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Applications of Blockchain Technology for Sustainable Supply Chain Management Systems

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Abstract

This paper explores the applications of blockchain technology for sustainable supply chain management systems with an attempt to address the challenges that are facing the manufacturing industry. The supply chain management systems should be viewed as three components, namely, the strategic component, the tactical component, and the operational component. Therefore, an intervention requires the ability to trace the root cause(s) to ensure that technology-based solutions are tested through the three main components for usability. A systematic review was used for this paper to explore the applications of blockchain technology for sustainable supply chain management systems. This paper advocates for the application of blockchain on the basis that this technology is "the factory of the future" with the capability of creating transparency and traceability through all phases of the value chain from sourcing materials to final production. The findings suggest that blockchain increases auditing and compliance functionality, reduces costs, and creates a reliable ecosystem shipment process to prevent shipping fraud. It should be conceded that there are technical challenges that cannot be overlooked, hence the evidence still suggests that there is a reluctance to adopt blockchain, which is making the industry lag behind. Furthermore, there is the possibility that some industries are still struggling with readiness assessment in order to justify and select the appropriate technologies.

Keywords
Blockchain technology, intelligent systems, supply chain management, value chain, operations management, manufacturing industry, and sustain competitive advantage.

1. Introduction

Manufacturers are facing tremendous pressure from the complexity of the global business environment that demands the integrated system approach to address the improvement of quality, safety, environment, cost reduction and sustain competitive advantage. This challenges the supply chain management systems to create an integrated partnerships linkage that ensures transparency, materials provenance, counterfeit detection, asset tracking, quality assurance, and the regulatory compliance and traceability of the flow of goods and services to the entire value chain. However, it is also imperative that manufacturers observe the second force that is complicating the global business environment in the form of the fourth industrial revolution. On the one hand, some manufacturers have taken advantage to flourish and build sustainable competitive advantage and human capital for sustainability, whilst, on the other hand, some are still reluctant to adopt these new technologies. On the other hand, these technologies create new business models that address some of the challenges.

Interestingly, Weking et al. (2020) declares that „firms lack an understanding of how blockchain technology can create business value for their respective business model". It is envisaged that manufacturers will transition from their traditional ways of doing things to the fourth industrial revolution, to be innovative, restructure, relearn, and adapt. The turbulent business environment demands innovation and change management as a source of growth and competitive advantage. It is imperative to explore the effects of blockchain technology to establish effective strategies for adoption and implementation. According to Kreitz (2007), globalization and international competition are forcing diversity in many arenas, which challenges organizations to adapt to these changes to build and sustain competitive advantage. Galea-Pace (2020), advocates a system readiness assessment of blockchain by manufacturers to address the existing challenges to choose the appropriate technology solutions. Most importantly, to consider the nature of the supply chain management systems, which requires monitoring, transparency, trust at all stages of the value chain, asset tracking, quality assurance, regulatory compliance, and counterfeit detection.

Keil (2019) maintains that blockchain reduces the company's costs, accelerates the whole process, and creates a transparent export ecosystem that could address the lack of poor recording-keeping systems. This paper is organized as follows: Section 1, is the introduction of the paper which cover the problem statement, research questions, aim of the research, and the research objectives. Section 2 presents recent studies on the application of blockchain within the manufacturing industry supply chain management systems; Section 3 presents an overview of the manufacturer's system readiness to adopt the blockchain technologies to create an integrated partnerships linkage that ensures transparency, materials provenance, counterfeit detection, asset tracking, quality assurance, and the regulatory compliance and traceability of the flow of goods and services to the entire value chain: Section 4 briefly provides some insights on the applications of blockchain technology for sustainable supply chain management systems. Finally, the last section presents the conclusion and future research needs

1.1 Problem Statement

Manufacturers are facing tremendous pressure from the complexity of the global business environment that demands the integrated system approach to address the improvement of quality, safety, environment, cost reduction and sustain competitive advantage. This challenges the supply chain management systems to create an integrated partnerships linkage that ensures transparency, materials provenance, counterfeit detection, asset tracking, quality assurance, and the regulatory compliance and traceability of the flow of goods and services to the entire value chain. However, it is also imperative that manufacturers observe the second force that is complicating the global business environment in the form of the fourth industrial revolution. On the one hand, some manufacturers have taken advantage to flourish and build sustainable competitive advantage and human capital for sustainability, whilst, on the other hand, some are still reluctant to adopt these new technologies.

1.2 Research question

What are the best practices for the applications of blockchain technology for sustainable supply chain management systems?

1.3 Aim of the research

This paper explores the best practices for the applications of blockchain technology for sustainable supply chain management systems with the belief that it could address the challenges that are facing the manufacturing industry. The notion is that there should be best practices that address the supply chain management systems in order to create an integrated partnerships linkage that ensures transparency, materials provenance, counterfeit detection, asset tracking, quality assurance, and the regulatory compliance and traceability of the flow of goods and services to the entire value chain. Most importantly, the aspect of the scalability of the integrated supply chain management systems that are adaptive to the everchanging and turbulent business environments.

1.4 Research objectives

The objectives of the paper are, firstly, to establish the characteristics of the current supply chain management systems and the integration of blockchain technologies. Secondly, to determine the extent of the blockchain technologies deployment with the capabilities of addressing the challenges. Thirdly, attempt to ascertain the **know-how** knowledge the supply chain practitioner possesses to address the supply chain management systems. Fourthly, to develop a theoretical model that will facilitate the applications of blockchain technology for sustainable supply chain management systems

1.5 Rationale and motivation

The manufacturers are facing both challenges and opportunities thanks to the advancement of blockchain technologies, which has created an integrated approach to the supply chain management systems for transparency, quality assurance, regulatory compliance, and traceability of goods and services. However, there are still challenges regarding the *know-how* and the scalability of blockchain technologies, and the reluctance of some manufacturers to adopt the technologies. Therefore, there is a need to sensitize both the industry and the supply chain practitioners to shed some insight into the subject to address these challenges. Most importantly, to create a platform of knowledge sharing and organizational learning practices that will enable a culture of continuous improvement and sustainability. The reflection on the current existing supply chain management systems such SAP, ERP, to name few.

2. Recent Studies

The approach to the implementation of blockchain technology has gained popularity in the past years with an emphasis on addressing the challenges of supply chain management systems. Kottler (2018) noted that challenges within the supply chain regarding data monitoring, authenticity, and transparency are due to the lack of understanding of how to implement blockchain technologies. Furthermore, his study suggests that there are limitations in terms of scalability, security, reliability, and accessibility. Despite all these facts, it is imperative to defend the benefits of blockchain and its significance in creating integrated supply chain management systems that enable data information that could address counterfeit products and transparency throughout the value chain. Reflecting on the *know-how* issue, there is a possibility that some manufacturers hesitate to adopt blockchain technologies without proper understanding or alignment with the existing supply chain management systems. Equally, there is an inability to conduct appropriate readiness assessments to identify potential barriers to the implementation and integrate blockchain technologies with the organizational strategy and business model. Whereas Weking, Mandelanakis, hein, Hermes, Bohm, and Krmar (2020) provides some new insights into the impact of blockchain technology on business models. These authors argued that there is little has been done to bridge the gap between possible business value and actual business value delivered. Hence most of the studies regarding blockchain solutions provided insights into the technological and application practices aspects. As a result, their contribution was the business model taxonomy to foster an understanding of how blockchain technology.

Seemingly Galea-Pace (2020) concedes with Weking et al. (2020, p.3) as he claims that blockchain has the potential to reinvent a new manufacturing business model to improve efficiency and product quality. Although he does not overlooks the challenges by pronouncing that there are barriers such as ‘‘maturity of the system, along with understanding, and the willingness to adopt‘‘, which means there is still a reluctance of manufacturers to adopt the blockchain technology. It is not surprising that readiness assessment and organizational change exercise is associated with the willingness to adopt to establish whether an organization has the necessary resources, capabilities, and knowledge of *how* or should be outsourced.

2.1 Readiness Assessment and Organizational Change

The approach to readiness assessment demands leadership and organizational intelligence maturity to use the existing knowledge to build and sustain competitive advantage in business environments. These organizational best practices serve as a foundation for competitive intelligence, meaning the ability of an organization to use its capacity, technology, people, and other resources to gather and analyze data about the business environment, competitors, and global drivers to forecast and predict future strategy. Most importantly, to understand the business environment their operating in. Successfully competitive intelligence is built out of knowledge management and organizational learning culture.

In the view of Akhavan and Pezeshkan (2014) knowledge management is a necessity for organizations to compete successfully and create value for the firm. Although building such infrastructure requires top management’s commitment hence some of the critical failure factors suggest that there is a lack of suitable insight and continuous involvement and support from top managers. Therefore, these could be some of the reasons that are resulting in the relevancy of manufacturers to adopt blockchain solutions. This paper is of the opinion that with knowledge management practices an organization will be in a better position to reflect on the current market standpoint to initiate such a business strategy without being under pressure. Nonetheless, the emphasis on readiness assessment also compensates for such gaps whereby an organization is unsure whether to advance on these new technologies or unknown marketplace. A readiness assessment is all about assessing an organization’s capabilities, knowledge and competencies, responsibilities, and willingness to reflect, monitor, and evaluate its strategic goals.

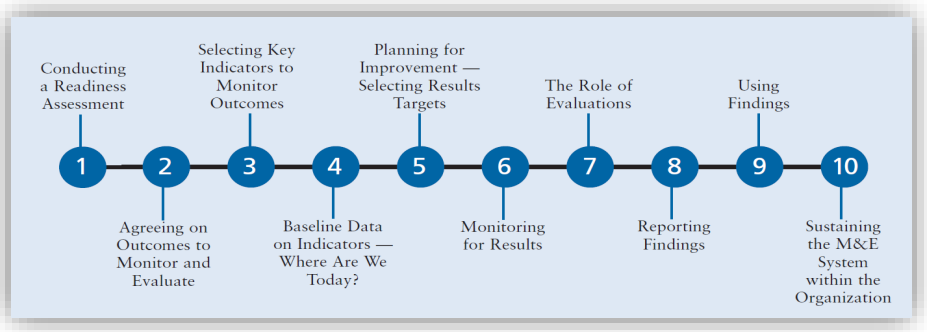

Figure 1. Conducting a readiness assessment (Source: Kusek & Rist, 2004)

The above Figure 1 illustrates the 10 steps of conducting a readiness assessment which could use to build monitoring and evaluation models/systems for an organization. It is worth noting that readiness assessment incorporated with the results-based monitoring and evaluation system enhances productivity (author, year). Coming to the outcome of the readiness assessment the most important part is the lessons learned, which call organizational readiness for change. According to Weiner (2009, p.1), readiness for change refers to organizational members' shared value resolve to implement a change (change commitment) and shared belief in their collective capability to do so (change efficacy)". It is more likely that the challenges of deploying the blockchain solutions' success could be the lack of appropriate readiness assessment and incorporation of lessons learned.

From a business perspective, the supply chain management systems could function better with integrated management systems to ensure quality products and services, stakeholder participation, and continuous improvement of processes (Talapatra et al. 2018,). These authors define integration „as a single set of interconnected processes that share a unique pool of human resources, information, materials, infrastructure, and financial resources to achieve multiple objectives" to meet the stakeholder's requirements. Therefore, an organizational structure is imperative to facilitate the integration of all subsystems to create transparency, and accountability on internal and external issues and products and services, which should be approached from risk-based thinking. In brief, there is a strong possibility that the application of blockchain technology seems to address these issues.

2.2 An Overview of The Application of Blockchain Technology

Blockchain technology has gained popularity in the past years with the capabilities of managing a vast amount of data, forensics, supply chain management, pharmaceutical, energy management, and service security through the value chain, to name but a few. Recent studies have been highlighting the different approaches/strategies regarding the deployment of blockchain technology with the challenges and opportunities. Most importantly, the application of different sectors/industries such as finance, supply chain, healthcare, and construction, attesting the popularity of blockchain technology. As a result, it is imperative to provide an overview of the emerging trends and applications of blockchain technology with the differing perspectives of the industries.

2.1 Emerging trends and applications in the blockchain technology

The application of blockchain and emphasis derives from its capabilities of creating traceability, and transparency, preventing fraud counterfeiting, and assets management. According to Akinbi, MacDermott, and Ismael (2022) there are notable challenges pertaining to the chain vulnerability and complexity of data transit, which requires serious attention to address the security issues, hence there have been several cases of cybercriminals and attacks. Yet, Gad et al. (2022) concedes with the above authors that there are issues around the system security and privacy that influence the use of e-commerce to address the fake product. Seemingly there has been a lack of trust regarding the guarantee of the product ordered online' s authenticity. Meaning that sometimes customers might not receive the exact product they ordered, therefore, such fraud and deceit need to be addressed.

Cheng et al. (2021) noted another emerging trend of integrating machine learning with blockchain technology in the healthcare sector to model intelligent behavior for cancer patients. These authors are of the view that such integration provides various statistical and probabilistic techniques from the vast amount of complex datasets. Furthermore, they claim that blockchain technology has been used for cancer prediction and prognosis and the digital architecture

capabilities ensure the resilience, traceability, and management of healthcare data. Meanwhile, Amponsah et al. (2022) also observed the application of the cloud-based blockchain within the healthcare sector with a particular focus on insurance industry fraud. Apparently, the healthcare sector has been losing billions, for example, Europe has an estimated amount of 56 billion and Korea 798.2 billion annually. Healthcare fraud is a challenge for both developed and developing countries, which calls for preventative measures and effective data management systems to validate, monitor, and control the claims. As a result, Weyori at al. (2022) proposed the application of the cloud-based blockchain (see Figure 2.) to facilitate the claims processing systems.

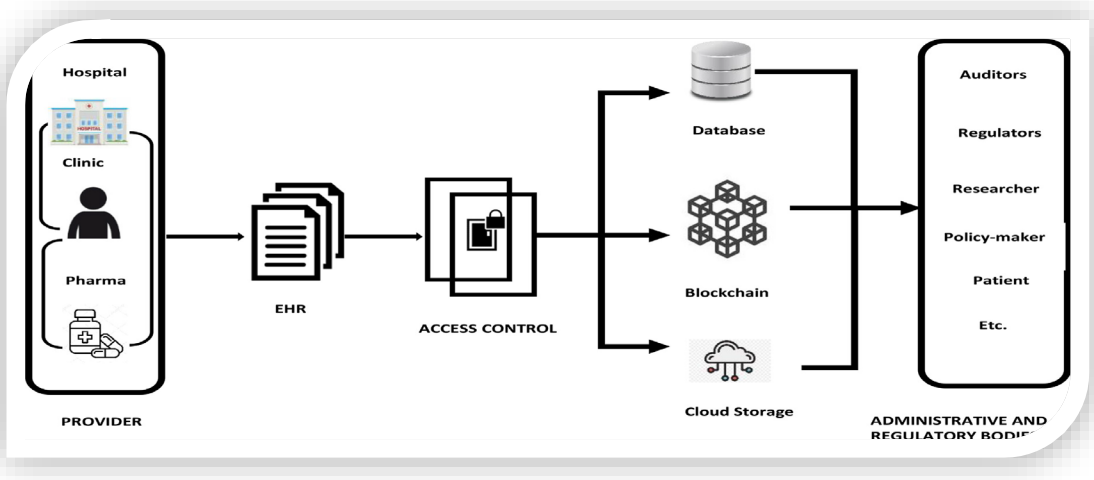

Figure 2. Data Management Framework (Source: Amponsah et al., 2022)

Figure 2 depicts the proposed data management framework of Amponsah et al., 2022 with the notion that this framework has the potential to address the following issues:

- Reduce the claims processing lifecycle
- Speeding the reimbursement of service providers
- Ensures the payment of legitimate claims
- Ensuring the sustainable operations of the scheme
- Inefficient bureaucratic procedure

We also observed the blockchain application in smart grids in order to integrate information and control infrastructure by Hua, Chen, Qadrdan, Jiang, Sun, and Wu (2022) and, in the smart sustainable city by Siddiquee, Khan, Al-Ismail, Allah, Alam and Ahmed (2022), which focuses on the aspects of energy, transportation, healthcare, and agriculture. Although the studies don't provide sufficient knowledge regarding the deployment of the smart city. Interestingly Wu et al., 2022 put forward the challenges that are affecting most countries, the information infrastructure capacity to provide the necessary information for forecasting and prediction analysis and managing the increasing demand of information flow. Most importantly, the accuracy of billing consumers, which means the intelligent operations of power systems is needed to assist cities to address these issues.

2.3 Sustainable organizational performance and knowledge management

The emphasis of blockchain technology adoption is because of sustainable organizational performance and knowledge management through traceability, transparency, and regulatory compliance to name but a few. Khanfar et al. (2021) study suggests that blockchain technology has a direct impact on the sustainability of manufacturing and supply chain management regarding the shared data on the peer-to-peer, open access network, enhancement of traceability, transparency, data immutability, optimize processes of food operations, and reduce unethical practices. This study also ascertains that there is an enhancement of food safety and quality through the use of verification and information-sharing system within the value chain. Although the most important contribution is the confirmation that blockchain

technology "positively influences the reliability and trustworthiness of supply chain transparency, supply chain operations, time of supply chain effectivities, and decision-making efficiency" Khanfar et al. (2021).

However, Dieterich et al. (2017) are of the opinion that there is still an issue of clarification as to what extent the use of blockchain technology has impacted the manufacturing industry. Notwithstanding the fact that there is a significant improvement in theoretical and empirical studies, which have demonstrated different models and frameworks within various industries. Yet, we are of the opinion that some of these frameworks might lack contextualization and integration hence certain elements from different models/frameworks might need to be combined in order to yield the desired results. Sandner et al., (2017) share some insights on the application of blockchain in logistics the use of tracking containers, preventing shipping fraud, preventing the sale of fake goods, and securing the traceability certification.

2.4 Factors influencing organizational adoption

The contributing factors of blockchain technology adoption differ per organization and industry. Although the main factor is the capabilities and desired results in terms of enhancing organizational performance. It is possible as well that some organizations have not yet articulated the precise need or use of blockchain technology due to the lack of appropriate readiness assessment and incorporation of lessons learned. Furthermore, the replication of different models and frameworks without appropriate customization or integration of various elements from these models. For example, see Figure 3 Change management

Lewin	Kotter[27]	Mento et al.[36]	Cummings and Worley[31]
Unfreezing	Step 1: establish a sense of urgency Step 2: create a guiding coalition Step 3: develop a vision and strategy Step 4: communicate the change vision	Step 1: determine the idea and its context Step 2: define the change initiative Step 3: evaluate the climate for change Step 4: develop a change plan Step 5: identify a sponsor	Step 1: motivating change Step 2: creating a vision Step 3: developing political support
Moving (transition)	Step 5: empower broad-based action Step 6: generate short-term wins Step 7: consolidate gains and produce more change	Step 6: prepare the recipients of change Step 7: create the cultural fit Step 8: develop and choose a change leader team Step 9: create small wins for motivation Step 10: constantly and strategically communicate the change Step 11: measure progress of the change effort	Step 4: managing the transition
Refreezing	Step 8: anchor new approaches in the corporate culture	Step 12: integrate lessons learned	Step 5: sustaining momentum

Figure 3. Change Management Integrated Model **Source:** Errida & Lofti, 2021,p.3

Figure 3 depicts the integration of various models to facilitate change management processes that could be used to ensure the deployment of blockchain technology, which a particular focus on sustainable supply chain management systems. From a business perspective, it is imperative that we also outline the factors influencing the blockchain technology adoption within the supply chain management that were noted, namely:

- Real-time transparency and cost savings
- Improvement of profitability and competitiveness
- Improves the firms' sustainability
- Avoid counterfeiting and fraud
- Improvement of sustainable performance

These factors are not limited, we just name but a few. Yet, there are elements regarding the integration of blockchain technology into the supply chain management systems that are probably been overlooked for capacity-building to build a culture of sustainability. Hence the lack of addressing these issues is hindering the deployment of blockchain technology.

3. Methods and Techniques

The paper employed a critical review of the most relevant studies to identify, analyze, and interpret the available variables and evidence regarding the applications of blockchain technology for sustainable supply chain management systems. See Figure 4 With the notion that there are sufficient theoretical and empirical studies that have been exploring this field of study about the critical success factors and technical aspects of things, however, there are still issues of security and transparency to name but a few. Therefore, to avoid a replication of current studies, this study focused on the challenges of deploying blockchain solutions' success through supply chain management systems.

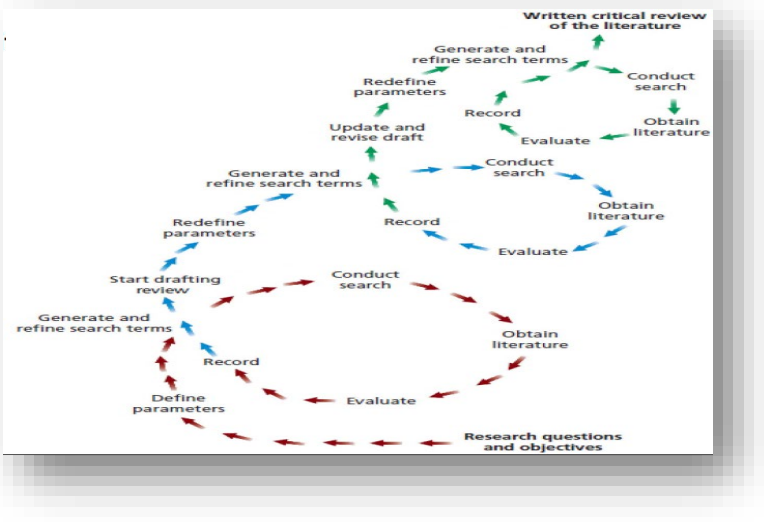

Figure 4. Critical review (Source: Pillai, 2020)

The purpose of providing a critical evaluation and interpretive analysis assists in establishing the progression of a study field and existing evidence regarding the factors influencing the field. In this paper, we managed to provide an overview of the application of blockchain technology and the emerging trends and patterns. Furthermore, the best practices elements for the applications of blockchain technology for sustainable supply chain management systems were noted as well. As a result, this paper presents the proposed theoretical model for the applications of blockchain technology for sustainable supply chain management systems

4. Proposed model for the applications of blockchain technology for sustainable supply chain management systems

Based on the established areas of concern regarding the extent of the blockchain technologies deployment with the capabilities of addressing the challenges within the supply chain management domain. It suggests that the **know-how** knowledge the supply chain practitioner possesses to address the supply chain management systems still lacks in terms of closing the gaps identified by blockchain technology. As a result, the paper proposes a model for the applications of blockchain technology for sustainable supply chain management systems that could facilitate the applications of blockchain technology for sustainable supply chain management systems. We believe that there is a need for an integrated approach to the supply chain management systems for transparency, quality assurance, regulatory compliance, and traceability of goods and services in order to improve the scalability of blockchain technologies. Most importantly, to create a platform of knowledge sharing and organizational learning practices that will enable a culture of continuous improvement and sustainability.

Although within the supply chain management systems we perceive that there is an element that has been overlooked pertaining to the aspect of building a culture of sustainability. We are not disputing the progress that has been made by many researchers and practitioners. To respond to the ever-changing global business environment, it is imperative that industries also reflect on their readiness to adopt these new technologies and learning to learn.

5. Conclusion and future research

The progress of blockchain technology as a field of study has gained popularity across disciplines and industries thanks to the advancement of technologies from healthcare, finance, renewable energy, supply chain, manufacturing, and agri-food value chain management, to name but a few. We also shed some insights on the emerging trends regarding the application of blockchain technology with the contributing factors for adoption and there is no doubt that blockchain is becoming prevalent in all industries' value chains. Enabling visibility across processes and allowing customers to assess information and track products. Yet, seemingly are areas of improvement needed to address the barriers to the implementation of blockchain technology such as conducting a readiness assessment before the adoption. Furthermore, assessing the technologies' actual potential within the context of the adopting organization. As a result, we believe that future research needs to investigate the approach or strategies that industries use to justify and select the appropriate technology with a particular focus on supply chain management.

References

A. Akinbi, A. MacDermott and A. M. Ismael, in: A systematic literature review blockchain-based Internet of Things (IoT) forensic investigation process models. *Forensic Science International: Digital Investigation*. p.42-43, 2022.

A. D. Gad, D. T. Mosa, L. Albualigah, A. A. Abohany, in: Emerging Trends in Blockchain Technology and Application: *A Review and Outlook*, Journal of King Saud University – Computer and Information Sciences. Vol 34, p. 6719- 6742, 2022.

A. S. K. Cheng, Q, Guan, Y. Su, Y. Zeng in: Integration of Machine Learning and Blockchain Technology in the Healthcare Field: *A Literature Review and Implementations for Cancer Care*. Asia Pac J Oncol Nurs; 8:720-4, 2021

S Siddique, M. H. Khan, F. S. Ali-Ismail, A. Ullah, S. Alam, H. Ahmed, in: Blockchain applications in smart sustainable city context: *A systematic mapping study*. Proceedings of the 5th International Conference on Renewable Energy and Environment Engineering (REEE 2022), 24-26 August, 2022, Brest, France

W. Hua, Y. Chen, M. Qadrdan, J. Jiang, H. Sun, J. Wu, in: Applications of blockchain and artificial intelligence technologies for enabling prosumers in smart grids: A review, Renewable and Sustainable Energy Reviews.

Y. Sun, M. Shahzad, A. Razzaq, in: Sustainable organizational performance through blockchain technology adoption and knowledge management in China. Journal of Innovation & Knowledge. Vol.7, 2022.

[D. Jain, M. K. Dash, A. Kumar, S. Luthra, in: How is Blockchain used in marketing: A review and research agenda. International Journal of Information Management Data Insights, Vol.1 , 2021.

V. Stallone, M. Wetzels, M. Klaas, in: Applications of Blockchain Technology in marketing: A systematic review of marketing technology companies. Blockchain: Research and Applications. Vol.2, 2022.

T, Nodehi, A. Zutshi, A. Grilo, B. Rizvanovic, in: EBDF: The enterprise blockchain design framework and its application to an e-Procurement ecosystem. Computer & Industrial Engineering. Vol.171, 2022.

T. Ko, J. Lee, D. Ryu, in: Blockchain Technology and Manufacturing Industry: Real-Time Transparency and Cost Savings. Sustainability, Vol.10, 2018.

A. A. A. Khanfar, M. Iranmanesh, M. Ghobakhloo, M. G. Senali, in: Applications of blockchain technology in sustainable manufacturing and supply chain management: A systemic review. Sustainability, Vol.13(14), 2021

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