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Research Article

An analysis of the integration of sustainability concepts into blockchain technology

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ABSTRACT

The acceleration of data production and consumption due to the transition to an information society and industrial revolutions has had a significant impact on the expansion of the global economy. The emergence of Industry 4.0 has led to the adoption of various technologies, including blockchain, which is known for its potential to transform different domains through its solutions. This is particularly relevant in the context of data governance. Thus, blockchain technology has the potential to enhance the sustainability of diverse industries. Sustainability is a crucial concept that refers to the capacity to meet the requirements of the current generation without compromising the ability of future generations to do so. The integration of blockchain technology across diverse industries holds the potential to greatly improve sustainability efforts. The objective of this study is to assess the relationship between blockchain technology and sustainability through a descriptive review of literature utilizing the latent semantic analysis topic modeling and clustering method, which is a social spider optimization technique. This study focuses on analyzing the impact of blockchain technologies on the sustainability sector. A corpus of 1069 papers has been sourced from the Scopus database. The results underscore the significance of cybersecurity, supply chain management, and the circular economy in the extant academic literature. The broad recognition of the supply chain domain's importance is evident in its application of blockchain technology and adherence to the sustainability principle. The present research focuses on the analysis and assessment of topics pertaining to traceability, cyber security, circular economy, energy, and transparency.

1. Introduction

As a representation of what public policies ought to achieve, the term sustainability has gained popularity in policy-oriented research. The Brundtland Report of 1987 was the major source of inspiration [1]. The term "sustainability" was first used to describe a forestry practice in which harvest levels were kept at or below replacement levels [2]. The concept of sustainability has subsequently become the focus of other disciplines. The sustainability issue of blockchain is growing as time passes. As a result of the shift to an information society and the industrial revolution, data generation and consumption are growing, which has a significant effect on the expansion of the global economy. In light of data governance, blockchain technology, one of the rising technologies of the Industry 4.0 era, transforms numerous fields through the solutions it offers. Therefore, blockchain has the potential to improve the sustainability of numerous industries [3]. Most individual and commercial monetary transactions in the modern world are governed by centralized systems. A separate entity may be responsible for their care in other situations. Third parties, such as banks or credit card companies, facilitate electronic transactions between companies. Client companies cover the costs of all successful deals. In this universal method, a single company oversees and controls all online communication and activity. A trusted third party is needed for this method to guarantee the safety of the transaction. In contrast, a blockchain is a distributed, decentralized, and securely maintained peer-to-peer

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network where information and trust between users may be managed without the need for a trusted third party [4]. As a distributed database, blockchain technology may share digital events among all blockchain participants. The data stored within each block is encrypted using a "hash" value. Each block in a blockchain contains the hash value of the preceding block. Therefore, it becomes extremely difficult for an adversary to modify blockchain data [5]. In light of these characteristics, it is evident that blockchain technology has significant effects on sustainability in a variety of industries. Sustainability is a core principle that aims to establish a global paradigm in which economic prosperity, social equity, and environmental conservation are mutually reinforcing. By embracing the transformative potential of blockchain technology, substantial progress can be made towards establishing a more sustainable and resilient future for all stakeholders involved.

The main aim of the proposed study is to assess the relationship between blockchain technology and sustainability through a descriptive literature review employing the latent semantic analysis (LSA) topic modeling and clustering approach, which is a social spider optimization method (SSO). There are two published articles that employ the aforementioned methodologies [6], [7]. This research investigates the effects of blockchain technologies on the sustainability area. The Scopus database is used to access a total of 1069 papers.

The remainder of the paper is organized as follows: Section 2 presents the literature review. Section 3 presents the related methodology. Section 4 summarizes results and discussions. Finally, Section 5 concludes the study.

2. Literature Review

Sustainability is a significant concept effect various of fields such as supply chain [8], energy [9], food industry [10], agriculture [11], transportation [12], cybersecurity [13], circular economy [14], and etc. In this section, the papers that combine blockchain technology and sustainability in the aforementioned fields are highlighted.

The contribution of blockchain technology to agri-food supply chain management was discussed on the circular economy in sustainable supply chain management in the study proposed by Yontar [15]. On the path to a circular economy, the purpose of the study was to investigate, analyze, and rank the critical success factors for the use of blockchain technology in the agri-food sector. Integrated use of the Analytic Network Process (ANP) and MultiAtributive Ideal-Real Comparative Analysis (MAIRCA) methods were employed to evaluate the degree of impact between the factors and identify the optimal ideal factor. The study focused on a narrower domain compared to the broader field of literature.

Rejeb et al [16]. conducted a systematic literature review of 70 influential articles published before July 2022. Six major themes emerged: a) circular economy concepts and practices, b) blockchain technology and the incorporation of the Internet of Things, c) sustainable supply chain management, d) blockchain technology and the circular economy in the context of COVID-19, e) sector-specific blockchain technology uses, and f) barriers to the adoption of blockchain technology in the circular economy. The initial stage of the Systematic Literature Review methodology involves the careful planning and execution of an extensive search across relevant academic publications. Subsequently, the research team proceeds to identify the appropriate journals for publication, establish the criteria for study eligibility, and assess the chosen studies. Moreover, they developed an extensive framework that incorporates stakeholders, tactics and practices, industry sectors, and a blockchain-enabled circular economy. However, the scope of the analysis was restricted to scholarly journals accessible through Scopus, the Web of Science, or a search conducted on Google Scholar. It is possible that certain noteworthy works may have been disregarded, and research studies published in journals that are not indexed in these databases may have been overlooked.

In order to determine the profitability and exergetic efficiency of the Bitcoin mining process, changes in the difficulty level of the block algorithm and the mining hardware's thermal power consumption were evaluated by [17]. The aim was to provide an original perspective on the topic, shedding light on how Bitcoin mining can be made more profitable in the long run by calculating the hardware's exergetic efficiency. The authors put forth a theoretical framework, and their efficiency model played a crucial role in leveraging the insights gained from ten years of Bitcoin mining operations to ensure the long-term viability of the industry. The model's assumption of a constant block mining time is a potential constraint that could impact the accuracy of their findings.

After reviewing the literature on blockchain's applications in the food market and the agricultural supply chain, the paper proposed by [18] discussed its potential uses for livestock-based products. The framework used blockchain technology to build a transparent and secure Smart Livestock Farming system, which incorporates Internet of Things technology. Finally, the study indicated that protecting records of agricultural output, monitoring processes involved in production, and keeping tabs on the finished products are the main concerns of blockchain implementation in this field. The article utilized sensors, Internet of Things, and Blockchain technology. The open design of the proposed system facilitated a range of potential applications, such as specialized surveillance and control management services, as well as the supervision and enhancement of agricultural livestock facilities, among others.

In the paper, the author [12] examined the application of blockchain technology to synchronized transportation. The author constructed a multi-objective mathematical model to optimize cost of transportation and blockchain, transportation time, and CO2 emissions. Then, compromise solutions were obtained utilizing several variants of the well-known weighting method and epsilon constraints method. Using a variety of multi-criteria decision methodologies, he assessed the obtained compromise solutions. Then, a metaranking technique was employed to produce an aggregated ranking. The findings indicated that the proposed methodology may aid in ensuring the safety, effectiveness, and sustainability of synchromodal transportation. The proposed study has the potential to be utilized as a case study.

Sadik et al.[19] examined the cybersecurity of smart grids and new issues, such as the use of blockchain in the Internet of Things. Emerging technologies, such as smart cities, were also examined in terms of their cybersecurity. In addition, cyber-risk prevention solutions based on artificial intelligence and machine learning methods were addressed in their study. The analysis of cyberthreats encompassed various industries, such as industrial control systems, particularly smart grids and smart cities, in order to examine their potential implications. This examination was conducted by considering real-world examples. Furthermore, the discussion also encompassed emerging trends.

The above is a summary of research on the use of the concepts of sustainability and blockchain technology in various domains. The focus of the proposed study is to develop a framework for the literature that incorporates these two concepts.

3. Methodology

This section describes the steps taken to determine the papers at the center of the data set by employing the LSA feature extraction method with the SSO algorithm. Search syntax is given in Table 1.

Table 1. Search strings on Scopus

Database	Search strings
Scopus (March 27,2023)	(TITLE-ABS-KEY ("blockchain") AND TITLE-ABS-KEY ("sustainability")

The search is resulted in 1069 papers. Abstracts of all papers are analyzed. Using MATLAB R2021a software, the pre-processing stage, which is the operation of cleaning data and preparing data for subsequent operations, is applied to data set. Because they induce misclassification of texts, URLs (Uniform Resource Locators) also known as web addresses have been deleted. Punctuations and search strings (blockchain, sustainability) are removed. Lastly, tokenization, the process of separating sequences into separate tokens, is carried out. After the pre-processing stage, the LSA method is applied on data-set. After the LSA, SSO algorithm is utilized to obtain center papers.

3.1. Latent Semantic Analysis (LSA)

For better document relevance determination based on query words, LSA is linked to document semantic structure [20]. Using LSA, you can determine which papers are related to one another. Dimensionality decrease is achieved via singular value decomposition (SVD). A spectral analysis of the term-document matrix forms the basis of this information search technique [21]. The words with similar meanings appear in comparable contexts throughout the text. Let the corpus be represented as a term-by-document matrix X (m x k), consisting of m distinct words in a collection of k documents. Figure 1 depicts a schematic SVD used to reduce the dimension of the term-by-document matrix [6].

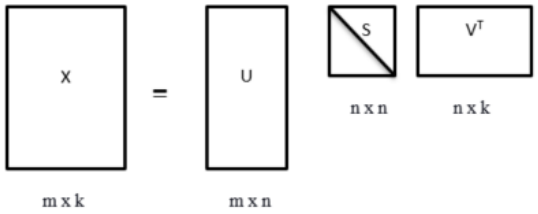

Figure 1. The SVD representation for dimension reduction

A bag-of-n-grams model is utilized by the model. Approximately five topics are represented when validation perplexity and elapsed time are taken into account.

3.2. Social Spider Optimization (SSO)

It is a nature-inspired algorithm comprised of the social members and communal web categories. The social participants are also divided into male and female categories. The SSO algorithm prioritizes social members [22]. In the proposed study, Eq. 1 is used to calculate the fitness function f of the spider si. Our problem is a minimization problem; consequently, the objective of the technique suggested is to minimize the fitness function as stated in reference [23].

$$f(s_i) = \frac{\sum_{i=1}^{K} \frac{\sum_{j=1}^{n_i} distance(center_i - document_j)}{n_i}}{K} = f(s_i = \{C_1, C_2, C_3, \dots C_K\}) \quad (1)$$

where number of clusters are demonstrated K symbol and it is considered as 3. Number of data-objects in cluster C_i is n_i, center of cluster C_i is $center_i$, $document_j$ is the j[th] data-object in cluster C_i. Distance is the distance between two data-object vectors utilized as Euclidean distance in our study. The distance between two data-object vectors is measured using the Euclidean distance. The flowchart depicting the SSO algorithm under

consideration is presented below, as referenced in source [6]:

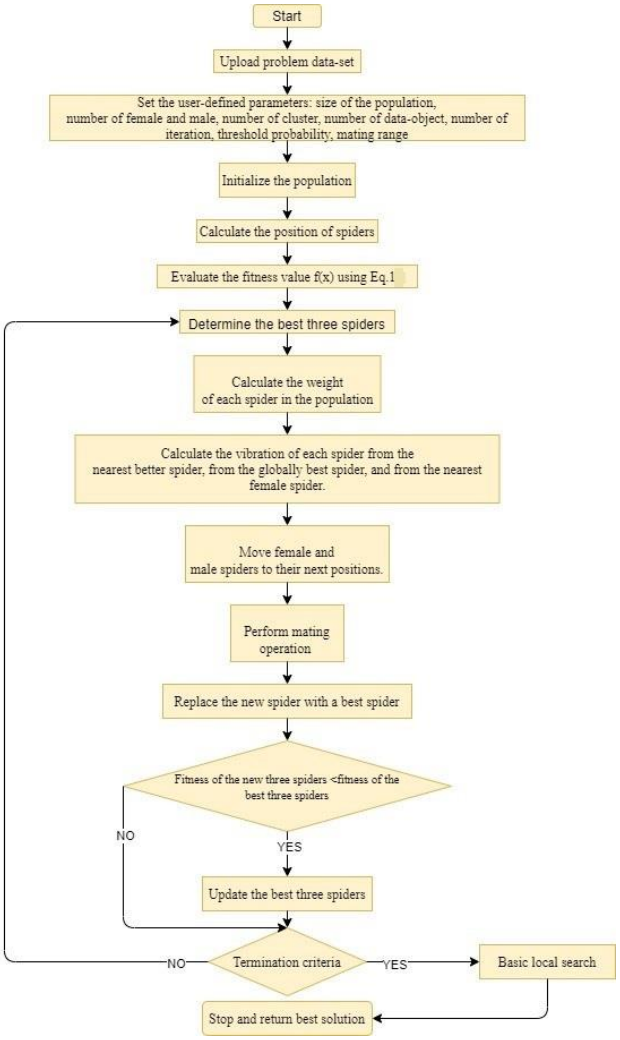

Figure 2. Flowchart of the SSO algorithm

4. Results and Discussions

The R2021a version of the MATLAB software package is utilized to execute all procedures associated with SSO. The data set is subjected to ten repeats with a population size of 100, each consisting of 1000 iterations, using a trial-and-error approach. Table 2 presents the data-sets outcomes based on the sum-of intra-cluster distances (SICD), comprising the optimal cluster centers as well as the elapsed time for each repetition.

Table 2. Results of Iterations

Center of the clusters	SICD	Elapsed time
799,747,4	142,37	63,30
799,852,85	**141,70***	**80,90**
831,437,465	142,68	83,60
323,7,1029	143,31	90,50
799,829,472	143,93	83,80
573,692,834	142,61	89,51
465,1042,254	144,05	90,83
465,831,463	143,39	78,94
892,321,1067	143,31	86,67
121,330,405	143,47	84,68

The Euclidean distance function is employed in the proposed algorithm. The optimal SICD value for the data set is determined to be 141,70. Thus, a total of three centers have been identified from a corpus of 1069 papers based on SICD value. The center of cluster 1 is the 799th paper title with 'Toward a sustainable cybersecurity ecosystem [19]'. Figure 3 shows word cloud of above mentioned paper (No: 799).

Figure 3. Word cloud of the first center of the document

As seen from Figure 3, cyber security is focus point of firs center. The first center focused on the subject of cybersecurity in relation to smart grids, with a particular emphasis on the latest developments, including the integration of blockchain technology within the Internet of Things. The discourse surrounding the security measures of nascent technologies, such as intelligent urban centers, was also being examined. Furthermore, the paper explored related solutions utilizing artificial intelligence and machine learning methodologies to mitigate cyber threats. The initial cluster is derived by selecting the studies in closest proximity to the first center paper. The first cluster comprises a total of 626 studies. Word cloud and word frequency graph of the first cluster are given in Figure 4 and Figure 5, respectively:

Figure 4. Word cloud of the first cluster

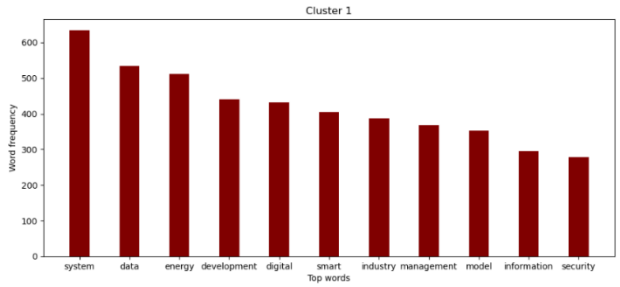

Figure 5. Word frequency distribution of the first cluster

Cybersecurity, data and information issues, and smart and digital systems connected to the energy subject are focal points of cluster 2 when blockchain and sustainability concepts are taken into account, as demonstrated by the first cluster's data analysis.

The center of cluster 2 is the 852nd paper title with 'Blockchain for Supply Chain Traceability: Business Requirements and Critical Success Factors [24]'. Figure 6 indicates the word cloud of mentioned paper (No:852).

Figure 6. Word cloud of the second center of the document

It can be concluded that from Figure 6, traceability in supply chain is focus point of the second center paper. The aim of the study [24] was to provide guidance for operations management research pertaining to the implementation of supply chain traceability systems. This was achieved through the identification of business requirements and critical factors that are necessary for successful implementation. The implementation of traceability systems was deemed necessary in disparate industries such as cobalt mining and pharmaceuticals. The paper outlined the business requirements and critical success factors for the implementation of such systems. The second cluster is formed through process of selecting studies that are in the closest distance of the second center paper. The second cluster encompasses a total of 209 papers. Figure 7 displays a word cloud and Figure 8 presents word frequency graph for the second cluster.

Figure 7. Word cloud of the second cluster

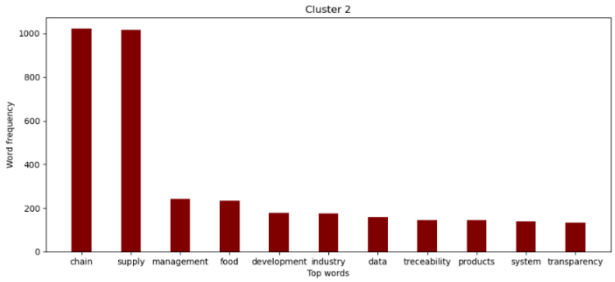

Figure 8. Word frequency distribution of the second cluster

It is seen that from figures of cluster 2, the subject of supply chain has been identified as the primary focus of 209 academic papers. The concept of traceability holds significant importance in the field of supply chain management, particularly in the context of blockchain technology and sustainability. Furthermore, the study of the aforementioned concept is significant in the field of food industry.

Lastly, the center of cluster 3 is the 85th paper with the title 'Role of Blockchain for Sustainability and Circular Economy [25]'. Word cloud of this paper (No:85) is given in Figure 9.

Figure 9. Word cloud of the third center of the document

Last center focuses on circular economy and practices. The objective of the paper [25] was to examine the utilization of blockchain technology in the pursuit of sustainability and the transition to a circular economy. The investigators were conducted an analysis on the function of blockchain technology in attaining the objectives of sustainable manufacturing. During the discourse on the

role of blockchain in promoting sustainability, reference was made to the experiences of IBM and Deloitte. Moreover, the circular economy was discussed in relation to the cases of Mitsui and Lablaco. Cluster three comprises a total of 234 academic papers. Figure 10 depicts a word cloud, while Figure 11 illustrates a graph of word frequency pertaining to the third cluster.

Figure 10. Word cloud of the third cluster

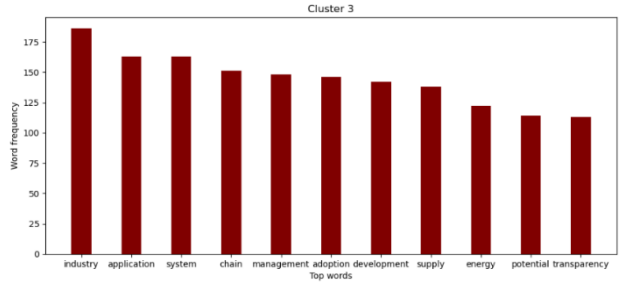

Figure 11. Word frequency distribution of the third cluster

In fact, supply chain and traceability come to the forefront in the third cluster, just as they are in the second cluster. In addition, it has been observed that both the first and last clusters show a significant emphasis on energy. However, the last cluster addressed these issues in terms of the circular economy within concept of blockchain and sustainability.

All in all, the supply chain field is considered to be of greatest importance in the context of blockchain technology and the concept of sustainability. The field under consideration places a greater emphasis on the discussion and analysis of traceability, cyber security, circular economy, energy, and transparency concerns.

5. Conclusion

The issue of sustainability pertaining to blockchain technology is progressively gaining significance over time. The expansion of the global economy is significantly impacted by the growth in data generation and consumption, which is attributed to the shift towards an information society and the industrial revolution. The advent of Industry 4.0 has brought about the emergence of blockchain technology as a promising solution in various fields, owing to its potential to address data governance concerns. Hence, the implementation of blockchain technology holds promise in enhancing the sustainability of various sectors. The aim of the proposed study is to assess the relationship between blockchain technology and sustainability through a descriptive review of relevant literature utilizing the latent semantic analysis topic modeling and clustering method, which is a social spider optimization technique. This study focuses on analyzing the impact of blockchain technologies on the sustainability field. A corpus of 1069 papers is drawn from the Scopus database. Based on the findings of the analysis, the identification of clusters reveals the significance of certain sectors. The results underscore the significance of cyber security, supply chain management, and the circular economy in the present academic literature. In the broader context of blockchain technology and the concept of sustainability, the supply chain field is widely recognized as being of utmost significance. The discipline being examined places a heightened focus on the examination and evaluation of traceability, cyber security, circular economy, energy, and transparency issues.

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