATION STRATEGY: Innovation is paramount for insurance companies as it enables them to stay competitive in a rapidly evolving industry by offering new and customized products and services to meet changing customer needs. Embracing technological advancements and data analytics allows insurers to enhance risk assessment, streamline operations, and improve profitability. Nevertheless, the willingness of companies to modernize their processes, to look for new methods to satisfy their clients depends on the management strategy. Some companies have powerful innovation strategies. They are more interested in research and development than others, which pushes them to be more flexible in adopting recent technologies and renewing their processes, [19].

STANDARDISATION: At the moment, the blockchain is neither regulated nor standardized, there is no legal code or compliance to follow. This limitless field may scare some organizations from taking a step in this very open world without any law to protect them or regulation to define their limits. But, at the same time, it would be a mistake to tighten the regulations related to blockchain before fully understanding its potential. Even for engineers and programmers, the lack of standardization makes it difficult for blockchain participants to communicate and work together effectively, [20].

PRIVACY: There are some particular concerns regarding privacy in blockchain. For instance, bitcoin as a blockchain may not have a good reputation because of the misuse of this currency. Many people around the world profit from the fact that transactions are anonymous, to use it in some illegal fields such as drug dealing and blackmailing, [21]. In general, if one malicious user engages in illicit behavior, this level of anonymity could be detrimental and damaging to all users. On the other hand, in a private blockchain network, the nobility is blind to one another's precise identity and relies on consensus for all transactions. Therefore, a blockchain may function as a private place instead of being a clear platform for plain and recognizable operations, [22].

INTEGRATION PROBLEMS: It costs money and takes time to integrate blockchain technology with the already existing processes. To connect new blockchain consortium apps with legacy systems, application programming interface (API) gateways are still needed, [23].

REGULATION ISSUES: Another barrier to blockchain adoption is related to regulation issues. We need to deal with the emergence of some technology-based methods and concepts, such as cryptographic signatures and intelligent contracts, which are not clarified in the existing regulations, [24]. Insurance companies may be reticent about adopting a technology with aspects that need regulations from governments to protect both service providers and customers. This aspect needs to be evaluated by companies to prevent any conflicts or non-conformity with the existing laws.

PROCESSING POWER AND TIME: There are some issues related to the processing power of blockchain. This technological aspect may lead us to think about the real potential of blockchain when used massively. Actually, with the current means, the transactions in the Bitcoin blockchain network do not exceed 7 transactions per second, which is not adapted to high-frequency trading. VISA allows 2000 tps while Twitter reaches 5,000 tps. Adding to this, the size of a block in the Bitcoin blockchain is limited to 1 MB, and a block needs ten minutes to be mined. But, if we want larger blocks, we will need more storage space and more time, which leads us to the next challenge of storage, [25].

STORAGE: As a decentralized system, data in blockchains are not stored in one central unit, but, at all the nodes of the network. This issue may create some problems because the amount of stored data will be huge over time, especially since what is written cannot be erased (immutability of blockchains), [26]. This issue can be very challenging for many devices with low storage capacities such as sensors.

3 Environment and Tools

The literature review we provided earlier, outlines the obstacles to blockchain adoption in the insurance industry. In an interval-valued intuitionistic fuzzy environment, we have decided to use an MCDM strategy to rank those obstacles from the most significant to the least important. The required tools for our investigation are presented in the following section.

3.1 Interval-valued Intuitionistic Fuzzy Environment

Fuzzy logic is a mathematical framework that deals with reasoning and decision-making in situations where uncertainty and imprecision are present. Fuzzy logic is different from classical logic, the latter is based mainly on two aspects either true or false. On the other hand, fuzzy logic is based on a membership function that represents degrees of truth with reflect uncertainties contained in data.

3.1.1 Introduction to Interval-Valued Intuitionistic Fuzzy Logic

In the 1960s, was the emergence of fuzzy logic as a method to deal with ambiguities and imprecise information. It is especially helpful in areas where human thinking is involved because it can replicate the adaptability and tolerance for error that people frequently express.

Fuzzy sets are important to understand fuzzy logic theory. A fuzzy set is a group of items having various degrees of membership, represented by a function that assigns to each object a grade of membership ranging from zero to one, indicating the degree to which it belongs to the set. This representation enables a better understanding of many real-world phenomena.

To model human reasoning and decision-making processes, we can make use of fuzzy logic also uses linguistic variables associated with fuzzy rules. Linguistic variables allow us to characterize concepts using natural language phrases, transformed to fuzzy sets.

Fuzzy logic has been applied in a variety of domains, including Information systems, Data analysis, Imagery enhancement, Sonar, Radar, medical applications, genetics, Control theory, and computer science. As we mentioned earlier, it is an effective technique for dealing with uncertain and imprecise information, allowing for resilient and adaptable solutions to complicated issues, [27]. To summarize, fuzzy logic offers a mathematical framework for thinking about uncertainty and imprecision. It provides a more sophisticated approach to decision-making and problem-solving when simple binary reasoning may be insufficient or irrelevant.

Since decision-making is frequently done under certain conditions, such as lack of information and expertise, lack of consensus among decision-makers, and time constraints, the rising complexity of socio-economic communities generates complexity and ambiguity in the priorities of decision-makers, [28]. Therefore, it would be practical to make decisions in such a case using an interval-valued fuzzy environment. The membership functions would be an interval instead of a precise number, which is the key characteristic of adopting an interval-valued fuzzy environment. It is challenging to fully convey an idea or linguistic variable by an integer number in the range [0, 1] in fuzzy set theory. Therefore, it would be more reasonable to describe the degree of confidence by an interval of [0, 1].

3.1.2 Some Definitions

Some fundamental IFS and IVIFS notions are briefly explained in the following paragraphs. Those definitions are essential to understanding the operations of fuzzy numbers using MCDM methods in the next sections.

Definition 1. Fuzzy set
Let $X = \{x_1, x_2, \ldots, x_n\}$ be a set.
A fuzzy set A' in X is defined as follows:
$A' = \{< x, \mu_{A'}(x) | x \in X >\}$
where $\mu_{A'} : X \rightarrow [0,1]$ is the membership function and $\mu_A(x)$ is the membership degree of $x \in X \, to \, A'$.

Definition 2. Intuitionistic fuzzy set
Let $X = \{x_1, x_2, \ldots, x_n\}$ be a set, an intuitionistic fuzzy set (IFS)
A” is defined as:

$$A'' = \{ \langle x, \mu_{A''}(x), v_{A''}(x) \mid x \in X \rangle \}$$

where $\mu_{A''}(x)$ and $v_{A''}(x)$ are the membership degree and non-membership degree of x to A, respectively, with the following conditions:

$$for\ all\ x \in X, 0 \leq \mu_{A''}(x) + v_{A''}(x) \leq 1$$
$$and\ \mu_{A''}(x), \quad v_{A''}(x) \in [0,1]$$

If $\mu_{A''}(x) = v_{A''}(x)$ the IFS A is an ordinary fuzzy set.

Definition 3. Interval-valued intuitionistic fuzzy set
Suppose that X is a non-empty set, an interval-valued intuitionistic fuzzy set (IVIFS) ˜A is defined as:

$$A = \{ \langle x, \mu_A(x), v_A(x) \mid x \in X \rangle \},$$
$$where\ \mu_A(x) = [\mu_A^L, \mu_A^U] \subset [0, 1]$$
$$and\ v_A(x) = [v_A^L, v_A^U] \subset [0, 1]$$

represent membership interval and non-membership interval of the element $x \in X$ to A, respectively, satisfying

$$max\, \mu_A(x) + max\, v_A(x) \leq 1, \forall x \in X.$$

$\pi_A(x) = [\pi_A^L, \pi_A^U]$ is the hesitation interval of x to A,

$$where\ \pi_A^L = 1 - \mu_A^U - v_A^U\ and\ \tilde{\pi}_A^U = 1 - \mu_A^L - v_A^L$$

Definition 4. Operations on IVIF numbers
Assume that

$$A = \{< xi\, [\mu_A^L(x_i), \mu_A^U(x_i)], [\mathrm{v}_A^L(x_i), \mathrm{v}_A^U(x_i)] > | x_i \in X\},$$
$$B = \{< xi\, [\mu_B^L(x_i), \mu_B^U(x_i)], [\mathrm{v}_B^L(x_i), \mathrm{v}_B^U(x_i)] > | x_i \in X\},$$

then the basic operations of IVIF are expressed by the following formulas:

Definition 5. Score function and accuracy function
α = ([a, b], [c, d]) is an interval-valued intuitionistic fuzzy number (IVIFN) satisfying that 0 ≤ a ≤ b ≤ 1, 0 ≤ c ≤ d ≤ 1 and b + d ≤ 1. The score function S(α) and the accuracy function H(α) of α are presented as follows:

$$S(\alpha) = \frac{a + b - c - d}{2}$$
$$H(\alpha) = \frac{a + b + c + d}{2}$$

Definition 6. Comparison between IVIF numbers
Assume that
$\alpha_1 = ([a_1, b_1], [c_1, d_1])$ and $\alpha_2 = ([a_2, b_2], [c_2, d_2])$ are two IVIFNs, then the comparison operations between IVIFNs are presented as below:

$$If\ S(\alpha_1)) > S(\alpha_2), then\ \alpha_1 > \alpha_2$$
$$If\ S(\alpha_1) = S(\alpha_2), then$$
$$(a)\ if\ H(\alpha_1) > H(\alpha_2), then\ \alpha_1 > \alpha_2;$$
$$(b)\ if\ H(\alpha_1) = H(\alpha_2), then\ \alpha_1 = \alpha_2.$$

3.2 Multicriteria Decision Making Tools

Multiple Criteria Decision Making, or MCDM for short, is a branch of research that examines the process of making decisions when several competing criteria must be taken into account. MCDM offers a systematic way to assist decision-makers in evaluating options and choosing the best course of action in a variety of real-world settings where they must make complicated decisions with many objectives. Multiple factors, including cost, time, quality, risk, and environmental effects, are intended to be included in the decision-making process using MCDM methodologies. The choice problem is intrinsically difficult since these criteria frequently have multiple dimensions, units of measurement, and levels of relevance

3.2.1 Why MDCM, Use and Applications

Giving decision-makers a systematic framework for evaluating and contrasting choices according to how well they perform against several criteria is one of the most important goals of multicriteria decision-making methods (MCDM), [29]. The process of solving an MCDM problem requires some essential milestones such as defining the problem structure, identifying the most relevant criteria, identifying and weighting them, analyzing alternatives, and finally decision synthesis, to efficiently find out the best solution, [30].

There are many multi-criteria decision-making techniques developed to solve several problems in various fields, let's mention some examples: AHP (Analytic Hierarchy Process), TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution), PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluations), and ELECTRE, [31].

The MDCM mentioned above utilizes mainly mathematical models, algorithms, and decision rules to rank or prioritize alternatives. The final goal is to provide decision-makers with meaningful information about the best alternatives depending on their priorities and preferences, [32]. We can also make use of MCDM methods and at the same time, study the impact of changes in criterion weights or input data, which enables us to measure uncertainty and also make a sensitivity analysis. The latter aims to identify significant factors and analyze the stability of the alternatives considered, [33].

The MDCM techniques mentioned earlier are used in management fields, engineering, healthcare, logistics, and public policy, but also education as well as industry development. They can help decision-makers in every stage from a project analysis to concrete realization, [34]. These strategies offer a systematic way to evaluate alternatives, classify actions, and achieve optimum results in a variety of disciplines where decisions require making important choices and must take into account a wide range of criteria, [35].

3.2.2 TOPSIS Method

After presenting what are MDCM techniques, now we move to the TOPSIS method, or the Technique for Order of Preference by Similarity to Ideal Solution as an example, this method was developed in 1981 and improved later. The principle of the TOPSIS method is quite simple, it assumes that the chosen solution for our problem is the option that is geometrically closest to the positive ideal solution (PIS) and the furthest away from the negative ideal solution (NIS), [36], which is quite intuitive and logical. No need to be precise that such a method has been utilized extensively in a wide range of industries, including manufacturing, financial analysis, quality evaluation, technology management but also mission planning, [37].

The TOPSIS method's key steps are the following. The first step is to make the decision matrix normalized. Then, determine the ideal solution matrix of positive and negative ideal solutions by using this formula:

$$A^{+} = \{(max\, t_{ij} \mid j \in J), i = 1,2,3, \dots ,m\}$$
$$A^{-} = \{(min\, t_{ij} \mid j \in J), i = 1,2,3, \dots ,m\}$$

Then, calculate the distance from the negative ideal solution and the distance between the alternative and the best condition. We can calculate the Euclidian distance or hamming distance or any other suitable formula of separation measurement. The last step is to calculate the similarity to the worst condition: $S_{iw} = 1$ if and only if the alternative solution has the best condition; and $S_{iw} = 0$ if and only if the alternative solution has the worst condition. This score enables us to Rank the alternatives.

4 Case Study Application

In the following section, we explain the general methodology and then we present the application to our case study “Ranking barriers to blockchain adoption in insurance” using Interval-valued intuitionistic Fuzzy TOPSIS as an MCDM technique.

4.1 General Methodology

After giving an overview of the literature and presenting the tools required in our study, we explain in the following section, the steps required to filter those factors. For this purpose, we make use of decision-making techniques in an interval-valued fuzzy environment. The output is to define the most significant among the selected barriers.

Step 1: The first step is to collect answers from experts in the insurance sector in blockchain technology to evaluate each one of the factors from the literature review.

Step 2: The second step is to transform the answers from linguistic variables into interval-valued fuzzy numbers according to the predefined scale chosen in the form, to obtain the decision-making matrix made of an IVIF number.

Step 3: In this stage, we make use of decision-making methods to make a classification of all the criteria of the matrix using IVIF TOPSIS.

Step 4: We obtain the results and run many scenarios to compare the results of each simulation and analyze sensitivity.

Step 5: We explain the output by highlighting the most important barriers to blockchain adoption that should be considered by managers and decision-makers.

4.2 Application of IVIF TOPSIS for Identification of Blockchain Barriers

4.2.1 Algorithm and Steps of the Simulation

When dealing with multi-criteria decision issues having uncertainties and taking into consideration the preferences of the decision-makers, fuzzy TOPSIS is an effective tool, [38]. The best alternative may be found using this technique, [39].

The alternatives here represent the criteria of blockchain adoption and the most important criterion is the one with the highest scores in the answers of experts. To use the TOPSIS method in our application, we ask 20 experts about 12 barriers to blockchain adoption and collect their answers in the form of linguistic variables.

Step 1: The survey intitled Barriers to blockchain adoption in the insurance sector, completed by each expert will be as follows, Table 1 is an example of an answer sheet.

Question: Based on your experience, what is the importance of each factor in the blockchain adoption in insurance?

VL: Very low, L: Low, M: Medium, H: High, VH: Very high.

Table 1. Answer sheet example

Criteria/Importance	VL	L	M	H	VH
Efficiency			X		
Cost				X	
Skills availability			X		
Security					X
Untested technology		X			
Innovation strategy		X			
Standardization			X		
Privacy			X		
Integration problems				X	
Regulation issues				X	
Processing power	X				
Problem of storage		X			

Step 2: We collect the answers and then transform linguistic variables to IFIV numbers using the Table 2.

Table 2. Transformation to IVIF numbers

Linguistic variable	Corresponding IFIV number
Very low	([0.3, 0.4], [0.4, 0.6])
Low	([0.5, 0.6], [0.3, 0.4])
Medium	([0.6, 0.7], [0.2, 0.3])
High	([0.7, 0.8], [0.1, 0.2])
Very High	([0.8, 0.9], [0.1, 0.2])

Step 3: We calculate the Positive Ideal solution and Negative Ideal Solution given by the following formula $I^+ = ([a_1^+, b_1^+], [c_1^+, d_1^+]), ([a_2^+, b_2^+], [c_2^+, d_2^+]), \dots, ([a_{10}^+, b_{10}^+], [c_{10}^+, d_{10}^+])$:

$$I^- = ([a_1^-, b_1^-], [c_1^-, d_1^-]), ([a_2^-, b_2^-], [c_2^-, d_2^-]), \dots, ([a_{10}^-, b_{10}^-], [c_{10}^-, d_{10}^-])$$

Where :

$$[a_j^+, b_j^+], [c_j^+, d_j^+] = [max_i a_{ij}^1, max_i a_{ij}^2]\ j \epsilon J_1\ [min_i a_{ij}^3, min_i a_{ij}^4]\ j \epsilon J_2$$

$$[a_j^-, b_j^-], [c_j^-, d_j^-] = [min_i a_{ij}^1, min_i a_{ij}^2]\ j \epsilon J_1\ [max_i a_{ij}^3, max_i a_{ij}^4]\ j \epsilon J_2$$

Step 5: Calculating distances

There are various methods of distance measurement used in different contexts, [34]. Some commonly used ones include Euclidean distance, Manhattan distance (also known as city block distance), Cosine distance, Hamming distance, and Jaccard distance. Each method has its properties and applicability depending on the data and problem at hand. In our case, we have chosen the normalized hamming distance because of its simplicity but also accuracy.

Distances from Positive Ideal Solution D^+

$$D^+(M_i, I^+) = \left\{ \frac{1}{4m} \sum_{j=1}^{m} \left[\left| a_{ij}^1 - a_j^+ \right| + \left| a_{ij}^2 - b_j^+ \right| + \left| a_{ij}^3 - c_j^+ \right| + \left| a_{ij}^4 - d_j^+ \right| \right] \right\}$$

Distances from Negative Ideal Solution D^-

$$D^+(M_i, I^+) = \left\{ \frac{1}{4m} \sum_{j=1}^{m} \left[\left| a_{ij}^1 - a_j^+ \right| + \left| a_{ij}^2 - b_j^+ \right| + \left| a_{ij}^3 - c_j^+ \right| + \left| a_{ij}^4 - d_j^+ \right| \right] \right\}$$

Step 6: Calculate Similarity to worst condition:

$$S_i = \frac{D_i^-}{D_i^+ + D_i^-}$$

The highest score of Si means that the barrier is very far from the worst one. It means that ranking the 12 barriers according to the best scores will give the most significant barriers to blockchain adoption.

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4.2.2 Results Discussion and Recommendations

a. Results and findings

After calculating the positive distance, and negative distance, from the IVIF matrix, results are given by Table 3.

Table 3. Results of the simulation

	D+	D-	Score	Rank
1	0,075	0,1475	0,662921	5
2	0,06	0,1725	0,741935	2
3	0,08	0,1425	0,640449	7
4	0,0525	0,175	0,769230	1
5	0,0775	0,145	0,651685	6
6	0,0625	0,16	0,719101	3
7	0,145	0,0875	0,376344	12
8	0,1425	0,09	0,387096	11
9	0,115	0,1075	0,483146	10
10	0,0725	0,15	0,674157	4
11	0,0875	0,14	0,615384	8
12	0,115	0,1175	0,505376	9

According to the findings, the following are the most important barriers to blockchain implementation in the insurance business, according to experts. The first is regulation, as there is no blockchain-related law in our nation and no legal framework to stimulate the use of this new technology. The second issue is cost. Switching from traditional technologies to a new tool that requires powerful devices and particular software may be pricey, and some businesses may not be willing to invest a large budget on this transition. Security is the third obstacle for financial professionals. The insurance industry and financial institutions in general may be hesitant to accept new technologies due to security concerns as long as they deal with sensitive data.

b. Sensitivity analysis

Sensitivity analysis is an important technique in modeling, especially when it comes to risk and decision-making. It involves determining how changes to a model's inputs or parameters impact the model's outputs. Sensitivity analysis in a model should be done for several reasons. In particular, making meaningful choices: Enables better-informed judgments to be made by accounting for the model's unpredictability and uncertainty. Particularly in the fields of finance, project management, and strategic planning, this might be helpful. Model validation is a second significant factor. Sensitivity analysis can highlight weaknesses or contradictions in the model by pointing out connections that don't make sense. As a result, model quality can be enhanced.

To carry out a sensitivity analysis of our model, we will run several simulations. The weights of the experts will vary in each scenario, hence the weighted matrix will change each time. The weights assigned are, in turn, interval-valued intuitionistic fuzzy numbers, and the computation will be completed by IVIF Topsis as previously mentioned. This change in weights will cause a change in the matrix, and so in the estimated distances, positive and negative, and thus in the scores, resulting in a change in the barrier ranking. Following that, we will compare the findings generated in each case to assess the model's sensitivity.

Simulation 1

In this scenario, we suppose that the weight of each expert is very important. w = [0.8, 0.9], [0.1, 0.2]

The results of calculated distances, scores, and ranking are given by Table 4.

Table 4. Results of simulation 1

	D+	D-	Score	Rank
1	0,075	0,1475	0,662921	5

2	0,06	0,1725	0,741935	2
3	0,08	0,1425	0,640449	7
4	0,0525	0,175	0,769230	1
5	0,0775	0,145	0,651685	6
6	0,0625	0,16	0,719101	3
7	0,145	0,0875	0,376344	12
8	0,1425	0,09	0,387096	11
9	0,115	0,1075	0,483146	10
10	0,0725	0,15	0,674157	4
11	0,0875	0,14	0,615384	8
12	0,115	0,1175	0,505376	9

Simulation 2

In this simulation, we try to give more importance to experts with 10 years of experience w_1= [0.7,0.8], [0.1,0.2] in comparison to experts with (5 to 10) years of experience w_2= [0.5, 0.6], [0.3,0.4] . Table 5 shows the results of this scenario.

Table 5. Results of simulation 2

	D+	D-	Score	Rank
1	0,051875	0,118375	0,695301	5
2	0,0495	0,12625	0,718349	3
3	0,0595	0,1135	0,656069	7
4	0,03475	0,13825	0,799132	1
5	0,05825	0,11475	0,663294	6
6	0,049	0,12675	0,721194	2
7	0,108625	0,061625	0,361967	12
8	0,1045	0,06575	0,386196	11
9	0,079625	0,090625	0,532305	9
10	0,04975	0,1205	0,707782	4
11	0,062125	0,110875	0,640895	8
12	0,08375	0,0865	0,508076	10

Simulation 3

To emphasize the financial point of view, we try to give more importance to insurance professionals w_1= [0.7,0.8], [0.1,0.2] in comparison to blockchain and IT experts w_2= [0.5, 0.6], [0.3,0.4] . Table 6 shows the results of this scenario.

Table 6. Results of simulation 3

	D+	D-	Score	Rank
1	0,039	0,101625	0,722666	3
2	0,036375	0,109	0,749785	2
3	0,049375	0,08975	0,645103	7
4	0,030375	0,111	0,785145	1
5	0,043875	0,1	0,695047	5
6	0,042875	0,099	0,697797	4
7	0,09075	0,055875	0,381074	12
8	0,087625	0,059	0,402387	11
9	0,06725	0,069875	0,509571	9
10	0,044625	0,09525	0,680965	6
11	0,055	0,089625	0,619706	8
12	0,072625	0,07325	0,502142	10

Simulation 4

In this simulation, we try to give more importance to fintech experts w_1= [0.7,0.8], [0.1,0.2] in comparison to professionals of the financial sector w_2= [0.5, 0.6], [0.3,0.4], to see if this perspective is going to change the findings. The results are mentioned in the Table 7.

Table 7. Results of simulation 4

Criteria	D+	D-	Score	Rank
1	0,040875	0,102875	0,715652	3
2	0,03975	0,10775	0,730508	2
3	0,0515	0,095	0,648464	8
4	0,0315	0,11775	0,788944	1
5	0,046	0,10425	0,693843	6
6	0,0435	0,10675	0,710482	4
7	0,085125	0,058625	0,407826	11
8	0,086	0,05775	0,40173	12
9	0,072625	0,071125	0,494782	10
10	0,0445	0,102	0,696245	5
11	0,049625	0,096875	0,661262	7
12	0,06875	0,075	0,52173	9

The following graph presented in Figure 1 shows the ranking result obtained by each simulation. We can see that there is not a huge difference between the findings of each scenario, the results are quite similar which gives more accuracy and consistency to our results.

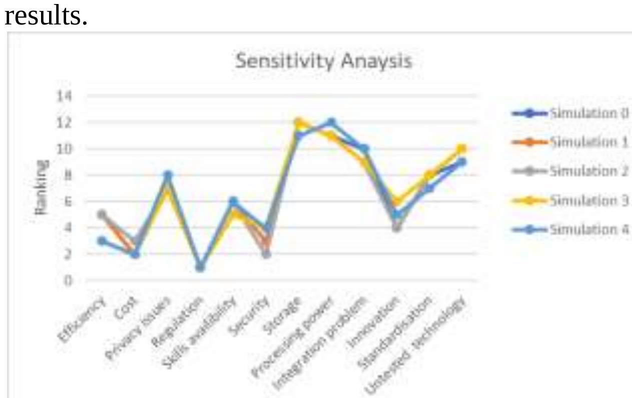

Fig. 1: Sensitivity analysis

c. Results analysis

According to the previous findings, the top three barriers to blockchain are regulation, cost, and security. We discuss each barrier in the following paragraph and then we compare our findings to similar studies.

First of all, concerning security issues, we all know that there are some risks such as 51% attack. It happens when one entity controls over 50% of the network's computational power, undermining its security. This can lead to fraudulent actions like double-spending, highlighting the importance of strong security in blockchain networks. But, the occurrence of this attack is very rare. Blockchain is quite safe for the financial sector since it employs cryptographic technologies and decentralized consensus to maintain data integrity and prevent tampering, [17]. Because of cryptographic hashing and distributed validation nodes, malicious users find it exceedingly difficult to alter financial data or compromise network integrity. Smart contracts, in large part, enable the automation of trustless financial transactions while minimizing the danger of fraud. In general, blockchain remains a robust and transparent platform for secure digital transactions within the financial industry

Secondly, although using blockchain technology in the insurance industry might be expensive, the significant advantages it provides make it worthwhile. A new level of confidence and transparency is made possible by blockchain's built-in mechanisms that increase data accuracy. By streamlining claims processing and reducing administrative expenses, this improved efficiency also eliminates the need for middlemen. Furthermore, blockchain records' immutability and auditability provide a reliable record of rules and claims history. Long-term cost reductions, enhanced client experiences, and a more robust and competitive insurance business are all promised in exchange for the initial investment in blockchain technology. That is why we should think about the gain behind investing a certain budget in such innovative technology.

Moreover, the lack of comprehensive regulation in the blockchain business has both advantages and downsides. On the one hand, it encourages innovation by lowering administrative hurdles to the development of new technologies and applications. This promotes investment and entrepreneurship in the blockchain sector. However, a lack of regulation exposes investors and consumers to risks such as fraud and market manipulation. People who do not fully appreciate the risks involved, especially risks incurring significant financial losses. But, in all cases, we can say that it is just a matter of time and countries are going to adopt, sooner or later, regulations to benefit from the full potential of this technology legally and safely.

To compare our findings, we conducted research on relevant journals, that were also interested in blockchain adoption barriers, using MCDM techniques in an interval-valued intuitionistic fuzzy environment. The chosen references are the following, Prioritization of factors affecting the digitalization of quality management using interval-valued intuitionistic fuzzy Best-Worst Method [40], Research on significant factors affecting the adoption of blockchain technology for enterprise distributed applications based on integrated MCDM FCEM-MULTIMOORA-FG method [41], Expert oriented approach for analyzing the blockchain adoption barriers in humanitarian supply chain, [42]. We selected these papers because of the similarities to our work, in the goal but also the methodology of the study.

According to reference [40], the interval-valued intuitionistic fuzzy Best-Worst technique was used to prioritize the aspects influencing the digitalization of quality management. Using the proposed approach, the most important significant criterion has been identified. as a "Management" element. When considering the sub-criteria, Digital skills, and talent, Digital quality management culture, and the Existence of digital strategy are ranked as the top three. According to the second reference [41], research on important variables influencing the adoption of blockchain technology for business distributed applications is based on an integrated MCDM approach. The findings show that Scalability, Performance, and Maintenance are the three primary variables influencing the adoption of blockchain technology for organizations' distributed systems. Concerning the third reference [42], Regulatory uncertainty, Lack of knowledge/employee training, and high sustainability Costs are the three main barriers. We can conclude that regulation, cost, performance or efficiency, and skills, which are very important according to our simulations, are the main intersections with the findings of related studies.

Similar problems are covered in several additional articles using other MCDM techniques. Depending on the replies and viewpoints of the experts, the outcomes can vary. In any event, it provides us with a general understanding of the most crucial aspects on which we should focus to successfully implement blockchain effectively.

5 Conclusion

As we mentioned earlier, there are no legislative limitations in the blockchain world, which scares many organizations from taking the plunge. It is also helpful to set standards to encourage more innovation, and at the same time, enable organizations to communicate on the systems they are developing through some general guidelines and basic standards to avoid ending up with incompatible systems.

Moreover, it is very helpful to associate a technology with another instead of talking about every technology alone. A new technology is not supposed to eradicate the others, on the contrary, combining them usually gives impressive results. For example, AI can be of great benefit to the blockchain especially when we talk about smart contracts. As the latter relies on oracles, building oracles based on AI tools will make it more efficient. The intelligent oracle will learn from the outside and train itself and thus, is going to solve the problems related to the irreversibility of transactions.

Last but not least, to fully understand blockchain technology, to discover its full potential, and to develop interesting applications through it, we have to train people, test this technology, and prove its efficiency, and all these measures take time. It is therefore time to fill the technical gaps of this technology, to be prepared for the new era of blockchain platforms, stay up to date on the news, and try to take advantage of this powerful tool, without overestimating it or underestimating its potential.

In the end, every scientific paper, no matter how meticulously conducted, is inevitably bound by its inherent limitations. These constraints may arise from the scope of the study, available resources, experimental design, or even the current state of scientific knowledge. Recognizing and addressing these limitations is a fundamental aspect of scholarly integrity. Embracing the inherent limitations fosters a culture of continuous improvement and encourages future investigations to enhance our understanding of the complexities within the scientific domain.

Our study has certain limitations, particularly due to the limited number of specialists involved in the research. Although the chosen sample is recognized for its expertise, it inevitably falls short of reflecting the full field of specialists. Potential errors and misunderstandings in the experts' interpretations of the submitted questions provide an extra degree of restriction. These considerations, taken together, highlight the importance of being careful when extending our findings. This work serves as a basis for future research that will overcome these issues and contribute to a more complete knowledge of the issue.

The coming study will aim to use other multi-criteria decision-making techniques such as Best worst method, ELECTRE, and PROMETHEE… to compare our findings and improve the consistency of our study. We can also aggregate many MCDM methods and create a combination to have more significant results. It will be the aim of our future research.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used QuillBot in few paragraphs in order to improve the readability and language of the manuscript. After using this tool, the authors reviewed and edited the content as needed and takes full responsibility for the content of the publication.

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Conflict of Interest

The authors have no conflicts of interest to declare.