Critical Success Factors of Blockchain adoption in Green Supply Chain Management: Contribution through an Interpretive Structural Model

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ABSTRACT
The main purpose of this paper is to study the critical success factors (CSFs) of the blockchain technology (BCT) adoption in green supply chain management (GSCM) which might be literally a first attempt and also propose a conceptual framework of aGSCM model adopting the BCT, which will be promoting the combination of these two areas in the future. A critical literature review of the BCT, GSCM, and BCT-based GSCM was conducted to identify the most relevant factors of BCT adoption, followed by the model formulation with the help of interpretive structural modelling (ISM) consisting of CSFs and relationships between those based on experts’ views. The overall results emphasized that “recording and trading-related factors may contribute to the BCT adoption, while others like smart contract must be enhanced. This study supports previous conceptual work on BCT and GSCM and could serve as a starting point to assist in decision-making.

1. Introduction
The use of block chain technology (BCT), which was introduced first in 2008, is growing rapidly in various sectors (Narayanan et al., 2016). Underwood (Underwood, 2016) classified BCT into two groups: public or private. In private BCT, participants are members in a closed group, whereas in public BCT, anyone can participate like Bitcoin. Nowadays, most of the sectors intend to adopt BCT into their activities due to the various benefits of this technology. Illustratively, across the industries, stakeholders will be able to monitor their data and the data provided by a trusted third-party organization with full confidence with the help of BCT (Liu et al., 2020). BCT particularly provides various advantages for the supply chains: information auditability, transparency, verifiability, and the supply chain members’ actions awareness (Iansiti & Lakhani, 2018). The scope of the supply chain will expand as it provides better tracking of smart products at the
customer location after the purchase with further customized experiences (Sanders & Ganeshan, 2018). The adoption of BCT in the supply chain can be thought as a private blockchain, where the participants seek to predetermine the members and thereby work in a regulatory environment through controlling the information access (Christidis & Devetsikiotis, 2016). Furthermore, the successful BCT adoption in the supply chain involves understanding the impact of the supply chain network on professional behavior within and across companies (Queiroz & Wamba, 2019), although adding the environmental component will further complicate the adoption of this technology in supply chain management with increased number and type of stakeholders. Additionally, the tracking of environmental conditions is one of the main concerns in green supply chain management (GSCM), which might represent a key area of BCT application (Adams et al., 2018). Some studies have tried to integrate the BCT in the green supply chain by considering only practices that could be relevant for its adoption. Recently, an implementation of BCT is reported in a GSCM case study using the life cycle assessment to evaluate the environmental impacts of a product/service (Zhang et al., 2020). Another example of BCT integration is where the BCT has been used in information management to facilitate on time delivery in the domain of construction supply chains (Wang et al., 2020). On the other hand, in the agriculture industry, the adoption of BCT focused primarily on ‘Agri-food traceability, information security, food production, and Agri-food trade’, etc. (Liu et al., 2020), which may be considered as a lack of its adoption towards the GSCM regarding the need to adapt the BCT to green practices. Nevertheless, according to Sternberg et al (Sternberg et al., 2020), there is other previous conceptual works that point to a paradox and various conflicts between the positive and negative determinants of BCT adoption that need to overcome in an inter-organizational framework. In summary, only a few studies have been conducted on BCT adoption in the GSCM, which leads to numerous research works to be carried out in the future.

The main contribution of this paper is to identify and prioritize the factors that can potentially influence the integration of the BCT with GSCM and determine the nature of their influence (negative/positive) using the ISM from existing literature and practicing experts. This paper focuses on the study of the relationship between BCT and GSCM, especially the identification of the critical success factors (CSFs) of BCT adoption in GSCM, to do so a critical literature review is first presented as an overview of the main concepts of the paper. Later, a hierarchical relationship model was established using interpretive structural modelling (ISM) on the identified 10 CSFs based on the literature and expert opinions. We established that the following five factors need more attention: smart contract, trust and reliability, tokenization, green practices, and collaborative logistics, whereas ‘recording and trading’ could pave the way towards the BCT adoption in GSCM.

The rest of the paper is organized as follows. Section 2 presents a critical literature review of as the background. The research methodology, method description, and model formulation are addressed in section 3. Section 4 is dedicated to the results and discussion; finally, in section 5, we conclude with theoretical contributions, limitations, and future research.
2. Background

2.1. Blockchain technology (BCT)

Competitiveness is a key factor for resilience in the international business market. Firms today are driven to understand their customers using various emerging variables (economic, social, etc.), particularly by adopting the new technologies including the BCT. BCT has become potentially a very useful application in different fields and especially suitable for processing valuable information (Davidson et al., 2016). The BCT was created based on four innovative technologies: cryptographic algorithms, peer-to-peer networks, distributed data storage, and decentralized consensus mechanisms (Wright & De Filippi, 2015).

A blockchain is ‘a concatenation of data, which are aggregated to single blocks and stored on all users’ computers. These data blocks create a sequence that maps the transactions flow as a chain and protects these data against further modification by using methods such as cryptography, an uninterrupted chain of related data blocks is constituted’ (Tönnissen & Teuteberg, 2020). Briefly, Pazaitis et al. (Pazaitis et al., 2017) define BCT as an open distributed ledger, which attributes responsibility, allows information sharing and transparency. The BCT is seen as a promising avenue for establishing integration over internet and can be regarded as a multi-dimensional integration model implemented in the public cloud to perform secure transactions swiftly (security enhancement) and cost-effectively (Korpela et al., 2017). Furthermore, Liu and Li (Liu & Li, 2020) claimed that BCT is particularly adapted to the unreliable and constantly fluctuating environments and regulations. Helo and Hao (Helo & Hao, 2019) limited the area of BCT application to only four main areas: ‘financial, healthcare, government, and retail and manufacturing’. According to Moulouki et al. (Moulouki et al., 2020), BCT applications in healthcare are categorized into ‘supply chain management, patient data management, clinical trials, data security, drug traceability, claims adjudication, billing and others’. For the government, BCT’s applications can be used to facilitate the regulation of logistics (Tan et al., 2020). One must bear in mind that BCT was applied first to the financial application Bitcoin (Tan et al., 2020) and may also facilitate payment transactions for banks (Korpela et al., 2017) eventually. In cryptography, Haber Storentta (Haber et al., 1992) demonstrated the security of the blockchain concept in the early 1990s. Then, the BCT was used as a crypto currency called the Bitcoin (Nakamoto, 2008), in order to introduce the concept of a pair to pair transaction with a third party (Yadav and Singh, 2020b). In manufacturing field, Westerkamp et al. (Westerkamp et al., 2020) proposed a system that provides traceability of manufactured products inclusive of their components using smart contracts. Nevertheless, Helo and Hao (Helo & Hao, 2019) suggested three categories for BCT application: assets, identity and transactions. An asset (tangible and intangible) includes machinery, ownership, intellectual property, and traceability that could be managed by the use of IoTs as a smart product (Francisco & Swanson, 2018); (Helo & Hao, 2019). Identity is non-financial applications that covers materials, people, machines, and distributors. However, in BCT, the payments are made based on a dynamic smart contract (Crosby et al., 2016); (Helo & Hao, 2019), and it also helps in identity (digital) management and finally for transactions. The BCT provides centralized and distributed transaction ledger to control
order chain, inventory, finance, and service (Helo & Hao, 2019); whereas, IoT refers to a connected network of physical devices, either an equipped item with electronics and software that allows exchange and collection of data (Ivanov et al., 2019).

According to the findings of Frizzo-Barker et al. (Frizzo-Barker et al., 2020) in BCT literature review carried out from 2014 to 2018 articles, BCT is still at an early-stage of theoretical, empirical, and methodological background. Otherwise, implementation of blockchain-based information systems implies gaining practical and theoretical value, which may lead to a growing interest in research (Pournader et al., 2019). On the other hand, concerning the rapid evolution of BCT in finance, firms recognize their lack of knowledge about BCT, because of its infancy, as well as the non-availability of application and case studies in the literature that outline the advantages of the BCT (Longo et al., 2019). Moreover, the BCT should be expanded to a profitable juncture by examining the strengths and weaknesses of the technology and the development of its potential in various fields of application (Schmidt & Wagner, 2019).

2.2. Supply chain versus blockchain

The involvement of new information-sharing technology might be an opportunity to significantly improve the supply chain performance. The BCT offers users the possibility to add value and check data due to a complete authentication mechanism (Shoaib et al., 2020) and may be helpful for the management of fluctuating demands and reduction of sales (Yoon et al., 2020). Otherwise, ‘blockchain is a new vision in the supply chain field, whereby the main challenges are the transparency and the visibility of product flows’ (Azzi et al., 2019). According to Kshetri (Kshetri, 2018), since BCT is safer with transparency and good traceability, the supply chain managers are required to adapt their operations to the BCT. Moreover, in the matters of trust and collaboration in the supply chain, Longo et al. (Longo et al., 2019) claimed that BCT is appropriate and considered as an effective tool to address these issues; thus, they encourage researchers to address and invest in the benefits and BCT applications, to persuade the supply chain managers adopting this technology, especially in an environment of mutual trust. Helo and Hao (Helo & Hao, 2019) highlighted the benefit of adopting BCT in the supply chain management, by addressing the benefit of each BCT key concept (tamper-proof transaction records, information sharing & synchronization, and smart contract execution) according to the corresponding supply chain indicators (improve overall quality, reduce cost, shorten delivery time, reduce risk, and increase trust). However, some BCT elements may constitute as barriers towards its integration in the GSCM; hence, the elimination of these barriers can therefore be hugely beneficial for GSCM. It is noticed that in most studied cases, the BCT is used to secure data-sharing, illustratively, Thakur and Breslin (Thakur & Breslin, 2020) used the BCT in multi-party perishable good supply chains, to secure data-sharing platform of product serialization, while Dwivedi et al. (Dwivedi et al., 2020) dealt with BCT in pharmaceutical supply chain systems by proposing a system for secure information sharing using smart contracts and consensus mechanisms.
2.3. **Green supply chain management-based blockchain**

Different factors have contributed in promoting the GSCM in terms of supply chain stakeholder, supply chain environment, and particularly the relationship among the supply chain members that may affect the global performance of the supply chain. The appearance of the BCT has upset the opinions between the protectors of the environment and the technology proponents, making the search for a compromise between two notions: scientific and managerial necessity of prime importance. There are many drivers (external or internal) which can influence the establishment of the GSCM and which contribute to the variation of its overall performance. These aforementioned drivers could be of an economic, social, environmental, and technological nature such as the BCT advent. According to Yli-huumo et al. (Yli-Huumo et al., 2016), 80% of BCT research is focused exclusively on Bitcoins, confirming the idea that BCT is yet to be adopted, especially in research related to the GSCM. Kouhizadeh and Sarkis (Kouhizadeh & Sarkis, 2020) reported that green issues are of mutual concerns for both members of the supply chain: operations team and all the stakeholders. Nevertheless, BCT can be a key solution in supply chain management with respect to speed, quality, cost, dependability, risk reduction, sustainability, and flexibility (Kshetri, 2018). In addition, the BCT also is among the innovative technologies that promote the sustainable supply chain (Kshetri, 2018); (Queiroz & Wamba, 2019); (Rajput and Singh, 2019a). Particularly, in the environmental dimension, this technology would help improving the area of GSCM by developing new applications that would manage and optimize the environmental factors and issues, like reducing carbon emission in transportation and production (Abl et al., 2018), improving the reverse logistics (Futurethinkers, 2017), tracking hazardous waste management (Chandan et al., 2019), and tracking pollution data (Giannakis & Papadopoulos, 2016). Moreover, Tan et al. (Tan et al., 2020) proposed some key applications of the BCT in GSCM, such as the vehicle routing application, which ‘is optimally designed to find routes for various vehicles to reach a set of buyers’, logistic traceability, energy-saving management, and collaborative logistics. All these applications would help in reducing energy consumption, carbon emission, and improving sustainability performance. Also Yadav, S. and Singh, S. P (Yadav and Singh, 2020a) dealt with a study attempt for the use of BCT to develop sustainable SCM. Most of the studies dealing with this topic tend to present the BCT as a new technology that implicitly depicts some barriers and opportunities beyond its integration in the supply chain; hence, the important contribution of this study is addressing this topic in a relevant manner based on a recognized tool for prioritizing factors. According to Dutta, P. et al. (Dutta et al., 2020), the BCT can help create sustainable and green CS through the following set of activities:

- **Vendor selection and supplier development (by tracking the sustainability performance history of suppliers)**
- **Materials management and inbound logistics (by enabling traceability of the sustainability values in the history of product and materials)**
- **Production and internal operations (by managing the required certifications, transforming operation into ecofriendly and the evaluation of the sustainability performance)**
• Outbound logistics and marketing (by evaluating the sustainability performance of transportation in outbound logistics and improving the green marketing)
• Reverse logistics (through supporting the location of the materials traceability)

Accordingly, it appears that the BCT has both benefits and drawbacks towards the GSCM, which will be addressed in the next section by using the ISM methodology as a contribution to the existing literature in this context. Furthermore, it is assumed that several key factors influence the integration of the BCT in the GSCM, i.e. green practices including all the possible green practices (improving the reverse logistics, reduction of carbon emission in transportation, tracking hazardous waste management, and tracking pollution data) that could be managed and optimized by developing new applications of BCT, collaborative logistics, organizational management (Top management), knowledge, tokenization, trust and reliability, smart contracts, transparency, traceability, recording, and trading.

In summary, Figure 1 presents a proposed conceptual framework of the GSCM model by adopting BCT. It is a preliminary model for the integration of the BCT in GSCM that summarizes the actors and parameters to be considered assuming a simple and typical model of GSCM, and based on the literature review above, notably inspired by models presented by Chang et al. (Chang et al., 2019) and Liu and Li (Liu & Li, 2020). The proposed model shows the added value of BCT, through integrating a third-party block, which could be devoted to the government, NGO, etc. The aforementioned third party will manage data related to environmental regulation and environmental report of each peer. In particular, the importance of intermediation in terms of verification and transaction of asset ownership processing (Nofer et al., 2017) may be exceeded due to the peer-to-peer feature offered by the BCT and its distributed data management (Tönnissen & Teuteberg, 2020). Additionally, the need to improve the transparency and traceability of the supply chain, referring back to the establishment of a policy focused on the transparency of the chain, secure data storage, and accurate data collection (Azzi et al., 2019). The BCT adoption will provide safe transaction and smart execution, which is achieved through intelligent contracts by including a user-defined program that can perform quality control

![Figure 1. Model of green supply chain adopting BCT.](image-url)
in real-time (Helo & Hao, 2019), starting with verification of received block from one party to another, followed by the approval, and then the insertion of the block in the chain, and finally the link of this block to the others blocks. During all these steps, all blocks are informed and aware of each transaction, particularly the third party block, which will ensure compliance with environmental practices and regulations.

3. Research methodology

3.1. Material and methods

This paper aimed to develop a general framework of BCT adoption in GSCM, using the ISM approach. The preference for ISM methodology is due to its advantage in analyzing/evaluating relationships between the identified criteria and providing a hierarchical presentation of a complex system (Janssen et al., 2018); in addition, it is applicable and exhaustively used in this field of application. This paper focuses on the latest research in this rapidly evolving and growing field, but only few research works have been conducted. Therefore, the results presented in this paper will help managers and academician incorporating the most relevant elements for the GSCM while adopting the BCT. First, a background study was carried out to identify and define the key elements as well as the applicability of ISM approach. Relevant contributions from journals, books, and conferences were analyzed from 2007 to 2020 (Table 1), using the following search engines: Sciedirect (Elsevier), Taylor & Francis group, Springer Link, Web of Science (ISI), Scopus, and Google scholar. Search for the keywords ‘Blockchain’, ‘Green supply chain’ and ‘Supply chain management’, ‘Green supply chain management’, ‘ISM methodology’ was selected from abstracts, keywords, and titles. In ISM approach, first, the data were collected from literature review by identifying and organizing 20 factors (Table 2), and these factors identified in the literature are implicitly disclosed and are not well exploited in these two study areas of BCT and GSCM. Based on the experts’ views of these 20 factors, ten CSFs were identified and organized to facilitate the model set. The selection of the these factors is made by taking into account the dependence of some factors on others by combining two or three factors into one factor while emphasizing the environmental dimension for both concepts (BCT and supply chain). The identified ten CSFs of the BCT adoption in the GSCM are described in Table 3. The next paragraph briefly describes the ISM approach and its implementation, additionally, the research methodology is summarized in Figure 2.

3.2. The ISM methodology

The ISM is an approach that helps to study the interrelationship between a set of different and directly related elements in the form of a comprehensive systematic model (Raut et al., 2017). The ISM approach provides a simple and understandable presentation of a complex system in many domains (Dhochak & Sharma, 2016); (Janssen et al., 2018), in addition, ‘it is a known technique used in solving industrial decision-making problems’ (Diabat et al., 2014). The ISM methodology is chosen because it generates a well-defined and visible hierarchical model by transforming less articulated models, specifying their complex relationship, and the generated model can be utilized in different applications
Table 1. Literature classification.

| Journals                                                      | No. of articles | Years                  | ISM | Blockchain | GSC/SC | Blockchain+GSC/SC |
|---------------------------------------------------------------|-----------------|------------------------|-----|------------|--------|------------------|
| Resources, Conservation and Recycling                        | 6               | 2009–2011-2018-2020    |     |            |        |                  |
| International Journal of Information Management              | 5               | 2018–2019-2020         |     |            |        |                  |
| International Journal of Production Research                  | 4               | 2018–2019-2020         |     |            |        |                  |
| Computers & Industrial Engineering                            | 3               | 2019                   |     |            |        |                  |
| Production and Operations Management                          | 3               | 2018–2019              |     |            |        |                  |
| Journal of Cleaner Production                                 | 3               | 2014–2015-2020         |     |            |        |                  |
| Sustainability                                                | 2               | 2020                   |     |            |        |                  |
| Journal of Information Security and Applications              | 2               | 2016–2020              |     |            |        |                  |
| Procedia Computer Science                                     | 1               | 2020                   |     |            |        |                  |
| Industrial Management & Data Systems                          | 1               | 2020                   |     |            |        |                  |
| Robotics and Computer-Integrated Manufacturing                | 1               | 2020                   |     |            |        |                  |
| Internet of Things                                           | 1               | 2020                   |     |            |        |                  |
| Supply Chain Manag.: An International Journal                 | 1               | 2018                   |     |            |        |                  |
| Digital Communications and Networks                           | 1               | 2020                   |     |            |        |                  |
| PLOS ONE                                                      | 1               | 2016                   |     |            |        |                  |
| IGI Global                                                    | 1               | 2020                   |     |            |        |                  |
| Journal of Business Logistics                                 | 1               | 2020                   |     |            |        |                  |
| International Journal of Management Reviews,                  | 1               | 2007                   |     |            |        |                  |
| Journal of Information Processing Systems                     | 1               | 2017                   |     |            |        |                  |
| Journal of Purchasing and Supply Management                   | 1               | 2019                   |     |            |        |                  |
| International Journal of Productivity and Performance Management | 1             | 2009                   |     |            |        |                  |
| Renewable and Sustainable Energy Reviews                      | 1               | 2017                   |     |            |        |                  |
| Journal of Supply Chain Management,                           | 1               | 2015                   |     |            |        |                  |
| Technological Forecasting & Social Change                     | 1               | 2017                   |     |            |        |                  |
| Business & Information Systems                                | 1               | 2017                   |     |            |        |                  |
| International Journal of Business, Excellence                 | 1               | 2018                   |     |            |        |                  |
| Public Management Review                                      | 1               | 2018                   |     |            |        |                  |
| Industrial Marketing Management                               | 1               | 2012                   |     |            |        |                  |
| Logistics                                                     | 1               | 2018                   |     |            |        |                  |
| Journal of Foodservice Business Research                      | 1               | 2016                   |     |            |        |                  |
| Decision                                                      | 1               | 2016                   |     |            |        |                  |
| Applied Innovation Review                                     | 1               | 2016                   |     |            |        |                  |
| IEEE Access                                                   | 1               | 2016                   |     |            |        |                  |
| International Journal of Research in Engineering and Technology, | 1           | 2016                   |     |            |        |                  |

(Continued)
Table 1. (Continued).

| Journals                                                      | No. of articles | Years | ISM | Blockchain | GSC/SC | Blockchain+GSC/SC |
|---------------------------------------------------------------|----------------|-------|-----|------------|--------|------------------|
| Transportation Research Part E: Logistics and Transportation Review | 1              | 2020  |     |            |        |                  |
| Journal of Enterprise Information Management                  | 1              | 2020  |     |            |        |                  |
| International Journal of Operations and Production Management  | 1              | 1994  |     |            |        |                  |
| Benchmarking                                                  | 1              | 2019  |     |            |        |                  |
Table 2. Selected CSFs.

| ID No | GSC   | Blockchain | Related area                      | CSF based on literature | Average rating | References                                                                 | Selected CSF based on experts overview |
|-------|-------|------------|------------------------------------|------------------------|----------------|-----------------------------------------------------------------------------|----------------------------------------|
| 01    | GSC   | Blockchain | Recording                         | Recording              | 6              | (Maersk, 2020), (Srivastava, 2007), (Agyemang et al., 2018) (Kshetri, 2018) | Recording, Tracking, and Trading       |
| 02    | GSC   | Blockchain | Tracking                           | Recording, Tracking    | 5              |                                                                           |                                        |
| 03    | GSC   | Blockchain | Information sharing                | Information sharing    | 3.5            |                                                                           |                                        |
| 04    | GSC   | Blockchain | Data manipulation                 | Data manipulation      | 2.5            | (Dwivedi et al., 2020)                                                    |                                        |
| 05    | GSC   | Blockchain | Traceability                       | Traceability           | 7.5            | (Ramachandran & Kantarcio glu, 2018), (Hastig & Sodhi, 2019),              | Traceability                           |
|       |       |            |                                    |                        |                | (Sund et al., 2020), (Kshetri, 2018), (Esmaeilian et al., 2020).           |                                        |
| 06    | GSC   | Blockchain | Tokenization                       | Tokenization           | 7              | (Treiblmaier, 2018)                                                       |                                        |
| 07    | GSC   | Blockchain | Cryptocurrency                     | Cryptocurrency         | 3              | (Kouhizadeh & Sarkis, 2020).                                              |                                        |
| 08    | GSC   | Blockchain | Network theory                     | Network theory         | 4              | (Rauer & Kaufmann, 2015)                                                   |                                        |
| 09    | GSC   | Blockchain | Collaborative logistics            | Collaborative logistics| 5.5            | (Tan et al., 2020);                                                       | Collaborative logistics                 |
| 10    | GSC   | Blockchain | Transparency                       | Transparency           | 6.5            | (Sharma et al., 2017), (Hyperledger, 2020), (Hoejmos e et al., 2012)      | Transparency                           |
|       |       |            |                                    |                        |                | (Sarkis & Dou, 2017), (Fosso Wamba et al., 2020).                         |                                        |
| 11    | GSC   | Blockchain | Organizational management          | Organizational management| 7              | (Hyperledger, 2020), (Hoejmos e et al., 2012)                              |                                        |
| 12    | GSC   | Blockchain | Reliability                        | Reliability            | 6              | (Sarkis & Dou, 2017), (Fosso Wamba et al., 2020).                         | Trust and Reliability                  |
| 13    | GSC   | Blockchain | Trust                              | Trust                  | 6.5            |                                                                           |                                        |
| 14    | GSC   | Blockchain | Knowledge                          | Knowledge              | 8              | (Ramachandran & Kantarcio glu, 2018), (Swan, 2015).                       | Knowledge                              |
| 15    | GSC   | Blockchain | Smart contract                     | Smart contract         | 7              | (Mao et al., 2018), (Esmaeilian et al., 2020).                            | Smart Contract                         |
| 16    | GSC   | Blockchain | Reverse logistics                  | Reverse logistics      | 7              | (Elhidaoui et al., 2020),                                                 | Green practices                        |
| 17    | GSC   | Blockchain | Environmental standard             | Environmental standard | 5.5            | [82],                                                                     |                                        |
| 18    | GSC   | Blockchain | Environmental performance          | Environmental performance| 6              | (Tan et al., 2020)                                                       |                                        |
| 19    | GSC   | Blockchain | Product life cycle assessment      | Product life cycle assessment | 7              |                                                                           |                                        |
| 20    | GSC   | Blockchain | Energy saving management           | Energy saving management| 6.5            |                                                                           |                                        |
| S. No. | CSFs                                      | Description                                                                                                                                                                                                 | References                                                                 | Pathways | Barriers |
|-------|-------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------|----------|----------|
| 1     | Recording, tracking, and trading          | To track a product it is important to track energy flows and material from retrieve of raw material to disposal at its end of life, whereas, tracking sustainability is basically carried out in reports and documents, exposure to fraud and error is therefore possible. Hence, this key concept of BCT represents a pathway towards its adoption within the GSCM. Also trading activities provide more efficiency to the supply chain. |
|       |                                           |                                                                                          | Vorabutra (2016), Srivastava (2007), Kshetri (2018).                        |          |          |
| 2     | Traceability                              | The difficulty of measuring the Environmental performance based on supply chain members could present an obstacle of traceability, which is one of BCT key concepts; moreover, traceability is tackled in previous studies with a particular emphasis on traceability of food and agriculture-related products. | Agyemang et al. (2018), Ramachandran and Kantarcigolu (2018), Hastig and Sodhi (2019), Sund et al. (2020).  |          |          |
| 3     | Transparency                              | Transparency in GSCM may represent a structural barrier, notably within supplier relationships while the BCT provides transparency as a pathway toward its adoption to GSC. | Rauer and Kaufmann (2015), Crosby et al. (2016), Sharma et al. (2017), Sodhi and Tang (2019). |          |          |
| 4     | Smart contracts                           | In the framework of BCT, smart contracts are digital agreements that contain predefined rules aiming to systematically deal and apply a contract between two parties, also developed to save as few data as necessary. | Swan (2015), Sund et al. (2020). |          |          |
| 5     | Trust and Reliability                     | Trust between supply chain members has been considered as a lack toward greening the supply chain. The BCT has the possibility of verifying certifications of products, including those of quality or sustainability. | Hojemose et al. (2012), Sarkis and Dou (2017). |          |          |
| 6     | Tokenization                              | Tokenization is one of the cryptocurrency applications of BCT, this application is very suitable for the governance of BCT in supply chain networks, and furthermore, it can potentially enhance the green supply chain management, by promoting consumer green behavior. | Esmaeilian et al. (2020), Kouhizadeh and Sarkis (2020). |          |          |
| 7     | Knowledge                                 | Knowledge is one of the key successes in the GSCM as an example, the knowledge of consumers about the environmental sustainability of products while the integration of BCT requires a set of knowledge among all the supply chain members, which may thus constitute a barrier to its adoption. | Agyemang et al. (2018), Fooso Wamba et al. (2020). |          |          |
| 8     | Organizational management                 | The BCT has potential capacities that may transform the management of the global supply chain in future, exclusively the GSCM.                                                                                   | Abeyratne and Monfared (2016), Hyperledger (2020). |          |          |
|       | Top management commitment                 |                                                                                                                                                                                                             |          |          |
| 9     | Green practices                           | Developing news applications in BCT may be useful for managing the environmental sustainability, like an application that allows tracking environmental sustainability, or managing the energy saving. | Mao et al. (2018), Elidaoui et al. (2020), Tan et al. (2020). |          |          |
| 10    | Collaborative logistics                   | In the process of logistic, the main purpose of stakeholders is to increase profitability and decreasing costs; additionally, the real time data sharing in BCT allows theme aligning planning and scheduling with real-world situations. | Tan et al. (2020). |          |          |
(Mandal & Deshmukh, 1994)(Rajput and Singh, 2019b). Based on the literature (Kannan et al., 2009); (Sagheer et al., 2009); (Ravi, 2015); (Faisal & Talib, 2016); (Narkhede & Gardas, 2018); (Cholewa et al., 2017), a brief description of the ISM steps is presented below:

Step 1: Determination of factors of the system under consideration;

Step 2: Establishment of the interrelationship between relevant factors based on the previous step;

Step 3: Development of the structural self-interaction matrix (SSIM) for relevant factors, as an illustration of the pairwise matrix between factors and system;

Step 4: SSIM transformation into an initial reachability matrix (IRM), in addition to the transitivity checking (which indicates that if a factor/variable ‘X’ influences ‘Y,’ and ‘Y’ influences ‘Z,’ then ‘X’ can influence ‘Z’);

Step 5: Transformation of the initial reachability matrix (IRM) to a final reachability matrix (FRM);

Step 6: Partition of the FRM into different levels;

Step 7: Diagram of a directed graph and removal of the links of transitivity;

Table 4. Structural-Self Interaction Matrix (SSIM).

| S.N | CSF’s                                           | Abbreviation | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 |
|-----|-------------------------------------------------|--------------|----|---|---|---|---|---|---|---|---|
| 1   | Recording, Tracking and Trading                 | C1           | V  | V | V | A | X | V | X | V | V |
| 2   | Traceability                                    | C2           | V  | V | X | A | A | A | A | X |
| 3   | Transparency                                    | C3           | V  | V | X | X | A | X | X |
| 4   | Smart contracts                                 | C4           | V  | X | V | A | X | V |
| 5   | Trust & Reliability                             | C5           | V  | V | X | V | X |
| 6   | Tokenization                                    | C6           | V  | V | V | X |
| 7   | Knowledge                                       | C7           | V  | V | X |
| 8   | Organizational Management (Top Management)      | C8           | V  | V |
| 9   | Green practices                                 | C9           | X  |   |
| 10  | Collaborative logistics                         | C10          | -  |   |   |   |   |   |   |   |   |
**Step 8:** Digraph conversion by substituting nodes with a statement of factors.

Given the nature of studied topic in terms of novelty and the aim of studying the relationship among two relevant concepts, namely, the GSCM and the BCT, the ISM is chosen as a suitable modeling technique that allows analyzing the influence between each variable (the CSFs) (Raut et al., 2017), as it provides a comprehensive system interpretation under consideration.

### 3.3. ISM model development

Based on the outcomes of the expert team using a questionnaire of the 20 factors deduced from the literature (Iansiti & Lakhani, 2018); (Kshetri, 2018); (Longo et al., 2019); (Kouhizadeh & Sarkis, 2020); (Liu et al., 2020), this questionnaire contains questions in order to give a score using Likert scale (1–8) for each option of adoption (Option1: Strong (7–8), Option2: Moderate (5–6), Option3: Weak (3–4), Option4: Not Considered (1–2)). Ten CSFs are factorized for BCT adoption in GSCM, which gained more than 4.5 ratings (average) for this study. These CSFs gather parameters that can be considered as basic barriers for GSCM, but as pathways and characteristics of the BCT adoption, and vice versa, the selected factors are interrelated, for example, the lack of knowledge and transparency may affect the lack of traceability. It bears noting that experts are from Morocco and India selected from diverse industry (Agri-food, automotive, healthcare, etc.) and academic area based on their experience and qualifications. With a minimum experience of 6 years, three supply chain managers, three project managers, four professors from the industrial and logistics department who have completed BCT training, and four experts of BCT are considered. Having approached all these experts, by sending e-mails and through professional meetings, they showed a strong motivation to contribute to such research work. The brainstorming technique is used to fill the contextual relationship between factors, by answering with ‘yes’ or ‘no’ to associate two factors. The selected CSFs of the BCT adoption in GSCM are described in Table 3, by designating whether the CSF provides pathways or barriers or both based on experts’ overviews.

#### 3.3.1. Structural-self interaction matrix (SSIM)

All the 14 experts were contacted and asked to complete the SSIM table individually. After receiving the responses, collective session was organized to remove the ambiguity on completed relationships. Based on the final consensus based on majority (>70%), the contextual relationship between the 10 CSFs was finalized and shown as the structural self-interaction matrix (SSIM) (Table 4). The relationship of influence between two CSFs (i and j) is denoted using symbols as follows:

- **V:** CSF i influences CSF j,
- **A:** CSF j influences CSF i,
- **X:** CSFs i and j will influence each other,
- **O:** CSFs i and j neither influences each other.

#### 3.3.2. The initial reachability matrix (IRM)

The SSIM is initially converted to an initial reachability matrix (IRM) as a binary matrix (Table 5), and using the following rules by transforming the SSIM values into binary digits:
\[(i, j) = 0: \text{if the entry in the SSIM is A or O;}
(i, j) = 1: \text{if the entry in the SSIM is V or X;}
(j, i) = 0: \text{if the entry in the SSIM is V or O;}
(j, i) = 1: \text{if the entry in the SSIM is A or X.}\]

### 3.3.3. Final reachability matrix for the CSFs

The final reachability matrix is formulated in *Table 6* by applying the transitivity rules on the initial reachability matrix.

**Table 6. The Final Reachability Matrix (FRM).**

| S.N | CSFs | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | Driving |
|-----|------|----|----|----|----|----|----|----|----|----|----|---------|
| 1   | C1   | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 10      |
| 2   | C2   | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 0       |
| 3   | C3   | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 10      |
| 4   | C4   | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 10      |
| 5   | C5   | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 10      |
| 6   | C6   | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 10      |
| 7   | C7   | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 10      |
| 8   | C8   | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 10      |
| 9   | C9   | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 10      |
| 10  | C10  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 5       |
|     |      | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 9  | 9  | 8  | 94/94   |

### Table 7. Level partitions of CSFs.

| Factors | Reachability set | Antecedent set | Intersection set | Level |
|---------|------------------|----------------|------------------|-------|
| C1      | 1                | 1              | 1                | I     |
| C2      | 2,3,7,8          | 1,2,3,7,8      | 2,3,7,8          | II    |
| C3      | 1,2,3,7,8        | 1,2,3,7,8      | 1,2,3,7,8        | II    |
| C4      | 1,2,3,4,5,6,7,8,9,10 | 1,2,3,4,5,6,7,8,9,10 | 1,2,3,4,5,6,7,8,9,10 | III   |
| C5      | 1,2,3,4,5,6,7,8,9,10 | 1,2,3,4,5,6,7,8,9,10 | 1,2,3,4,5,6,7,8,9,10 | III   |
| C6      | 1,2,3,4,5,6,7,8,9,10 | 1,2,3,4,5,6,7,8,9,10 | 1,2,3,4,5,6,7,8,9,10 | III   |
| C7      | 1,2,3,7,8        | 1,2,3,7,8      | 1,2,3,7,8        | II    |
| C8      | 1,2,3,7,8        | 1,2,3,7,8      | 1,2,3,7,8        | II    |
| C9      | 1,2,3,4,5,6,7,8,9,10 | 1,2,3,4,5,6,7,8,9,10 | 1,2,3,4,5,6,7,8,9,10 | III   |
| C10     | 4,5,6,9,10       | 1,2,3,4,5,6,7,8,9,10 | 4,5,6,9,10       | III   |
3.3.4. **Level partition**

Table 7 presents the antecedent set, intersection set, and the corresponding levels of each reachability set derived from the FRM. Three levels are found in this study, besides the CSF’s (C1) of recording, tracking, and trading, which hold level I implying that this CSF would be at the top of the ISM model. The set of levels will be used in constructing the digraph and the ISM model.

3.3.5. **ISM model formation**

The ISM digraph is formulated from the FRM and the given levels (Figure 3). Subsequently, after deleting the transitivity, this digraph is converted into the final ISM model by exchanging the node numbers with CSFs values (Figure 4).

3.3.6. **MICMAC analysis**

The 'Matrice d’Impacts Croisés Multiplication Appliqués à un Classement’ (MICMAC) is an approach used for analyzing the influence between factors based on driving power and dependency calculated in Table 6. The purpose of carrying out this approach is to analyze and identify the relevant CSFs of the BCT adoption in GSCM. To this end, the final reachability matrix is explored by calculating the driving power and dependency of each CSFs and then classify them into four clusters (Kannan et al., 2009); (Diabat et al., 2014) as indicated below:

![Figure 3. Hierarchical structure based on ISM.](image1)

![Figure 4. ISM model.](image2)
**Autonomous**: CSFs in this cluster have a weak driving power and dependency both as well as their disconnection from the system.

**Dependent**: CSFs have low influential power and strong dependency.

**Linkage**: In this cluster, CSFs have strong driving power as well as dependency.

**Driving/Independent**: CSFs have strong driving power and low dependency.

### 4. Results and discussion

Most of the studies in the literature focused on the supply chain and its relationship to the BCT, this study aimed to address a set of pathways/barriers for the implementation of BCT in GSCM. The steps in Figure 2 are followed to formulate the ISM final model shown in Figure 4. Based on the data collected from the literature and considering expert inputs, 10 CSFs were identified, subsequently, the structural self-interaction matrix (SSIM) and the final reachability matrix (FRM) were developed. The finalised 10 CSFs were partitioned into three levels (Table 7), and MICMAC analysis was conducted for establishing the driving power and dependency of the factors (Figure 5) within the model. It is noticed that the top level of model structure is assigned to ‘recording, tracking, and trading’ (C1), which may be described as the most influencing factor (Mandal & Deshmukh, 1994); (Kouhizadeh & Sarkis, 2020). At the second level, four

![Figure 5. MICMAC analysis.](image-url)
CSFs were found as moderately influencing factors, namely, traceability (C2), transparency (C3), knowledge (C7), and organization management (C8). Followed by level 3 with 5 CSFs, with less influence, these factors are smart contract (C4), trust and reliability (C5), tokenization (C6), green practices (C9), and collaborative logistic (10), which requires more attention in adopting BCT in GSCM.

In the MICMAC analysis, based on the driver and the dependence diagram (Figure 5), it is shown that only two quadrants contain CSFs, the quadrant of linkage, and dependent. Nine CSFs appeared in the linkage quadrant with a high dependency and driving power (≥9), and only one CSF (collaborative logistics (C10)) appeared in the dependent quadrant with high dependency (10) and moderate driving power. Therefore, it can be recognized that all factors are dependent and influence the BCT adoption in GSCM, whereas the collaborative logistic needs to be encouraged and oriented towards blockchain (Tan et al., 2020). However, in the proposed conceptual framework in Figure 1, it is noticed that the third party is directly related to the factor of green practices, and it contributes to facilitate the BCT adoption in GSCM. In addition, this model implicitly and explicitly incorporates certain CSFs analyzed in the ISM model, which promotes the integration of the BCT in GSCM.

5. Conclusion

Nowadays, research on GSCM has been strongly promoted at the academic and practical levels; therefore, many barriers and shortcoming can be dealt with, on the other hand, the BCT has recently shown the performance in some areas, and advantages that can be further exploited in GSCM to solve problems and contribute to its improvement. This paper studies the interrelationship between the CSFs of BCT adoption in GSCM. A literature review insight was conducted to present the key terms of this paper. In this study, only ten CSFs were identified based on literature and expertise (managerial and academia), by carrying out the ISM approach. The obtained results showed that two key concepts of BCT: smart contract and tokenization need more support to facilitate their adoption in GSCM, while trust and reliability must be enhanced toward its adoption in GSCM, as well as the green practices and collaborative logistics need more preparedness to be adapted to BCT. On the other hand, ‘recording, tracking, and trading factors’ provided by the BCT could be investigated as a pathway toward its adoption in GSCM, which may help managers and academicians in investigating these two timely topics, the GSCM and the BCT in the future.

5.1. Managerial implications

This paper proposes a model that could assist manager in decision-making with regard to the interrelationships among the CSFs of BCT adoption in GSCM and could help them to investigate other CSFs, with some more sophisticated tools to deal with it. Due to the lack of knowledge, several studies have not sufficiently tackled the topic of BCT adoption in GSCM as well. Moreover, this paper could be a starting point to study the interrelationship among the CSFs of BCT adoption in sustainable supply chain management in its entirety.
5.2. *Theoretical contributions*

Even at an early stage, the paper provides in-depth starting point for academics and managers who are interested in adopting the BCT to GSCM. The proposed structural model and conceptual framework have both academicians and managerial insights that would help in decision-making in terms of the relevant CSFs that will contribute and encourage the BCT adoption in GSCM. Furthermore, the following paper explicitly highlights the lack of a commitment to deal with comprehensive metrics and studies regarding this area of study.

6. *Limitation and future research*

BCT adoption in GSCM is promising and in its infancy; thus, there are several avenues for further research. However, the identified CSFs are limited to ten, which may be extended to other CSFs, as well as being specialized in a particular domain. In addition, the existence of other MCDM methods, which helps to prioritize the set of CSFs, like AHP, ANP, etc. Admittedly, it is worth noting that it is crucial to review all available contributions on this topic other than those presented in this paper.

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