Blockchain adoption barriers in Moroccan sustainable supply chain: a proposed approach

Abdesadik Bendarag¹, Omar Boutkhoum², Driss Abada², Mohamed Hanine¹

¹Department of Mathematics and computer science, Faculty of Polydisciplinary, Cadi Ayyad University, Safi, Morocco
²Department of Computer Science, LAROSERI Laboratory, Faculty of Sciences, Chouaib Doukkali University, El Jadida, Morocco

Article Info

Article history:
Received Apr 17, 2021
Revised May 31, 2022
Accepted Jun 10, 2022

Keywords:
Blockchain
Document security systems
Intuitionistic fuzzy analytic hierarchy process
Sustainable supply chain

ABSTRACT

Currently, the emerging countries like Morocco seeks to benefit from the potential of blockchain technology to meet its various growing demands, especially in sustainable supply chain management (SSCM). This explains the need for more effort to understand blockchain implementation and identify the barriers influencing the blockchain adoption decision in SSCM, especially, from Moroccan industry and service sectors perspective. In this context, this research paper proposes a group decision-making approach to identify the barriers from a comprehensive literature search, then evaluate them based on intuitionistic fuzzy analytic hierarchy process (IFAHP). Due to the varied importance of the selected barriers, IFAHP is utilized to allocate priority weights for each barrier according to its importance level. The evaluation results reveal that “Government policy and support” and “Challenges in integrating sustainable practices and blockchain technology through sustainable supply chain management (SCM)” are the best ranked barriers that impact the implementation of blockchain technology in Moroccan context. The main objective is to inquire the barriers preventing the blockchain implementation, and assist industry decision-makers in developing short- and long-term decision-making strategies for better sustainable supply chain management.

This is an open access article under the CC BY-SA license.

Corresponding Author:
Omar Boutkhoum
Department of Computer Science, LAROSERI Laboratory, Faculty of Sciences
Chouaib Doukkali University
El Jadida, Morocco
Email: boutkhoum.o@ucd.ac.ma

1. INTRODUCTION

In last years, blockchain technology has become an integral part of public discourse, where it's waiting to be integrated in various sectors such as cryptocurrencies, digital marketing, business practices, inter-organizational collaborations, and so on. As well as fifth generation (5G) cellular networks, the Internet of things (IoT), machine learning, blockchain technology is getting attention day by day, as its high scalability, its compatibility, and its technological readiness. It is a “shared, cryptographically unaltered distributed ledger” to record and maintain the digital transaction history [1], [2]. It stores and transmits transparent and secure information, and operates without a central controller. Due to the notable success of cryptocurrencies, especially, bitcoin, a wide range of practitioners and researchers have paid considerable importance of blockchain technology. In fact, blockchain can be an efficient technology thanks to its properties of immutability, decentralization, stability, and faster transaction [3], [4]. Divers’ sectors have been influenced by blockchain technology such as real-time IoT operating systems, managing secure medical
data, cryptocurrency transactions, food transparency and traceability, logistics monitoring, and supply chain sustainability, which is one of the foremost blockchain applications [5] because of global supply chain networks increasing its complexity.

Supply chain sustainability faces several significant strategic and competitive challenges related to the verification and confirmation that the supply chain processes and its products meet certain sustainability criteria and certifications [6]. Besides, industrial supply chain is in full transformation, so, control requirement in terms of transparency, quality, and traceability is increasingly important. Moreover, the lack of transparency harms the various actors in the supply chain. On the one hand for the consumer, if there is no means to verify the origins of the articles, on the other hand for the company which sometimes lacks vision on its supply chain. With its capability to improve supply chain security, transparency, durability, and process integrity [7], blockchain is proposed as a powerful technology that can deal with all these issues. Nevertheless, despite the large advantages offered by this emerging technology, its implementation is still in the Naïve stage [8], [9] in many industrial and service sectors. Morocco, like emerging countries, seeks to take advantage of the potential of the blockchain to meet its various growing demands, particularly in sustainable supply chain management (SSCM). This clarifies the necessity for more effort to understand the blockchain implementation mechanisms and identify the barriers that influence the decision to implement blockchain technology in SSCM from the point of view of Moroccan industry and service sectors.

Hence, the objective of this contribution is to develop a group decision making approach based on the intuitionistic fuzzy analytic hierarchy process (IFAH) to identify, evaluate and rank the different identified barriers based on their priorities depending on the appreciation of expert. These barriers are identified from an exhaustive literature search while incorporating expert assessments from industrial and academia.

In this direction, several contributions have been proposed to study blockchain technology and its ability to grant the durability of the supply chain system. For example, multicriteria decision support methods approach is applied in several studies such as [10]-[13]. Moreover, recent works [14]-[17] have focalized their studies on various applications of blockchain in logistics and supply chain systems. Since Moroccan sustainable supply chains (SCMs) and SSCMs are very complex and suffer from several weaknesses, and many negotiators are called for, there is a need to adopt an appropriate consolidation platform such as blockchain technology to overcome these limitations. Beforehand, the proposed works in the available literature have not investigated the barriers that prevent the application of blockchain technology in the context of Moroccan SSCMs. In this paper, contributions are proposed in this direction.

2. THE PROPOSED APPROACH

In this contribution, modeling the barriers influencing the implementation of blockchain technology in Moroccan SSCM context is analyzed. Our aim is to propose a collective decision-making approach based on the intuitionistic fuzzy analytic hierarchy process (FAHP) technic to assist decision makers in identifying, evaluating and ranking the barriers that affect the implementation of blockchain technology in SSCM from the Moroccan industry and service sectors perspective. The stepwise group decision-making approach for the evaluation of barriers impact on blockchain adoption in Moroccan SSCM is presented in Figure 1.

![Figure 1. Proposed collective decision-making approach](image)

*Blockchain adoption barriers in Moroccan sustainable supply chain: a proposed ... (Abdesadik Bendarag)*
3. METHOD AND APPLICATION

Intuitionistic fuzzy analytic hierarchy process (IFAHP) [18] is among the most used multi-criteria analysis methods to settle complicated problems where decision making is characterized by uncertainty and hesitation. Indeed, IFAHP which combines hesitancy, membership and a non-membership functions, has the advantage of modeling human’s perception and cognition more comprehensively, compared to the FAHP method. The details of IFAHP steps applied in this contribution to evaluate all identified barriers influencing the blockchain adoption are presented in the following (see also [18, [19]).

Step 1: In this step, a hierarchal decision-making structure is constructed to identify and investigate the problem as presented in Figure 2.

![Figure 2. The proposed structure of the problem](image)

In this paper, we have developed an online questionnaire to facilitate and simplify data collection. It is built on the basis of a set of barriers identified via an exhaustive documentary research, and validated by the views of industry and academic experts. The details of these identified barriers are presented in:

a. Technological and system (TB):
   - Absence of system scalability and speed (TB1) [9, 10, 20].
   - Availability of special blockchain tools (TB2) [21, 22].
   - The complication of designing blockchain based (TB3) [20, 23]).
   - Privacy and security issue (TB4) [21, 22, 24].

b. Environmental (EB):
   - Government policy and its encouragement (EB1) [10, 24, 25].
   - High durability costs [Energy uptake and exhaustion of materials] (EB2) [26, 27].
   - Defiance in combining sustainable practices and blockchain technology via SCM (EB3) [25, 28].

c. Intra-Organizational (OB):
   - SCM-Stakeholder Opposition to embracing blockchain culture (OB1) [1; Experts opinion].
   - Leadership encouragement and ability of human resources (OB2) [10].
   - Shortage of tiding organizational policies for the application of blockchain technology (OB3) [29, 30].

Step 2: The experts importance level is computed. Assume that \( D_k = [\mu_k, \nu_k, \pi_k] \) become an intuitionistic fuzzy (IF) number (IFN) to rate the \( k \)th decision-maker (DM) (see Table 1). The \( k \)th DMs weight can be computed using (1) as presented in Table 2.

\[
\lambda_k = \frac{\frac{\mu_k + \pi_k}{\mu_k + \pi_k + \nu_k}}{\sum_{k=1}^{n} \frac{\mu_k + \pi_k}{\mu_k + \pi_k + \nu_k}}
\]

Where \( \lambda_k \) represents the influence weight of each DM, and \( \sum_{k=1}^{n} \lambda_k = 1, \lambda_k \in [0,1] \).
Step 3: The barriers evaluation is performed via linguistic pairwise comparison matrices which are filled by \( k \) DMs taking into consideration the linguistic scale of Table 3 as defined by (2). In this context, the decision makers' judgments regarding the importance of each barrier are illustrated in Table 4 (here we focus our attention on the main barriers presented in Figure 2).

\[
R^{(k)} = (r_{ij}^{(k)})_{n \times n} = \begin{pmatrix}
\frac{1}{r_{11}^{(k)}} & \frac{1}{r_{12}^{(k)}} & \cdots & \frac{1}{r_{1n}^{(k)}} \\
\frac{1}{r_{21}^{(k)}} & \frac{1}{r_{22}^{(k)}} & \cdots & \frac{1}{r_{2n}^{(k)}} \\
\vdots & \vdots & \ddots & \vdots \\
\frac{1}{r_{n1}^{(k)}} & \frac{1}{r_{n2}^{(k)}} & \cdots & \frac{1}{r_{nn}^{(k)}}
\end{pmatrix}
\]

where \( r_{ij}^{(k)} = (\mu_{ij}^{(k)}, v_{ij}^{(k)}, \pi_{ij}^{(k)}) \)

Step 4: Considering all DMs opinions, the aggregated IF judgment matrix \( R^{(k)} = (r_{ij}^{(k)})_{n \times n} \) is built using IF weighted averaging suggested by [31]. The specification of the aggregated IF decision matrix is given using (3) and (4) as presented in Table 5 (this aggregated matrix is carried out by transforming the DMs judgment to IFN then using (3) and (4)).

\[
R = \begin{pmatrix}
r_{11} & r_{12} & \cdots & r_{1n} \\
r_{21} & r_{22} & \cdots & r_{2n} \\
\vdots & \vdots & \ddots & \vdots \\
r_{n1} & r_{n2} & \cdots & r_{nn}
\end{pmatrix}
\]
where:
\[
r_{ij} = IFWA_{t}(r_{ij}^{(1)}, r_{ij}^{(2)}, \ldots r_{ij}^{(t)})
= \lambda_1 r_{ij}^{(1)} \oplus \lambda_2 r_{ij}^{(2)} \oplus \cdots \lambda_t r_{ij}^{(t)}
= (\mu_{ij}, v_{ij}, \pi_{ij}),
\]
(4)
and,
\[
\mu_{ij} = 1 - \prod_{k=1}^{t-1} (1 - \mu_{ij}^{(k)})^{\lambda_k},
\quad v_{ij} = \prod_{k=1}^{t-1} (1 - v_{ij}^{(k)})^{\lambda_k},
\quad \pi_{ij} = \prod_{k=1}^{t-1} (1 - \mu_{ij}^{(k)})^{\lambda_k} - \prod_{k=1}^{t-1} (1 - v_{ij}^{(k)})^{\lambda_k},
\quad i, j \in N.
\]

Table 5. The aggregated intuitionist fuzzy judgment matrix

| Main Barriers | TB  | EB  | OB  |
|--------------|-----|-----|-----|
| \(r_{ij}\) matrix | \(\mu\) | \(v\) | \(\pi\) | \(\mu\) | \(v\) | \(\pi\) | \(\mu\) | \(v\) | \(\pi\) |
| TB | 0.5000 | 0.6000 | -0.1000 | 0.8300 | 0.8609 | -0.6909 | 0.8500 | 0.8874 | -0.7374 |
| EB | 0.1391 | 0.1700 | 0.6909 | 0.5000 | 0.6000 | -0.1000 | 0.7450 | 0.8089 | -0.5539 |
| OB | 0.1126 | 0.1500 | 0.7374 | 0.1911 | 0.2550 | 0.5539 | 0.5000 | 0.6000 | -0.1000 |

Step 5: Computing the criteria IF entropy weights and final entropy weight using (5) and (6) as presented in Table 6. An exemplification of main barriers weights is illustrated in Figure 3.

\[
H_j = -\frac{1}{\ln(2)} \sum_{i=1}^{n} \left[ \mu_{ij} \ln \mu_{ij} + v_{ij} \ln v_{ij} - (1 - \pi_{ij}) \ln (1 - \pi_{ij}) - \pi_{ij} \ln 2 \right]
\]
(5)

Then W can be obtained as shown in:

\[
W_j = \frac{1-H_j}{\sum_{i=1}^{n} H_j}
\]
(6)

Table 6. Main barriers intuitionistic fuzzy entropy weight and final entropy weight

| Intuitionistic fuzzy entropy weight | Final entropy weight |
|-----------------------------------|---------------------|
| H1 | 0.9958 | W1 | 0.3588 |
| H2 | 0.9955 | W2 | 0.3850 |
| H3 | 0.9970 | W3 | 0.2562 |

Step 6: By carrying out the same calculations of the IFAHP process presented in steps 3 to 5, we obtain the definitive results illustrated in Table 7 for all the sub-barriers. Each sub-barrier weight (local weight) is calculated by multiplying it by the main barrier weight (global weight) in the hierarchical structure [32].

Figure 3. Weight distribution for main barriers
The main aim of this contribution is to present a decision-making approach based on Intuitionistic Fuzzy AHP to collectively identify and evaluate the barriers influencing the blockchain adoption in Moroccan SSCM. To construct this approach, we took help from a comprehensive literature search and use of expert views on most significant barriers to blockchain adoption.

Concerning the IFAHP process, the obtained results frequently represent short-term decision-making strategies by distributing priorities to all identified barriers impacting the implementation of blockchain. Therefore, the main advantages of using the IFAHP method are to structure and assess the evidences of factors/barriers in a systematic and rational way and to give decision makers the opportunity to express evidence of support, objection and hesitation in a such situation of assessing barriers to blockchain adoption.

Thus, other research work dealing with the topic of barriers impacting the adoption of blockchain technology, as already explained in the introduction section, can be compared to our final results. As a perspective, we are working on a fuzzy group decision making framework combining IFAHP and Fuzzy DEMATEL to assist decision-makers in adopting flexible procedures of short and long-term decision-making approaches to conduct a sustainable SCM. This will help decision makers to address the different interactions and relationships amongst the investigated barriers.
Blockchain adoption barriers in Moroccan sustainable supply chain: a proposed … (Abdesadik Bendarag)

M. Hanine, O. Boutkhoum, T. Agouti, and A. Tikniouine, “A new integrated methodology using modified Delphi-fuzzy AHP-PROMETHEE for Geospatial Business Intelligence selection,” Information Systems and e-Business Management, vol. 15, no. 4, pp. 897–925, Nov. 2017, doi: 10.1007/s10257-016-0334-7.

BIOGRAPHIES OF AUTHORS

Abdesadik Bendarag holds a Ph.D. in corpuscular physics from the University Blaise Pascal Clermont Ferrand France. He has worked for two years as an ATER (Temporary teaching and research associate) in computer science at the University of Auvergne in the GTR and Computer Science departments. He is currently an assistant professor in the Mathematics and Computer Science Department at the Polydisciplinary Faculty of Safi, Caddi Ayyad University. He is a member of the L.M.C. Laboratory, Polydisciplinary Faculty of Safi UCAM, Safi, Morocco. He can be contacted at a.bendarag@uca.ac.ma.

Omar Boutkhoum is an Associate Professor at computer Science department in the Faculty of Sciences of Chouaib Doukkali University, EL Jadida, Morocco. He received his PhD degree in Computer Science from the Faculty of Sciences and Techniques of Caddi Ayyad University, Marrakesh in 2017. His research interests are in the application of decision support systems and Blockchain technology to sustainable supply chain management. He can be contacted at email: boutkhoum.o@ucd.ac.ma.

Driss Abada is an assistant professor at faculty of science, Chouaib Doukkali University, Morocco, since May 2019. He received Master's degree in Computer Science and Distributed Systems form faculty of science, Ibn Zohr University, Morocco, and Ph. D degree in Computer Science with specialization Networks. He is member of both lab, Information system and Computer Vision Lab, Department of Computer Science, Faculty of science, Ibn Zohr University, Morocco, and LAROSERI Lab, Department of Computer Science, Faculty of science, Chouaib Doukkali University, Morocco. His research interests are in wireless ad-hoc, Internet of things and 5G. Particularly, he works on wireless routing, routing protocols in Internet of things, inter-vehicular communications and security, Quality of service, and MAC layer performance evaluation. Recently, his researches are focused on clustering communication in heterogeneous wireless networks such as VANET and LTE (4G). He can be contacted at email: drissmisr@gmail.com.

Mohamed Hanine is an Associate Professor at the National School of Applied Sciences, University of Chouaib Doukkali, EL Jadida Morocco. He Holds a PhD degree in Computer Science with specialization in spatial decision making. His research areas are Big Data, Multicriteria Decision Making, and Business Intelligence. In 2017, he obtained the Ph.D. degree in computer science from the University of Cadi Ayyad, Marrakesh (Morocco). Then in 2018 he joined the Department of Telecommunications, Networks and Computer Science at the National School of Applied Sciences, teaching engineering students in the area of Big Data and Business Intelligence. He can be contacted at email: Hanine.m@ucd.ac.ma.