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Identification of Factors Affecting Blockchain Technology in Sustainable Supply Chain of the Steel Industry Using SPCA and KPCA Methods

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Abstract

Sustainable supply chain management develops the business, environmental and social dimensions. In this regard, the use of block chain in the sustainable supply chain provides a platform for secure data exchange and protects documents and events against fraud and manipulation in the process of transportation. Block chain-based sustainable supply chain systems boost transparency and reduce fraud risk. The aim of this study was to identify the factors affecting block chain technology in sustainable supply chain of Mobarakeh Steel Company. Using the Delphi technique, factors have identified with the maximum agreement of experts, in-depth study of previous studies, judgments of respected professors and experts in the field of management and experts working in Mobarakeh Steel Industry. The factors were analyzed using SPCA and KPCA methods. The research methodology is a descriptive/ correlational survey, data were collected in terms of practical research and library research has been in compiling the theoretical foundations and related literature. The statistical population of this study includes 74 experts in the field of sustainable supply chain, and finally the opinions of 56 experts have been analyzed. A researcher-made a questionnaire was used to collect data and the face and content validity of this questionnaire was confirmed by experts in the field of university and industry. The reliability of the questionnaire was confirmed with Cronbach’s alpha = 0.961. Statistical data were analyzed in SPSS and R software and SPCA and KPCA methods were implemented. The results showed that the identified factors in three general dimensions are business, social and environmental, respectively, which are affecting on block chain technology in the sustainable supply chain of Mobarakeh Steel Company.

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Introduction

The blockchain technology gained prominence because of its use in Bitcoin and the latter's prevalence, adoption, and rising price (Nakamoto,2009). Nowadays, various models of blockchain have such a broad range of applications that it's difficult to properly. In the other hand, concepts like quick money transfer, integration, management, secure hardware and software systems, and supply chains have dominated the minds of many engineers and managers. Blockchain technology is one of the most modern technologies that will assist organizations in overcoming many of the obstacles they will face in the future. Although there are many examples of how emerging technology can create new opportunities for individuals and organisations, they often come with new risks. The potential advantages of this new technology seem to be many. Blockchain can be viewed as a transformative tool that will radically alter the market environment. Data transparency and security, immutability and traceability, providing a suitable platform for information sharing and reducing forging and increasing trust are some of the visible benefits of the blockchain and are the motivations for driving applications to further grow blockchain's penetration into the business world by which organizations can truthfully change and develop their business models. Many companies are looking to outsource or contract their operations into inter-contractual arrangements these days. This technology, based on its promising features, will deter forgery, theft, or data abuse, as well as hinder conflicts of interest or possible clashes between the contracting parties (akhavan, dehghani 2019).

Blockchain helps to put transparency, security, traceability, and also controls cost from the manufacturer to the end-users via retailer/ supplier(Banerjee, 2018) . Customers and end-users are unaware of the procedures, flow of goods at the production floor and hazard, misery involved in manufacturing, transportation, handling, etc. The flow of information helps customer to gain and regain the trust (Anjum etal., 2017). Usage of blockchain has the advantages of security, irreversibility, distributed, transparency (Chiaronietal, 2019), and accuracy (IansitiandLakhani,2017).

Blockchain can be described as an empowering technology that will quickly transform the business environment. Data transparency and security, immutability and traceability, providing a platform for information sharing, and countering counterfeiting are some of the features that blockchain brings with it, and organizations can rely on blockchain capabilities, even business models. Nowadays, when many organizations seek to outsource, contract or outsource their activities through inter-contractual agreements, this technology, based on its characteristics, on the one hand, prevents the occurrence of forgery, fraud or manipulation of data. And on the other hand can prevent disagreements between the parties to a contract. (akhavan, 2018).

The two components of China Blockchain's reliability and transparency are to better examine the production and supply process, to better understand the flow of materials, and to obtain more accurate information through the supply chain. These components can lead to a broader shift from a flexible and sustainable industrial economy, goods and products to an information-based economy and order-based production (Pazaitis, De Filippi and Kostakis, 2017).

While boosting its competitive advantage, an organization can engage in activities that have a positive environmental and societal impact. This aspect must be analyzed in terms of supply chain activities. (Carter & Rogers2008).

Modern and emerging supply chains are inherently complex relationships involving multi-layered and geographically heterogeneous institutions that compete to serve consumers. Entering global markets, diverse regulatory guidelines, and diverse cultural and human patterns in supply chain networks make information analysis and risk management in these complex networks almost impossible (Sarpung, 2014; Ivanov). , (Dolgi, and Sokolov, 2018). Inefficient and additional transactions, fraud and forgery, theft and weak supply chains, lead to less trust and thus the need for shared and transparent information and better final verification. The provenance of luxury and high-value goods that depend on paper certificates and receipts can easily be misplaced or tampered with. In reality, the lack of clarity in the supply value of any commodity makes it impossible for supply chain agencies and consumers to check and validate the item's true value.

Fortunately, the different aspects of this technology are increasingly evolving, and the responsible remarks of several senior managers from countries who are considering entering this area demonstrate an awareness of the problem and the effect of this technology in various dimensions and applications. Blockchain is used in almost all industries including insurance, medicine, health, food, banking network, healthcare system, transportation network, supply chain, pharmaceuticals, social networks, agriculture and animal husbandry, import and export, clothing, marketing, stock exchange, travel and tourism services, identification, security, counterfeiting, transfer of ownership, elections, energy, internet of things (IOT) and military systems.

Such concerns raise the question of whether existing supply chain information structures will retain the information needed to find the starting point for products and services in a safe, transparent, and reliable manner. Improving supply chain reliability, protection, longevity and integration, and interconnected processes are key to solving these complex issues. The answer to this problem may be in the use of China Blockchain technology. Developments and changes and applications of Emerging technology with the concept of China Blockchain technology makes these improvement goals more possible in terms of organizational dimension, technology upgrades and economic progress. Blockchain technology, as a powerful malicious technology with the characteristics of an "unreliable" decentralized database, enables global-scale trading, intermediation, control, and disengagement of processes between different parties.

Within companies, past and present supply chains are heavily dependent on centralized information management systems, often different and separate. In order for supply chain organizations to hand over their confidential and important information to an organization or broker, they must have a high level of trust. (Abiratneh and Monfared, 2016). Another drawback of centralized information management is that if a crash occurs at one point, the entire system fails, and can easily be hacked and corrupted by a cyber attack (Dong et al., 2017).

In addition, to understand and validate supply chain sustainability, there is a new emphasis on supply chain performance and management. When managing the supply chain, the principle of the triple line, which includes balance in the three categories of environmental, social and commercial, is described as sustainability (Seuring et al., 2008). Questions can be asked about whether the current information systems in the current supply chain have the ability to support the information provided to them to quickly identify the origin of goods and services, so that they are sufficiently secure and to the desired extent. Clear and powerful, it creates. The solution to these difficult problems is to increase the rate of supply chain transparency, security and impenetrability, durability and process integrity(Saberi et al., 2018). These goals became more sustainable in terms of organizational dimension, strategic dimension and business dimension with the advancement of new technology and implementation based on the principle of China Blockchain technology (Swan, 2015; Abiratneh and Monfared, 2016).

The importance of this study is that the sustainable supply chain among students and faculty and professionals has been considered and welcomed (Fahimnia, Sarkis and Davarzani, 2015). The commercial aspects of the supply chain are an important component for long-term sustainability, and the focus on the environmental and social dimensions has led to a more complete and comprehensive view of the supply chain. Extraordinary features of China Blockchain technology may be a remedy for some uncertainty in the evaluation criteria of three elements of sustainability: financial, social and environmental evaluation criteria. As a result, recording and defining examples used for sustainable supply chains will demonstrate the large dimensions of the use of China Blockchain technology. China Blockchain technology can support and collect data collection, storage and management capabilities, as well as important product information and supply chain information (Abiratneh and Monfared, 2016).

Customers and governments are also demanding accountability across the supply chain due to the transparency component of blockchain technologies. Companies who were ahead of their time recognized the business advantage of openness, which leads to increased consumer loyalty, which leads to more purchases and financial gain for the company (Ward, 2017).

Via stronger guarantees of human rights and equitable and safe labor practices, blockchain traceability leads to sustainability. A comprehensive record of product records, for example, assures customers that the goods they are buying are supplied and manufactured by ethically sound manufacturers (Saberi, 2018).

The use of blockchain technologies will also help to ensure the long-term viability of supply chains that are environmentally friendly. It is capable of doing so from a variety of perspectives.

Blockchains could be used to verify that ostensibly green goods are still green. Green product production information is often inaccessible and impossible to check. Customers who care about the environment will be more likely to buy green goods If the packaging process does not harm the environment in terms of greenhouse gas emissions and is so-called green. China Blockchain technology reduces emissions and further preserves the environment during travel by providing basic principles and solutions for visualizing and modeling the supply chain and implementing optimal design, development and transportation of low-emission products. The product will help (de Sousa Jabbour et al. 2018a).

Blockchain technology can contribute to the fast supply of factory consumable parts and additional storage costs can be avoided. Due to the characteristics of blockchain such as transparency of information and their accuracy and also their non-manipulation potential in the steel industry, the elimination of technical defects and repairs of the production line is possible in less time. This can prevent unwanted stops of the production line and develop the production based on customer needs and feedback. Other benefits include the reduction in financial and accounting calculations times, increase the mutual trust between units and parts and factory personnel, management is always aware of all the activities of the organization which in turn increases the level of confidence and ultimately can increase the quantitative and qualitative efficiency in the factories by obtaining fast, accurate and transparent information, which finally leads to better planning. Accordingly, the above benefits can evoke any researcher to conduct a research in the steel industry.

Raw materials from the mine are the main source of the supply chain in the steel industry. The consumables parts used for maintenance and fossil energy and electricity are two main sources of supply which include the production line (production units, mechanics, electricity and facilities), finance and support (warehouse, finance and accounting, logistics, administration, sales and security) and most importantly the senior management of the organization. The current environmental conditions and its requirements, the principles of customer orientation, employees' satisfaction and high efficiency of the production line must work in line with the three principles of sustainable supply chain (environmental, social and business dimensions). This connection and transparency can have a clearer and better path with the help of blockchain units and blocks, which consists of features such as distributed database and decentralization, security and auditing.

If a maintenance schedule is created, for example, all departments can be immediately aware of their roles and obligations based on transparency and non-concentration of responsibilities not assigned to a single individual or unit, allowing for prompt and appropriate action. This planning with the help of blockchain should be done in a way that each part is not seen as a separate island and the necessary information is share at the moment (it is important to note that, according to blockchain rules, the information are approved when confirmed by all members of the subgroup. Information is documented when everyone is informed, and if a change occurs again, all blocks must confirm the change, and this indicates the transparency of information in blockchain technology). For example, anyone can see the price and form of commodity, as well as its features, quantity, consumption tools, and demand input at any time, making preparation and strategy development easier. With proper preparation, a private blockchain in a factory will provide the available results of discoveries and information to the responsible people in various areas of the factory.

The sharing of information can be restricted in private Blockchain networks. A steel plant, for example, may use holograms on sheets and goods to record general details such as the type of raw materials used, the number of employees, the amount of CO_2 emitted, the amount of dust and waste generated, energy consumption, product properties, and use. Transparency of the information promises a sustainable supply chain and provides customer and consumer with satisfaction and trust.

A special hologram, for example, may be used by a private Blockchain network to provide accurate and reserved information about the manufacturing line, such as used goods, type of fuel and raw materials, laboratory information, and net benefit. The factory's approved staff can read this material, but it is not accessible to the general public.

The management tracks the work of all teams, individuals, and devices with precise statistics and figures, and makes the right judgment in the field of policy and foresight, as well as continuous progress of the organisation, thanks to the openness of all units' work and the blockchain features outlined above. Another practical example is purchasing refractory materials used in the steel plant according to the physical and chemical analysis that can be trusted. This is made possible by refractory producers introducing blockchain for their consumers. This strategy would certainly assist the end user in making smarter choices in terms of refractory content use, both in terms of type and quantity. The use of blockchain can create better mutual trust between departments, management, partners, suppliers and consumers. Also, it can help the plant take the optimal decisions in areas such as production planning, maintenance, supply of raw materials and consumable parts. This is made possible by the blockchain's simplicity, as well as the decentralization of the plant's current affairs, which improves the optimum efficiency of all units and individuals.

1. Literature Review

The following review of the related literature provides an overview of current knowledge which allowing us to identify relevant theories, methods, and gaps in the existing research.

Despite being a thirty years old technology (Haber and Stornetta, 1991), blockchain owes its recent popularity to Nakamoto (2008), who exploited its potential for the Bitcoin cryptocurrency (Yermack, 2017). Although its disruptive potential was initially observed in the financial-oriented applications (Crosby et al., 2016), enthusiast also sought potential for nonfinancial applications such as e-government (Navadkar et al., 2018), healthcare (Plant, 2017), energy (Hu et al., 2019) and supply chains (Treiblmaier, 2018). Applications involving real-world assets, better known as real-world blockchains (Sharma, 2019), are, however,often criticized by experts due to the lack of trust in the communication channel (Oracles)between the real-world and blockchains (Antonopoulos and Woods, 2018; Egberts, 2017).

Hofmann & Rüsch (2017) suggests blockchain will help facilitate further supply chain integration. Nonetheless, for industries and firms already well integrated, they may not be willing to substantially invest in blockchain that does not provide significant benefits over present solutions.Much is still yet to be learned about this emerging technology.

Pavli Skender et al (2020) explored the overall perspectives of blockchain technology and the potentials of blockchain to allow sustainable supply chains in their study. A conceptual framework was provided to help better understand the benefits and challenges of blockchain technology. Comparing three different cases of global supply chains, with a focus on corporate sustainability in agriculture, and manufactured goods, the results showed that blockchain has the potential to boost the supply chain sustainability, however the blockchain can't guarantee that all supply chain stakeholders provide accurate, uniform and verifiable data.

Vu and Trinh (2021) concentrated on the analysis of Strengths, Weakness, Opportunities and Threats (SWOT) of blockchain-applied supply chain relevant to agri-food products. They prescribed some policy recommendations and implications for agri-food stakeholders such as regional policy makers, agri-food based blockchain platform designers, executives, and farmers as users in relevant to facilitate the blockchain technology for agri-food chains in Vietnam agriculture.

Hervani et al (2021) explored the blockchain interrelationship with social sustainability and supply chains. They introduced the way valuation – using economic market and non-market valuation – relates and can support to these major integrated issues. The findings addressed a critical concern of sustainability valuation and blockchain technology; how they are related.

Nayak and Amol (2019) proposed a conceptual model of sustainable supply chain management (SSCM) in small and medium enterprises (SME) using blockchain technology (BT). To develop its conceptual model, multi-criteria decision making has been used and various managerial and theoretical concepts along with the field of future research have been discussed in their research.

Using (5W+1H) pattern to formulate research objectives and questions, Paliwal et al (2020) reviewed 187 papers published since 2015 and proposed a literature classification level (ETLCL) framework-based on Grounded Theory. The results showed traceability and transparency as the key benefits of applying blockchain technology.

Ming et al (2021) used descriptive and content analysis to review publications related to blockchain-based supply chains between 2017 and 2020 inclusive. A detailed analysis of findings was provided to identify the future opportunities of blockchain-based supply chains, including prospects for tertiary industries and concerted efforts that are necessary to explore sustainability themes.

Juniper Research Conducted a study amongst 369 MD, CEOs,managers and all this study said that more than 76 percent gave a vote to implement blockchain and less than 24 percent said blockchain is quite beneficial for the industry. Implementation of BC in the manufacturing and services industry will show the possibility of employment (Castillo, 2017) for unemployed youth.

Yadav and Singh (2020) studied the use of BC technology and a try to develop efficient sustainable supply chain management (SSCM) rather than the inefficient design of supply chain management (SCM). Important variables related to blockchain were identified from the literature and analyzed and modeled using Principal Component Analysis (PCA), Fuzzy-Decision making trial and evaluation laboratory (DEMATEL).

Yang et al. (2019) implemented the data layer, network layer, and consensus layer of block chain technology before establishing the steel logistics architecture. Then, using the entity, feature, and role dimensions, it examines the management of logistics information services in the supply chain. Finally, the improved PFBT algorithm is used to test their de-centralization security and algorithm performance in the system of iron and steel enterprise logistics transactions. The experimental comparison showed that the improved PBFT algorithm has been greatly improved in the aspects of algorithm security, algorithm delay, and algorithm throughput and algorithm fault tolerance.

Azimifard et al. (2018) used an empirical ladder method to assess the weights of sustainability requirements and assessed suppliers on four key criteria: CO2 emissions, number of workers in the suppliers' country sector, water use, and distance from the supplier's country to the destination at three SC levels and the macroeconomic (international) level. According to the results, Iran's mining sector is the best long-term supplier for the country's steel industry. Furthermore, based on the three SC sustainability metrics at three stages, Iran was found to be the best sustainable supplier country for most suppliers in Iran's steel industry SC.

In their research, Esmaeilian et al (2020) provided an overview of Blockchain technology and Industry 4.0 for advancing supply chains towards sustainability. Capabilities that Blockchain offers for increasing sustainability were investigated. Blockchain technology capabilities for contributing to social and environmental sustainability, research gaps, adversary effects of Blockchain, and future research directions are discussed.

3. Research Methods

This study identifies the factors affecting blockchain technology in the sustainable supply chain of the steel industry using SPCA and KPCA methods. So, it is considered a practical research in terms of purpose, and it is classified as a descriptive survey (non-experimental) research according to the method of collecting statistical data. Since a set of bivariate and multivariate correlations has been used in the form of correlation matrix or covariance, the present paper is a correlational study with a comparative approach. The statistical population is all 74 managers and senior experts of Esfahan's Mobarakeh Steel Company active in the field of sustainable supply chain. Due to the limited size of the community, the research questionnaire was sent to all members of the research population to obtain more accurate results. 56 questionnaires were completed and returned, so the research sample consists of 56 people. The identified factors were recognized using the Delphi method and full consensus of experts in three phases, and the research literature was performed using the library method. The factors were discovered after a thorough review of the findings of previous studies, as well as the opinions of professors and management experts, as well as experts from Esfahan's Mobarakeh Steel Company. The factors are those affecting blockchain technology in the sustainable supply chain of Mobarakeh Steel Industry. The identified factors are presented in Table (1). Field research and a questionnaire with specialized questions about the dimensions of research have been used to collect information in the operational field. The main phrases of the research questionnaire are designed based on the Likert scale on the continuum from strongly agree, agree, undecided, disagree and strongly disagree.

According to the expert judgments, the content and face validity of the questionnaire were Confirmed. Besides, the reliability of the questionnaire was confirmed with Cronbach’s alpha = 0.961. Criteria such as mean and standard deviation have been used

to describe research phenomenaand factors to analyze statistical data in the descriptive statistics section. Standard Principal Component Analysis (SPCA) and Kernel Principal Component Analysis (KPCA) are the method of statistical data analysis in inferential statistics. SPSS25 and R3.6.3 software were used for statistical analysis.

4. Results and Discussion

The mean and standard deviation of the identified factors affecting the blockchain technology in the sustainable supply chain of the steel industry are presented in Table (2). The mean of all identified factors affecting blockchain technology in the sustainable supply chain of the steel industry is higher than the average Likert scale, ie 3, and indicates the above average attitude of respondents about the impact of factors on blockchain technology in the sustainable supply chain. The standard deviations are also close to each other indicating of equal accuracy in the values.

Table (1): Factors identified based on experts' opinion

Identified factors affecting blockchain technology in the sustainable supply chain of the steel industry	Description
Quality assurance	This feature facilitates trading and make easy to take steps to produce uniform and high quality goods and services
Detailed review	Blockchain technology acts as the center of transaction accounts which provides management with better and more accurate access to data
Scalability	Blockchain integration can be done without losing data validity, such as the time of registration of information in the blockchain, to name a few.
Transparency	Updated data cannot be modified or hacked, blockchin provides a transparent system of data
Energy	Blockchain reduces energy consumption by decreasing transportation, work hours and less paperwork which ultimately reduce greenhouse gas emissions.
Integrity	Blockchain uses integration to do streamline commodity management in the supply chain. For example, digital barcodes, sensors, and tags, such as rfid tags, can be converted by using blockchain.
Solve the problem of double spending	Peer-to-peer transaction is done after validation. Data cannot be sent to two or more recipients.
High quality data	Blockchain data is complete, consistent, accurate and timely, without human error, and it is 100% accurate and valid.
Smart system	Contracts and concepts are naturally verifiable and valid exchanges affect economic development.
Government policy	Frauds can be found quickly during audit in organizations with supply chains.
Encryption capability	Due to the ability to approve any transaction or information flow from one place to another, no change in the blockchain is possible without recording.
Durability and longevity	The risk of system failure, data loss, malicious attack and interference of responsible authorities is eliminated by using blockchain and all transaction records and data flow are verified and protected.
Speed	Speed is a feature which is necessary for goods with short life cycle, such as some chemicals and vegetables and fruits. Blockchain helps the shelf life and quality of the products in supply chain.
Time	Time is a feature which makes the data completely permanent and free of erasure or deletion.
Return flow	Return flow enables traceability during product life cycle.
Automation	Using the distributed ledger, automation restricts everybody's access to all information, the definition of transaction and product information flow.
Accounting	Blockchain transactions reduce human error and ensure information security.
Effectiveness	High-speed data flow and elimination of intermediaries, smart contracts and the ability to track information save time and money.
Information flow and control (information flow control)	Customer's response is sent to retailers and manufacturers using blockchain via fixed feedback for more accurate future planning.
Inventory management in warehousing	Blockchain facilitates inventory management because everyone has an accurate copy of the inventory information.
Quality truth	Quality truth allows data to be shared between different parties free of human bias and error.

Table (1): Factors identified based on experts' opinion (continue)

Ecosystem simplification	Ecosystem can be simplified by identifying the connections between the components of the organization.
Impossibility of data loss	Due to the nature of non-manipulation and ability of storage of information with the approval of all people, data loss seems impossible.
Protection	Due to the nature of non-manipulation and ability of storage of information with the approval of all people, data protection is reliable.
Decrease in management value	The necessity of highly experienced managers, whose abence considers a deficiency for the system, is lessens.
Identify outputs and objectives	Everyone is aware of organizational goals and effective and better steps can be takes to achieve the goals.
Eliminates intermediaries	The intermediaries between the units, manufacturers, buyers and the end customer are eliminated with the ease of direct communication between them.
Control access to information in supply chain management	Level of data access restriction can be created for groups, units or individuals.
Invoices find a specific path	Invoices find a specific path because of the transparency of sales information
Regulations	Provide smart contracts to validate them and conduct transactions without third parties and it is not possible to delete or modify the data.
High accessibility	Data are available even after nodes break or nodes leave (nodes are the data connection points in the blockchain algorithm)
Disruptive Mediation	Blockchain technology never deploys a headquarters because of enjoying the distributed ledger.
Simplify the current paradigm	It has a multifaceted nature of dealing with different rules. Investors eliminate it by reducing the paradigm model.
Decentralization	Blockchain is a system for collecting information with a decentralized database.
Customer orientation	Increase confidence by providing the customer with clear information such as the source of a manufacturer's product
Demand for sharing information in supply chain management	Sharing the information flow such as maintenance process, supply and production, adjustment and assembly from manufacturer to supplier and vendors in supply chain management
Cost	Overload costs for transactions have been reduced due to the elimination of intermediaries. So, transaction costs ar decreasing.
Ability to access and view	Traceability and visibility are essential to the supply chain.
System deserves trust	Using features such as origin recognition, this system is reliable.
Supply of parts and consumer goods at the right time	The supply chain, ranging from the producer and the buyer to the final consumer, is informed due to transparency of the information and statistics. So, planning is facilitated.
Avoid increasing storage costs	The supply chain, ranging from the producer and the buyer to the final consumer, is informed due to transparency of the information and statistics. So, it is possible to prepare and store goods in the required amount and at the right time.
Help to fix technical problems in the shortest time and with previous forecasts	Since all relevant repair units are kept potsed and informed, it is impossible to skip the repairs and. Thus, sharing information and also finding solutions in the shortest time are facilitated
Mutual trust between factory units is increasing	This system is founded upon elimination of secrecy and developing the transparency, thus it increase the mutual trust

Table (1): Factors identified based on experts' opinion

Better understanding of management of the activities of the whole organization at any time and thus more accurate planning based on transparency of information	According to transparent and non-manipulative reports, management is aware of the decisions of the entire workshop and the company's major decisions are made better and more effectively.
Changeability	Due to the ability to approve any transaction or information flow from one place to another, no change in the blockchain is possible without saving
Reliability	The risk of system failure, data loss, malicious attack and interference of responsible authorities is eliminated by using blockchain and all transaction records and data flow are verified and protected.

Table (2): Statistical criteria for the impact of identified factors affecting blockchain technology in the sustainable supply chain

Identified factors affecting blockchain technology in the sustainable supply chain of the steel industry	Mean	Standard deviation
1. Quality assurance	4.38	0.65
2. Detailed review	4.14	0.64
3. Scalability	3.89	0.68
4. Transparency	4.02	.98
5. Energy	4.34	0.75
6. Integrity	3.96	0.85
7. Solve the problem of double spending	3.73	0.84
8. High quality data	3.97	0.97
9. Smart system	4.05	0.70
10. Government policy	3.79	1
11. Encryption capability	3.80	1.07
12. Durability, and longevity	4.16	0.85
13. Speed	3.98	0.88
14. Time	3.86	0.90
15. Return flow	4.09	0.90
16. Automation	4.04	0.95
17. Accounting	4.11	0.85
18. Effectiveness	4.14	0.94
19. Information flow and control (information flow control)	3.79	0.87
20. Inventory managment in warehousing	4.04	1.09
21. Qualitive Truth	3.89	1.02
22. Ecosystem simplification	4	0.79
23. Impossibility of data loss	3.91	0.92
24. Protection	3.93	0.99
25. Decrease in management value	3.71	1.06
26. Identify outputs and objectives	4.11	0.80
27. Eliminates intermediaries	4	0.91
28. Control access to information in supply chain management	4.07	0.76
29. Invoices find a specific path	4.02	0.92
30. Regulations	3.96	0.83
31. High accessibility	4.11	0.76
32. Disruptive Mediation	3.86	0.84
33. Simplify the current paradigm	3.75	0.88
34. Decentralization	4.02	0.80
35. Customer orientation	4.09	0.88
36. Demand for sharing information in supply chain management	4.09	0.58
37. Cost	4.21	0.87

Table (2): Statistical criteria for the impact of identified factors affecting blockchain technology in the sustainable supply chain (continued)

38. Ability to access and view	4.04	0.83
39. System deserves trust	4	0.79
40. Supply of parts and consumer goods at the right time	4.04	0.89
41. Avoid increasing storage costs	4.16	0.83
42. Help to fix technical problems in the shortest time and with previous forecasts	3.88	0.92
43. Mutual trust between factory units is increasing	4.04	0.89
44. Better understanding of management of the activities of the whole organization at any time and thus more accurate planning based on transparency of information	3.95	0.92
45. Changeability	3.80	0.90
46. Reliability	3.96	1.01

To identify the relationships between the research factors and perform the main component analysis, Pearson correlation coefficient has been used to examine the relationship between the identified factors affecting blockchain technology in the sustainable supply chain of the steel industry. The correlation matrix of the identified factors is considered a large one with of 46 × 46 dimension, so only the correlation between 46 factors and the first 12 factors have been

reported. Pearson correlation coefficients between the identified factors are presented in Table (3) and it is observed that a large number of binary relationships between the

factors at different levels of 0.01 and 0.05 are significant. This indicates that Standard Principal Component Analysis (SPCA) and Kernel Principal Component Analysis (KPCA) can be applied.

4.1 The process of implementing Delphi technique

Through library studies, data in previous documents, official statistics, unofficial statistics, and organizational documents were reviewed. English and Persian books and papers, dissertations and websites were searched to collect information related to the literature of this research and theoretical framework of the study.

In the second phase, identifying the experts, 14 out of 15 judgments (93%) from experts including the university professors, management specialists and experts in Mobarakeh Steel Industry were obtained. The identified factors were distributed among the panel members and they expressed their opinions in the form of agree or disagree.

The factors identified regarding the factors affecting the blockchain technology in the sustainable supply chain of the steel industry in the second phase of Delphi, are presented based on the maximum agreement of the Delphi panel members.

The respondent of the third phase were 13 out of 15 experts who commented on the identified factors based on Likert scale ranging from strongly agree to strongly disagree.
Delphi panel members in the third stage confirmed 90% of the identified factors regarding the factors affecting blockchain technology in the sustainable supply chain of the steel industry. It is worth mentioning that 6 factors (40 to 46) were finally added by opinions of the experts.

4.2 Standard Principal Component Analysis (SPCA)

In this section, while identifying the relationships between research factors, the Standard Principal Component Analysis

(SPCA) performed and then the correlation between the principal components with the research variables has been presented. The share of each component in the total variance has been expressed.

Regarding the eigenvalues of the correlation matrix between the research factors, it can be said that the first 3 eigenvalues of the correlation matrix of the variables are listed in Table (4).

Eigenvalues greater than 1 are presented here, and eigenvalues less than 1 are omitted.

The first standard principal component which has the largest eigenvalue determines 62.34% of the total variance.

The second standard principal component explains 18.89% of the total variance.

The third standard principal component explains 5.85% of the total variance. The 3 eigenvalues, which correspond to the 3 standard principal components, explain 87.07% of the total variance altogether.

The first standard principal component corresponds to the largest eigenvalue of the covariance matrix. The variance of the first standard principal component explains 62.34% of the total variation (total variance). Eigenvector is corresponding to the first standard principal component (the first eigenvector) with relatively large factor loads of information flow and control indices (information flow control), encryption capability, inventory management in warehousing, avoid increasing storage costs, reliability, better understanding of management of the activities of the whole organization at any time and thus more accurate planning based on transparency of information, etc. This represents the "business" component which is of great importance based on the identified factors affecting blockchain technology in the sustainable supply chain of the steel industry. The second standard principal component corresponds to the largest eigenvalue of the covariance matrix. The variance of the second standard principal component explains 18.89% of the total variation (total variance). Eigenvector is corresponding to the second standard principal component (the second eigenvector) with relatively large factor loads of automation, regulations, decentralization, increasing the mutual trust among factory units; the system deserves trust, protection, quality truth and government policy, and represents a "social" component. Considering the number of factors that are involved in the formation of the "social" component, the "social" component based on the identified factors affecting blockchain technology is significant in the sustainable supply chain of the steel industry following the "business" component.

The third standard principal component corresponds to the largest eigenvalue of the covariance matrix. The variance of the third standard principal component explains 5.85% of the total variation (total variance).

Eigenvector is corresponding to the third standard principal component (the third eigenvector) with relatively large factor loads of returns and energy and represents and "environmental" component. The "environmental" component based on the identified factors affecting blockchain technology in the sustainable supply chain of the steel industry is of great importance and significant following the "business" and "social" components.

The results show that the three standard principal components explain 87.07% of the total variance in total. Considering the first three standard principal component, the results represent that a substantial summary of information can be presented on affecting blockchain technology in the sustainable supply chain in the steel industry.

Table (3): Correlation coefficients between the identified factors affecting blockchain technology in the sustainable supply chain of the steel industry

	q1	q2	q3	q4	q5	q6	q7	q8	q9	q10
q1	1									
q2	.522**	1								
q3	.299*	.451**	1							
q4	0.246	.427**	0.221	1						
q5	.409**	.276*	.289*	.315*	1					
q6	.354**	.274*	.402**	0.131	.506**	1				
q7	.321*	.373**	0.172	.402**	0.234	0.164	1			
q8	.420**	.371**	0.214	.330*	0.103	0.255	.375**	1		
q9	.316*	0.225	.357**	0.105	.314*	.370**	.334*	0.206	1	
q10	.265*	0.245	.312*	0.188	.318*	.267*	-0.048	0.158	.380**	1
q11	.292*	.490**	.321*	.471**	.359**	.411**	.324*	.275*	.501**	.418**
q12	.451**	.323*	.409**	0.171	.372**	.310*	0.214	0.087	.476**	.404**
q13	.424**	.387**	.391**	.357**	.534**	.603**	.384**	.336*	.414**	.282*
q14	.435**	.379**	.419**	.475**	.316*	.324*	0.164	.381**	.416**	.447**
q15	.440**	.416**	.522**	.286*	.415**	.502**	.320*	0.190	.426**	.404**
q16	.625**	.495**	.315*	.369**	.469**	.584**	.329*	.443**	.380**	.293*
q17	0.124	.338*	0.242	0.239	.403**	.384**	0.245	0.095	.421**	.477**
q18	.387**	.475**	.337*	.489**	.499**	.301*	.530**	0.214	.513**	.264*
q19	.339*	.446**	.361**	.410**	.311*	.457**	.343**	.356**	.679**	.343**
q20	.339*	.379**	.421**	0.236	.341*	.352**	0.247	0.213	.497**	.570**
q21	.336*	.493**	0.245	.328*	.502**	.288*	.304*	.289*	.390**	.367**
q22	.392**	.395**	.375**	0.141	0.186	0.244	.385**	0.167	.430**	0.000
q23	.301*	.267*	.450**	0.143	.469**	.529**	0.180	0.244	.404**	.314*
q24	.411**	.359**	.476**	.283*	0.231	0.105	0.261	.307*	.269*	0.131
q25	.265*	.408**	0.109	.285*	0.218	.271*	.423**	0.259	.391**	.267*
q26	0.236	.427**	.422**	-0.002	.334*	0.245	0.232	.265*	.541**	.278*
q27	0.061	0.154	.439**	-0.061	.293*	.350**	0.071	0.062	0.256	.356**
q28	.388**	.499**	.332*	.437**	0.181	.285*	.343**	.516**	0.198	0.116
q29	0.262	.392**	.264*	.300*	.493**	.624**	.310*	0.086	.308*	0.259
q30	.566**	.485**	.380**	.335*	.402**	.409**	.350**	.511**	.442**	.361**
q31	.325*	.304*	.307*	0.194	-0.001	0.204	.446**	0.206	.368**	0.079
q32	.367**	.307*	0.100	0.003	0.253	.297*	0.253	.320*	0.261	0.092
q33	.295*	0.193	0.076	.342**	0.187	0.231	0.252	0.171	.348**	.268*
q34	0.198	.313*	.339*	0.209	0.204	0.188	-0.020	0.123	0.129	0.255
q35	.482**	.458**	.503**	0.188	.369**	.490**	0.156	.279*	.347**	.269*
q36	.585**	.499**	.440**	.316*	.265*	0.227	.310*	.488**	.346**	0.252
q37	.275*	0.204	.286*	0.230	.504**	.478**	0.229	0.142	.491**	.346**
q38	.515**	.330*	.523**	.289*	.333*	.439**	0.196	.281*	.435**	.424**
q39	0.250	0.251	.307*	0.188	.403**	.461**	0.137	-0.072	.364**	.322*
q40	0.227	0.243	.426**	0.165	.609**	.503**	0.134	0.030	.434**	.536**
q41	.428**	.263*	.290*	.355**	.471**	.499**	0.220	.362**	.489**	.481**
q42	.295*	.493**	.417**	.346**	.330*	.414**	.380**	.298*	.522**	.485**
q43	.416**	.370**	.456**	.331*	.582**	.360**	.351**	0.156	.492**	.333*
q44	.277*	.380**	.339*	0.242	.450**	.460**	.332*	0.231	.597**	.517**
q45	.283*	.268*	.410**	-0.016	.398**	.511**	0.217	0.138	.507**	.394**
q46	.466**	.428**	.579**	.350**	.524**	.443**	0.160	0.216	.390**	.369**

**. Correlation is significant at the 0.01 level

*. Correlation is significant at the 0.01 level

Table (4): The largest eigenvalues (eigenvalues greater than 1) of the index correlation matrix

Eigenvalues of index correlation matrix	1	2	3
	27.179	7.169	2.690
Ratio of total Variation (total variance)	62.335	18.890	5.848
Percentage of accumulated total variation (total variance)	62.335	81.225	87.073

Table (5): The first standard principal component with coefficients of factors

Factors	Coefficients	Factors	Coefficients
Accounting	0.604	information flow and control indices	0.751
Scalability	0.601	Encryption capability	0.720
Decrease in management value	0.686	Inventoary managment in warehousing	0.704
Identify outputs and objectives	0.656	Avoid increasing storage costs	0.708
Ecosystem simplification	0.755	Reliablity	0.708
Control access to information in supply chain management	0.685	Better understanding of management of the activities of the whole organization at any time and thus more accurate planning based on transparency of information	0.708
Demand for sharing information in supply chain management	0.650	Help to fix technical problems in the shortest time and with previous forecasts	0.691
Simplify the current paradigm	6.76	Effectiveness	0.678
Transparency	0.745	Speed	0.678
High quality data	0.674	Time	0.664
Disruptive- Mediation	0.714	Ability to access and view	0.650
High accessibility	0.704	Customer orientation	0.637
Eliminates intermediaries	0.642	Integrity	0.636
Durability and longevity	0.695	Changablity	0.636
Smart System	0.504	Impossibility of data loss	0.623
Supply of parts and consumer goods at the right time	0.677	Detailed review	0.622
Invoices find a specific path	0.613	Cost	0.607
Solve the problem of double spending	0.704	Quality assurance	0.605

Table (6): The second and third standard principal components with coefficients of factors

The second standard principal component		The third standard principal component	
Factors	Coefficients	Factors	Coefficients
Automation	0.718	Returns	0.693
The system deserves trust	0.598	Energy	0.618
increasing the mutual trust among factory units	0.725		
Decentralization	0.729		
Regulations	0.740		
Protections	0.653		
Quality truth	0.615		
Government policy	0.633		

4.3 Kernel Principal Component Analysis (KPCA)

The polynomial kernel function, $k(X,Y)=(X.Y)^d$, is used to perform the kernel principal component analysis. For different degrees from 1 to 3, Kernel matrix eigenvalues are calculated. The first 3 eigenvalues calculated are presented in Table (7). There is an Eigenvector corresponding to each of the eigenvalues, which is actually located in the higher dimension space of the dot product. Eigenvector are skipped here due to their large volume.

Table (7): Eigenvalues corresponding to polynomial kernel degrees

Polynomial kernel degrees		**1**	**2**	**3**
Eigenvalues corresponding to polynomial kernel degrees	1	27.179	25.125	30.142
	2	7.169	7.660	7.985
	3	2.690	2.715	2.824

The eigenvalues corresponding to the polynomial kernel with degree 1 are the same eigenvalues as the standard principal component. Table (7) shows that the eigenvalues increase as the degree of the polynomial kernel increase, and the difference between the eigenvalues for each degree of the polynomial increases. In other words, the role of each component becomes clearer. The degree of a polynomial kernel can be increased to the extent that the eigenvalues corresponding to the degrees of the polynomial kernel do not increase significantly.

Therefore, for degrees higher than 3 for polynomial kernels (degrees 4 and 5), there is no significant change in eigenvalues corresponding to degrees 4 and 5 of polynomial kernels compared to grade 3 kernels. Finally, the degree 3 polynomial kernel has been used. According to the eigenvalues in Table (7), the ratio of variance explanation for the first to third principal components of the kernel has been determined for degrees 1 to 3 of polynomial kernels. The calculated ratios are presented in Table (8).

Table (8): Explanation of variance ratio for kernel principal components

kernel principal components	**Degrees of polynomials**		
	1	**2**	**3**
The first kernel principal components	62.335	63.285	65.306
The second kernel principal components	18.890	19.205	19.315
The third kernel principal components	5.848	5.941	5.995
Percentage of accumulated total variation (total variance)	87.073	88.431	90.616

Table (8) shows when the degree of polynomial kernel increases, the ratio of variance explanation for the first principal component increases but the ratio of variance explanation for the other principal components does not increase significantly. The results show, for d =3, the first principal component explains 65.306% of the total variation (total variance). Given the upward trend in the total variance ratio for the first principal component, the importance of the first principal component, "business," can be highlighted. This indicates, according to blockchain technology, "business" component is of substantial importance in the sustainable supply chain of the steel industry.

Results in Table (8) represent when kernel degree increases, the percentage of accumulated total variation (total variance) increases. (This is quite clear for the first three principal components of the kernel). It should be noted that the three principal components of the kernel provide us with a convincing summary of the information altogether. Nevertheless, considering the first three prinicpal components, the kernel method with grades 2 and 3 explains the data structure much better than the standard principal component method. If a higher percentage of variation is considered, a polynomial kernel with a grade 3 can be considered, because considering the three kernel principal components, a very large percentage of total variation (total variance) is considered. In any case, the kernel principal component method provides us with components that explain the variance of the data better and more clearly.

Table (9): The first kernel principal components with coefficients of factors

Factors	**Coefficients**	**Factors**	**Coefficients**
Accounting	0.620	information flow and control indices	0.780
Scalability	0.618	Encryption capability	0.735
Decrease in management value	0.695	Inventory management in warehousing	0.715
Identify outputs and objectives	0.674	Avoid increasing storage costs	0.715
Ecosystem simplification	0.765	Reliability	0.720
Control access to information in supply chain management	0.695	Better understanding of management of the activities of the whole organization at any time and thus more accurate planning based on transparency of information	0.710
Demand for sharing information in supply chain management	0.685	Help to fix technical problems in the shortest time and with previous forecasts	0.705
Simplify the current paradigm	0.686	Effectiveness	0.685
Transparency	0.760	Speed	0.680
High quality data	0.675	Time	0.669
Disruptive- Mediation	0.725	Ability to access and view	0.674
High accessibility	0.715	Customer orientation	0.652
Eliminates intermediaries	0.645	Integrity	0.639
Durability and longevity	0.698	Changeability	0.639
Smart System	0.615	Impossibility of data loss	0.638
Supply of parts and consumer goods at the right time	0.679	Detailed review	0.635
Invoices find a specific path	0.645	Cost	0.617
Solve the problem of double spending	0.715	Quality assurance	0.615

The first kernel principal component corresponds to the largest eigenvalue of the covariance matrix. The variance of the first Kernel component explains 65.306% of the total variation (total variance). Eigenvector is corresponding to the first Kernel component (the first eigenvector) with relatively large factor loads of information flow and control indices (information flow control), encryption capability, inventory management in warehousing, avoid increasing storage costs, reliability, better understanding of management of the activities of the whole organization at any time and thus more accurate planning based on transparency of information, etc. This represents the "business" component. Given the large number of factors that are involved in the formation of the "business" component, it can be said that the "business" component based on the identified factors affecting blockchain technology in the sustainable supply chain of the steel industry is of great importance. It should be noted that the qualitative truth index has been transferred to the "business" component from the "social" component in the first Kernel component.

Table (10): The second and third kernel principal components with coefficients of factors

The second kernel principal components		The third kernel principal component	
Factors	Coefficients	Factors	Coefficients
Automation	0.725	Returns	0.693
The system deserves trust	0.625	Energy	0.618
increasing the mutual trust among factory units	0.744		
Decentralization	0.750		
Regqulations	0.765		
Protections	0.675		
Government policy	0.643		

The second kernel principal component corresponds to the largest eigenvalue of the covariance matrix. The variance of the second kernel principal component explains 19.315% of the total variation (total variance). Eigenvector is corresponding to second kernel principal component (the second eigenvector) with relatively large factor loads of automation, regulations, decentralization, increasing the mutual trust among factory units; the system deserves trust, protection and government policy, and represents a "social" component.

Considering the number of factors that are involved in the formation of the "social" component, the "social" component based on the identified factors affecting blockchain technology is significant in the sustainable supply chain of the steel industry following the "business" component. It should be noted that the second kernel principal component, qualitative truth index, has been transferred to the "business" component from the "social" component. The third kernel principal component corresponds to the largest eigenvalue of the covariance matrix. The variance of the third kernel principal component explains 5.995% of the total variation (total variance). Eigenvector is corresponding to the third Kernel principal component (the third eigenvector) with relatively large factor loads of returns and energy and represents an "environmental" component. The "environmental" component based on the identified factors affecting blockchain technology in the sustainable supply chain of the steel industry is of great importance following the "business" and "social" components.

The results show that the three standard principal components explain 90.616% of the total variance in total. Considering the first three principal components, the results represent that a substantial summary of information can be presented on affecting blockchain technology in the sustainable supply chain in the steel industry. This can be concluded from Table (10), which shows a diagram of the kernel principal component compared to eigenvalues. In other words, such a diagram clearly shows that only three large eigenvalues of the covariance matrix based on kernel functions can be used.

4.4 Comparing (SPC) and (KPC) Analyses

(KPC) analysis showed that a total of 87.073% of the total variations (total variance) explained by the three standard principal components correspond to the largest eigenvalues of the covariance matrix. But the kernel principal component analysis showed that a total of 90.166% of the total variations (total variance) explained by the three kernel principal components with the grade 3 kernel function correspond to the largest eigenvalues of the covariance matrix. With increasing the degree of kernel, the polynomial accumulated percentage of variance has increased, and therefore the 3 kernel principal components provide us with a better convincing summary in comparison with the 3 standard principal components altogether. In other words, considering the first 3 principal component, the kernel method with a grade 3 functions explains the data structure much better than the standard principal component method.

Table (11): Comparing (SPC) and (KPC) Analyses

Analysis	Percentage of accumulated total variation (total variance)
(SPCA)	87.73
(KPCA)	90.616

5. Conclusions

The findings of this study on identifying the factors influencing blockchain technology in the steel industry's sustainable supply chain indicated that the established factors in three general dimensions of market, social, and environmental have an effect on blockchain technology in the steel industry's sustainable supply chain. The findings are close to those of Golzar et al. (1398), Rezaei and Taeizadeh (1398), Aghaei and Nasser (2019), Nosohi et al. (1398), Hosseinpour (1397), Cole et al. (2019), Mistry et al. (2020), Yadav and Singh (2018), Saberi et al. (2018) and Kshetri (2018).

All the above mentioned researches have studied blockchain technology and sustainable supply chain. The following suggestions are presented based on the results of this research:

1. The capabilities of blockchain technology and its relevance to the manufacturing supply chain, as well as its structure and future new components, can be used to efficiently control a supply chain.
2. The widespread use of distributed ledger technology in the blockchain network provides the global economy with the wide-ranging benefits. Since this technology creates new standards in trade and production, it can be considered and employed by the organizations and industries.
3. The security of critical data can be increased by using a better model and standard contracts.
4. Companies will use blockchain technologies to create a more stable networking environment, promote greater inter-company cooperation, fuel creativity, and open up new market opportunities.
5. Given the speed of change in the field of "blockchain" as well as other technologies that have applications for the manufacturing industry, they need to adapt to a changing business environment.
6. Companies must foster a sense of urgency in their workers to coordinate with blockchain technologies in the workplace so that they can be empowered to build value and respond to developments in the world of technology and business.

7. The high potential of Blockchain will assist companies in meeting consumer demands, such as quicker and safer order fulfillment, communication, protection, confidence, accountability, and consistency, in order to meet customer demands and prevent losing customers to rivals.

8. Since quality assurance is in line with company priorities and generates further benefit and consumer orientation, if blockchain technology is used in Mobarakeh Steel Company, a major effect on quality assurance can be anticipated, according to the findings.

9. Future researchers are suggested to examine the factors affecting blockchain technology in the sustainable supply chain of the steel industry with respect to corporate social responsibility.

Although this research, like any other research, has its limitations, these limitations can open new windows on future research. Therefore, due to the limitations of the research and the challenges of distributing the questionnaire among the statistical population, it is expected that in future research the effect of each of the external factors will be controlled and considered.

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