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THE ROLE OF BLOCKCHAIN IN THE SUSTAINABILITY OF SUPPLY CHAIN WITH A FOCUS ON THIRD-PARTY LOGISTICS (3PLS)

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ABSTRACT

The identified challenges prompt questions about how Blockchain (BC)-based services provided by Third-Party Logistics (3PL) companies can contribute to the establishment of a sustainable supply chain. The purpose of this study is to explore the role of Blockchain in the sustainability of the supply chain with a focus on third-party logistics (3PLs). Employing a qualitative methodology, the author performs thematic analysis on a dataset obtained from the interviews with 3PLs managers. The study identifies six key aspects of blockchain implementation in a blockchain-driven sustainable supply chain (BT-driven SSC) in the form of one refined framework and sheds new light on the role of blockchain in sustainability in the supply chain. The study results contribute to theory by linking all aspects and adding one new theme, the external environment, with existing aspects in the supply chain namely to use the unique features of blockchain to achieve its benefits it is necessary to overcome blockchain implementation challenges via management skills, connection to other technologies and external environment cooperation. The author also demonstrates that blockchain-based services of 3PLs enhance sustainability. Reliance on data from just accessible managers and firms is a major limitation in this study. The six aspects identified in BT implementation and their relationship or dependence on each other in this study as a proposed framework are recommended for managers of various supply chain echelons to promote sustainability in BT-based SSC. To the best of our knowledge, this is the first study to link all elements of blockchain implementation in the BT-based SSCM to enhance sustainability. Moreover, the author obtains empirical evidence from managers in international 3PLs corporations.

Keywords: Blockchain, Sustainability, Third Party Logistics (3PLs), Supply Chain, Sustainable Supply Chain

INTRODUCTION

Third-Party Logistics (3PL) companies play pivotal roles in the supply chain, undertaking diverse functions as highlighted by Baglio et al. (2019). These companies deliver a broad spectrum of services that significantly influence the cost and efficiency of businesses. The research delves into the specific advantages that blockchain technology offers within 3PL firms and explores how services based on BT within 3PL can bolster the competitive strengths of a sustainable supply chain.

Blockchain technology, characterized by its potential for disruption and incorporation of decentralized database features, facilitates global-scale transactions and the disintermediation and decentralization of processes among multiple parties (Crosby et al., 2016). Ongoing advancements and applications in blockchain technology align with organizational,



technological, and economic improvement objectives (Swan, 2015; Abeyratne and Monfared, 2016).

In recent years, there has been a growing trend among enterprises to outsource logistics to third-party entities (Kroes and Ghosh, 2010; Hilletofth and Hilmola, 2010). Third-party logistics (3PL) agencies, as outlined by Baglio et al. (2019), undertake a myriad of functions, aiming to optimize logistics processes, reduce operational expenses, and enhance overall profitability (Yuan et al., 2020). Concurrently, these agencies must ensure effective management of their activities to align with the ultimate goals of logistics processes, as articulated by Lynch (2001).

Despite the growing research focus on the drivers, barriers, and consequences of 3PLs' low-carbon supply chain initiatives, the majority of studies concentrate on intra-organizational aspects such as transportation execution and warehousing (Colicchia et al., 2013). Comparatively, there is less attention paid to inter-organizational initiatives, such as low-carbon collaboration with customers (Baz and Laguir, 2017). Notwithstanding, Supply Chain Integration (SCI) has garnered substantial attention in Supply Chain Management (SCM) research (Flynn et al., 2010; Huo et al., 2016; Jayaram and Tan, 2010) and has been empirically proven as an effective strategic approach to decarbonizing supply chains (Mao et al., 2017).

Third-party logistics providers (3PLs) grapple with the challenges posed by centralized, and at times, disparate and stand-alone information management systems present in the organizations they serve. This includes struggles with enterprise resource planning systems, which themselves come with inherent drawbacks. Additionally, there is a need for significant trust when supply chain entities consider relying on a single organization or broker for storing their sensitive and valuable information, as highlighted by Abeyratne and Monfared (2016).

The identified challenges prompt questions about how Blockchain (BC)-based services provided by Third-Party Logistics (3PL) companies can contribute to the establishment of a sustainable supply chain. While various studies have explored the conceptual aspects of Blockchain Technology (BT) and Sustainable Supply Chain (SSC), they often focus on general benefits without delving into a comprehensive investigation of the BT implementation in BT-based SSC from all dimensions (BT features, challenges in BT implementation, managerial skills, integration with other technologies, benefits of BT-based SSC and linkage all these aspects). This study aims to investigate how blockchain technology (BT) contributes valuable insights into BT-based SSC within 3PL companies, emphasizing the enhancement of sustainability in SC.

MATERIALS AND METHODS

Data collection

To gather data for this study, I focused on the logistics supply chain, specifically third-party logistics (3PL) companies, and conducted interviews with managers from eight leading multinational firms. These interviews spanned from February 3, 2023, to July 12, 2023. The research approach involved a questionnaire survey, and participants were provided with detailed information about the study and assured of the confidentiality of their data. The questionnaire was designed based on the proposed framework derived from the systematic literature review (SLR). It covered various elements related to blockchain technology-based



sustainable supply chains (BT-based SSC), including attributes of BT, challenges in BT implementation, managerial skills, connections to other technologies, and the benefits of BT-based SSC. The choice to focus on 3PL companies for data collection is contextualized within the logistics field, where numerous functions are performed (Baglio et al., 2019).

Regarding the criteria for selecting 3PL providers, research by Aguezzoul (2014) using the Pareto method identified key factors:

- **Cost:** Cost-related attributes such as price, cost reduction, and operational expenses were found to be crucial, with 68.66% of studies considering cost as a primary criterion.
- **Quality:** Quality-related factors, including service quality, continuous improvement, and adherence to standards, ranked fourth in importance, with 59.70% of studies emphasizing quality.
- **Delivery:** Attributes related to delivery performance, such as timeliness, on-time delivery, and delivery speed, were also significant, with 38.8% of studies taking delivery into account.

These criteria provide insights into the considerations that companies take into account when selecting 3PL providers for their logistics needs.

In addition, 3PL providers offer a means for companies to mitigate financial risks by outsourcing to subcontractors. Investment in logistics assets typically involves significant upfront expenses. In such cases, selecting suitable 3PL providers becomes a critical strategic decision for companies aiming to highlight their core competencies as competitive advantages and entrust other activities to specialized firms (Marasco, 2008).



Interviewees were selected from companies participating in the project, and data collection took place between February and July 2023. The LinkedIn profiles of these companies were monitored, and through a formal procedure involving a questionnaire, relevant managers were invited to participate in the interviews. To ensure that only firms operating as third-party logistics providers in sustainable supply chains were included, their official websites were reviewed to verify the information available on these companies' websites.

Following the completion of the questionnaire and considering the increasing importance of outsourcing logistics to third-party providers in recent years (Kroes and Ghosh, 2010; Hilletofth and Hilmola, 2010), interviewees were selected with a specific focus on third-party logistics (3PL) companies operating within the context of sustainable supply chains on a global scale.

The inclusion criteria for 3PL providers were as follows: the company had to be actively engaged in a blockchain-managed sustainable supply chain system and operate as a multinational corporation. Information was gathered both from secondary sources and through direct contact with the companies, involving cold calls and messages, to identify firms meeting these criteria.

Out of a total of 120 companies participating in the project, only eight 3PL companies with a total of 18 managers were included in the final analysis. To protect anonymity, they have been labeled numerically as 1 through 8, as indicated in **Table 1**.

Table 1. Details of the Interviewees and the Interview Protocol.

Company Category	Interviewee	Operations Scope	Job Title
Logistics-3PL (1)	A, B	Multinational	-Project Manager -Product Manager
Logistics-3PL (2)	C, D	Multinational	-Innovation Manager - Supply Chain Manager
Logistics-3PL (3)	E, F	Multinational	-Project Manager - Innovation Manager
Logistics-3PL (4)	G, H	Multinational	-Product Manager -Project Manager
Logistics-3PL (5)	I, J, K	Multinational	-Innovation Manager -Business Manager -Supply Chain Manager
Logistics-3PL (6)	L, M	Multinational	-Operations Manager -Innovation Manager
Logistics-3PL (7)	N, O	Multinational	-Supply Chain Manager -Innovation Manager
Logistics-3PL (8)	P, Q, R	Multinational	-Manufacturing Manager -Supply Chain Manager -Innovation Manager

Part 1: Implementation of Blockchain Technology (BT) in the Company and Scope of Operation. Criteria for selecting the 3PL company to interview.

Part 2: Questions about the Company Category. Inquiries about the Interviewees' Roles and Job Descriptions to Understand the Level of Expertise and Authority in the Organization.

Part 3: Basic Understanding of the Interviewees about Digitalization in General and Blockchain Technology (BCT).

Part 4: Questions on the Presented Framework Based on the Systematic Literature Review (SLR) Results.

Part 5: Data Gathering, Conducted Directly via Interview or Through the Completion of Questionnaire Forms.

These parts provide a concise overview of the different sections of my interview protocol and what each part entails.

Validity and reliability of the method

We employed Clarke and Braun's systematic guidelines for conducting thematic analysis (2006, 2013) to analyze the semi-structured, in-depth interviews. These guidelines comprise six phases:

1. Familiarization with the data: I began by immersing myself in the collected data to gain a deep understanding of it.
2. Initial coding generation: In this phase, I generated preliminary codes based on key concepts from the literature and applied them to relevant portions of the interview transcripts.
3. Search for themes based on the initial coding: I examined the coded data extracts to identify potential themes that were of broader significance to the research objectives.
4. Review of the themes: The identified themes were reviewed and evaluated to ensure their meaningful alignment with the research questions.
5. Themes identification and labeling: After a thorough review, I selected and labeled five final themes that encapsulated the research findings.
6. Report writing: The final step involved reporting and explaining these themes in the research report.

Phases 2 and 3 played a crucial role in establishing the reliability of the resulting codes before identifying the emergent themes. To ensure reliability, I relied on "reliability as the researcher's interpretative awareness." I implemented a "coder reliability check" by sharing the codes and different participants' transcripts with another coder, with the participants' permission. The percentage agreement between the coders before and after consultation exceeded 75%, indicating reasonable reliability.

To enhance the validity of the qualitative research, I followed the procedural perspective recommended by Creswell and Creswell (2017). This included strategies and approaches to verify the accuracy and credibility of the findings:

- Continuous cross-checking of generated codes and emerging themes with the transcriptions.
- Ensuring the relevance of themes to the research questions.
- Employing a rich and thick description approach to present realistic and detailed narratives.
- Maintaining objectivity during the analysis to minimize researcher bias and promote transparency.
- Ensuring objectivity throughout the interviews, question formulation, and data collection to deepen understanding of the subject.

To bolster the reliability of the qualitative research, I implemented various strategies, such as comparing data with codes and transcripts, preventing drift and shifts in code definitions, documenting the entire research process, and cross-checking codes through memo writing. Additionally, audio files were cross-checked against transcriptions before conducting a thematic



analysis. The themes were double-checked with the transcripts to confirm their alignment with the research questions before reporting them (Creswell and Creswell, 2017).

In this research, the evaluation of the primary data's quality was conducted based on two key criteria:

1. **Validity:** This criterion assesses the extent to which the data accurately reflects the real-world phenomena or aspects that the researcher intended to measure. To ensure validity, the researcher asked themselves whether they directed their questions to the appropriate respondents. In other words, they questioned whether the data collected truly captured the intended aspects of the research subject.
2. **Reliability:** Reliability evaluates the consistency and repeatability of research procedures. It seeks to determine to what extent the same data would be obtained if the research process were repeated. In this context, the researcher achieved a high level of reliability, as indicated by a 99% consistency rate (citing Silverman, 1993). This suggests that the research procedures were highly repeatable, leading to consistent results when the study was replicated.

These two criteria, validity and reliability, are fundamental in ensuring the robustness and trustworthiness of research findings. Validity ensures that the data accurately represents the real-world phenomena of interest, while reliability ensures that the research process is consistent and dependable, producing similar results when repeated.

Data analysis

This study utilized a qualitative approach known as Thematic Analysis as the chosen method for data analysis, specifically adopting an inductive approach.

The inductive research process unfolds through three distinct steps:

1. **Observation:** In the initial phase of inductive research, meticulous observations of the studied phenomenon are undertaken. Various methods, such as surveys, interviews, or direct observation, may be employed to gather comprehensive data.
2. **Pattern Recognition:** Following data collection, the next step involves a detailed examination of the acquired data. This entails scrutinizing the information for discernible patterns, themes, and relationships. The objective is to identify insights and trends that can serve as the foundation for forming initial categories and ideas.
3. **Theory Development:** During this stage, the researcher initiates the creation of preliminary categories or concepts based on the identified patterns and themes from the data analysis. The data is organized into groups based on similarities and differences, establishing a framework for understanding the phenomenon under study.

These three steps often form a cyclical process, allowing the researcher to refine their analysis and deepen their understanding of the phenomenon over time. Notably, inductive research is oriented towards generating new theories and ideas based on the observed data, as opposed to the deductive approach that tests existing theories.



The initial step in the thematic analysis process is to immerse oneself in the collected empirical data, gaining familiarity with its content. This phase involves reading and rereading the transcribed interviews, using note-taking to grasp the underlying meanings and narratives within the data.

In the second phase, initial codes are generated. During this stage, preliminary codes start to emerge from the unstructured data, reflecting relevant aspects tied to research interests, questions, and connections between data elements. This phase involves identifying key concepts from the literature review that are pertinent to the research questions and applying these codes to segments of the interview transcripts that are most relevant and recurrent.

A total of 246 initial codes were generated in this phase, and they were organized into a table for further analysis. Following this, a secondary coding process was conducted to group similar codes together, resulting in a consolidation of 45 codes.

The third phase revolves around scrutinizing the coded data extracts to identify potential themes of broader significance. This step involves further categorization of the codes and an analysis of their interrelationships. Consequently, several themes emerged that were pertinent to the research objectives.

In the fourth phase, the identified themes were reviewed and evaluated to ensure their meaningful alignment with the research questions.

The fifth phase culminated in the selection of five themes that encapsulate the research findings.

The sixth and final phase involves reporting and explaining these themes.



RESULTS AND DISCUSSION

The discoveries arising from the thematic analysis of the collected data encompass themes related to Blockchain Technology, including features, challenges in BT implementation, managerial skills (human resource aspect), digital technology (technology resource aspect), and the benefits of BT-based SSC and depicts the linkage among these themes. These identified themes and connection and reliance among them are systematically presented in the following sections. The narrative sequence is designed to facilitate a coherent comprehension of the research findings. Each section's significance is further expounded upon and illustrated with relevant quotes extracted from transcriptions, organized in separate segments.

It is crucial to note that while this thesis primarily delves into managers' perspectives on BT-based SSC within 3PL companies, the classification and extent of BT implementation in each 3PL company's SSC are integral to the research framework. The study highlights the diverse phases of BT adoption and implementation across the eight 3PL companies, with a predominant use of consortium blockchain as opposed to public, private, and hybrid alternatives expounded.

BT Features and Challenges of BT Implementation

Barriers to implementing BT in SSC encompass factors such as high investment and organizational culture. Furthermore, participants unanimously acknowledged specific challenges related to implementing blockchain in the supply chain of 3PL companies.

Participants elaborated on the comparison between obstacles to blockchain implementation in the supply chain, such as investment costs, lack of awareness, the need for a specialized workforce, and collaborative cultural issues. In this discourse, they emphasized that the distinctive features of blockchain technology stand out more prominently than the challenges, indicating its unique position and potential in the supply chain domain.

The data analysis revealed that the implementation of BT in 3PL companies demanded substantial investment. Some participants expressed the view that a lack of investment posed a significant challenge, particularly for 3PL firms with limited financial resources. Participants indicated that financial constraints hindered their ability to invest in acquiring and implementing BT in their supply chain operations.

Regarding the features of blockchain technology, despite facing obstacles in its implementation, the majority of participants highlighted transparency, traceability, and security as prominent and desirable attributes of BT that motivated their decision to adopt BT.

In summary, gaining access to and leveraging the specific features of blockchain, particularly transparency, tracking, and security, as outlined in the proposed framework of this study and echoed in the responses of participants, entails overcoming several challenges. These challenges encompass high investment requirements, considerations related to organizational culture, the need for increased awareness, and the necessity for a specialized workforce.

Resources

The expectation was that managers with multi-skilled capabilities would demonstrate proficiency in overcoming barriers to the adoption and implementation of BT-based Sustainable Supply Chain Management (SSCM). Moreover, the integration and embedding of digital technologies, such as the Internet of Things (IoT), Radio-Frequency Identification (RFID), Artificial Intelligence (AI), etc., in conjunction with blockchain, were anticipated to provide exceptional advantages for supply chains. This integration, resulting in BT-based SSCM, was projected to contribute to enhanced supply chain sustainability, particularly in emerging markets.

Human resources

It was asserted that a company's capacity to overcome various barriers to Business Transformation (BT) application in Shared Service Centers (SSC) is indicative of its managerial skills. Given the involvement of numerous cross-border activities in Blockchain Technology (BCT)-based Supply Chain and Management (SSCM), the preference is for a diversity of skills over depth. In navigating a highly uncertain and dynamic environment, firms increasingly rely on managers with versatile skills to flexibly handle various tasks (Huo et al., 2016; Oke, 2013). According to participants, all Third-Party Logistics (3PL) companies needed managers with ample management knowledge and skills to serve as critical actors in this domain. There was unanimous agreement that the development of BT infrastructures had significant effects on the digitization and sustainability of the supply chain by ensuring both the availability of BT and the presence of skilled managers, thereby contributing to increased competition.



Likewise, all participants emphasized that, in addition to facilitating BT, the presence of skilled managers enabled companies to effectively manage and overcome challenges posed by blockchain implementation, including addressing cultural differences among employees throughout the supply chain.

Participants consistently highlighted the crucial role of skilled managers in overcoming obstacles related to BT implementation in the supply chain of 3PL companies. This consensus emphasized that the availability of skilled managers is a key success factor in addressing this issue.

In summary, the interview responses highlight the critical role of a diverse set of management skills, encompassing technical and interpersonal abilities like data analysis, leadership, problem-solving, and communication, in overcoming the challenges of BT implementation.

Technology Resources

In conjunction with management skills in overcoming challenges related to BT implementation, as outlined in the proposed framework of this research, the integration of other digital technologies with BT emerges as a key factor in achieving a sustainable supply chain and realizing its intended outcomes. All participants unanimously agreed that, beyond management skills serving as the primary facilitator in navigating the hurdles of blockchain implementation for sustainability, the integration with other technology sources, such as the Internet of Things (IoT) and Big Data, plays a crucial complementary role in the sustainability process of the supply chain.

In essence, participants emphasized that the convergence of BT with other technological advancements, particularly IoT, contributes significantly to supply chain sustainability and enhances the capabilities of blockchain technology. This emphasizes the importance of a holistic approach involving both management skills and the integration of various digital technologies.

Moreover, all participants shared a collective belief that advancements in the digital infrastructure of BT and other technologies have led to an increased demand for skilled employees, particularly proficient managers. Consequently, many managers have actively enrolled in relevant training programs. This has eliminated the hurdle of a shortage of trained professional managers in overcoming challenges associated with BT implementation in the supply chain. Capable, experienced managers are now readily available. Participants also recognized the establishment of specific departments within 3PL companies dedicated to addressing issues related to blockchain and digital technology.

Participants also discussed the impact of the availability of other technologies on the intensification of competition, which all participants viewed as a positive driver for enhancing sustainability in BT-based SSC for 3PLs. Participant K highlighted how the availability of BT and digital technologies has heightened competition, leading to market complexity. They emphasized the need for a strategic approach to manage changes and challenges through skilled managers to survive in evolving markets.

In conclusion, participant N voiced apprehension regarding the sustainability status of food Third-Party Logistics (3PLs) by emphasizing the digital dominance of food chain stores. The participant underscored the urgency of the situation, stating, "*It is now a necessity, an urgent*



one at that. We must act now or never. We have already lost a significant portion of the market. The only viable option to maintain our sales and reclaim the lost market is to harness the capabilities of Business Transformation (BT) and other digital technologies with proper management, accelerating our sustainability efforts."

In summary, based on the insights shared by the interviewees from 3PLs, the importance of not only having skilled managers to navigate and overcome the challenges of BT implementation but also establishing connections with other emerging technologies such as IoT, AI, Big Data, etc., is undeniable. This holistic approach is seen as essential for survival in competitive markets, aligning with the theoretical framework of the study.

Benefits of BT-based SSC

The effective utilization of blockchain attributes within a sustainable supply chain grounded in blockchain necessitates adept management of the challenges inherent in blockchain implementation in addition to the incorporation of other emerging technologies, such as IoT, which is imperative to achieve the benefits of BT-based SSC. This holistic approach possesses the potential to propel BT-based Sustainable Supply Chain (SSC) initiatives within the realm of Third-Party Logistics (3PLs) toward the acquisition of competitive advantages on a global scale.

All participating individuals uniformly characterized the connection among themes in addition to identified themes like advantages of BT-based SSC as a pivotal component within the domain of Supply Chain Sustainable Management (SSCM). Each participant illuminated distinct facets relevant to this core concept and expounded upon the outcomes derived from the sustainability of BT-based SSC, leveraging skilled managers and relevance to other emerging technologies to vanquish challenges and crisis management of obstacles.

It is important to highlight a unanimous agreement among all participants regarding a significant benefit attributed to BT-based SSC, namely the heightened efficiency it brings. The analysis of the gathered data uncovered those participants perceived a direct correlation between the awareness of benefits associated with BT-based SSC and improvements in decision-making. They viewed this awareness as a critical factor for achieving sustainability in the supply chain.

When queried about the benefits of BT-based SSC, participant K highlighted significant enhancements in decision-making, communication, information sharing, and the facilitation of value chain processes within the economic and societal context and emphasized the substantial volume of communication and data exchange occurring across various stakeholders throughout the entire supply chain, each piece of which holds great value.

When participants were queried about BT-based SSC, a common theme emerged as they collectively highlighted the transparency, traceability, immutability, smart contracts, and security features inherent in blockchain technology (BT). They unanimously believed that the integration of BT into the supply chain of Third-Party Logistics (3PLs) has led to a significant enhancement in preventing environmental and social damages as BT benefits. Moreover, it has contributed to a reduction in fraud, consequently improving the overall quality of products and aiming for heightened customer satisfaction.



The participants collectively identified Circular Economy (CE) as a significant and shared benefit arising from the implementation of Blockchain-based SSC. They expressed a unanimous belief that Blockchain (BT) has played a crucial role in fostering Circular Economy principles by reducing transaction costs, improving overall performance and communication along the supply chain, and decreasing resource consumption through enhanced transparency and traceability. This, in turn, facilitates efficient tracking of the provenance of items.

To sum up, based on the review and analysis of the interview responses, regarding the five themes and their interconnectedness with one another, participants consistently highlighted the significant benefits of implementing blockchain to apply its features in the context of SSC for Third-Party Logistics (3PLs). These benefits become accessible when blockchain is integrated with other emerging technologies under the efficient management of skilled professionals to overcome the challenges of BT implementation. The key advantages include: increasing agility and efficiency (Blockchain implementation was seen as a means to enhance the agility and efficiency of operations within the 3PL supply chain); Decision-Making Improvement (participants emphasized that blockchain contributes to improved decision-making processes by providing transparency, traceability, and real-time data); enhancing communications and flow sharing (Blockchain facilitates better communication and information sharing across the supply chain, contributing to more streamlined processes); value chain impact in economic & society (Blockchain was noted to play a pivotal role in preventing environmental and social damages, reducing fraud, and ensuring product and service quality in real-time, thereby positively impacting the economic and societal value chain); reducing waste and discouraging unfavorable practices (participants highlighted the reduction of waste, discouragement of environmentally unfriendly practices, and the promotion of Circular Economy principles as notable outcomes of blockchain implementation); Real-Time quality assurance (Blockchain's ability to prevent fraud and ensure transparency contributes to the real-time assurance of product and service quality); reducing working capital and costs (Blockchain's impact on inventory management and transparency was acknowledged for reducing working capital tied up in the supply chain and minimizing associated costs); boosting Circular Economy (Blockchain was seen as a key enabler for Circular Economy practices, promoting sustainable resource management, waste reduction, and positive consumption behaviors). Overall, the participants specified the multifaceted benefits of blockchain integration in BT-based SSC for 3PLs, underscoring the importance of efficient management and integration with complementary technologies to dominate the challenges of BT implementation and fully realize these advantages.

The findings indicated that, overall, managers in the selected BT-based 3PLs perceive BT as a critical factor in simplifying and improving the efficiency of the supply chain., they expressed the belief that implementing blockchain alongside technologies like the Internet of Things (IoT) and devices such as smart sensors and RFID has significantly enhanced productivity of firm process via reducing time applied in the recording of product movement throughout different stages of the supply chain. This data is then securely stored in a blockchain, and smart contracts are applied to ensure real-time visibility.

Indeed, participants in the study presumed that BT offers the firm a range of advantages, including faster, easier, more precise, and more efficient activities aimed at enhancing the quality of products and services while concurrently reducing costs and time in the supply chain.



The research findings also unveiled another competitive advantage associated with the role of BT in ensuring quality. The ability of blockchain tracking to reveal the individuals handling a product at any given time contributes to safety and quality assurance using blockchain and environmental sensors.

Furthermore, based on the findings, it became evident that supply chain managers, through the implementation of BT, gain lower costs via visibility into the flow of materials. BT's enhanced visibility allows them to strategically reduce the working capital tied up in the supply chain, minimize administrative errors, and mitigate the risk of costly supply chain fraud. These outcomes represent significant competitive advantages, leading to cost reductions and contributing to increased income for the company.

In the context of developing BT infrastructures for achieving sustainability in the supply chain, participants identified it as a critical success factor. They viewed the success of sustainability efforts as being facilitated by several key elements, including the increased availability of BT, a growing pool of skilled managers, and heightened competition. Additionally, the findings revealed that heightened awareness of the benefits offered by BT is considered another significant success factor in its application. Participants highlighted various aspects of this factor, emphasizing increased adoption and implementation of BT, as well as improved decision-making, as concepts intricately linked to a deeper awareness of the advantages associated with BT.

Moreover, the findings highlighted that at the initial stages, 3PLs encounter challenges related to a lack of substantial investment, which is perceived as a hurdle in the implementation of BT. The necessity for significant investment became particularly apparent when discussing the acquisition and implementation of various BT elements, as well as the financial requirements to offset costs stemming from changes within the supply chain. Participants emphasized the pivotal role of investment in overcoming this challenge.

Participants also demonstrated a profound understanding of how the traditional supply chain structure impacts the BT-oriented transformation required for achieving sustainability. They identified various challenges within the traditional supply chain, including organizational culture, hierarchical management, lack of data integration, and a general lack of awareness, all of which pose obstacles to the application of BT in the supply chain of the selected 3PLs.

The research findings further indicated that successful BT implementation necessitates the adoption and implementation of BT across all facets of the firm. These facets are defined by the proposed framework, underscoring that BT implementation is not merely a technical change; rather, equal consideration must be given to its social, economic, and environmental aspects. In the technical signification, participants displayed an awareness that BT is an evolving concept, continuously providing supply chains with new capabilities and benefits. This insight emphasized the need for 3PLs to stay abreast of new technologies in the supply chain, with employees actively staying informed about industry trends.

Crucially, once the necessary technology is acquired, managers play a vital role in encouraging stakeholders to adopt and implement it correctly, ensuring efficient integration with other existing systems. The organizational level represents another critical dimension in the



implementation of BT in the supply chain. Participants emphasized that the traditional supply chain often lacks the appropriate organizational structure to fully leverage the benefits of BT implementation.

The findings suggested that participants recognize the necessity for a shift in the traditional business model and identified specific aspects hindering the effective implementation of BT. Based on these insights, participants expressed a shared perception regarding the imperative for BT implementation at the organizational level, emphasizing the need for changes in the business model and the incorporation of new digital technologies. These findings reinforce the idea that BT implementation goes beyond simply acquiring and using digital technologies; rather, it necessitates the preparation and adaptation of the organizational structure to align with the chosen technological strategy.

The third critical aspect that managers of 3PLs should consider for successful BT implementation is the environmental significance in which the supply chain operates. The findings indicated that participants expressed less concern about technology service providers and regulatory requirements, as they frequently pointed to government plans supporting 3PLs. Instead, participants consistently voiced concerns about competitors and macroeconomics. Notably, they indicated a degree of uncertainty in the political situation and apprehensions about growing competition, considering it a challenge in BT implementation. This insight suggests that participants are more likely to expedite and maximize the benefits of BT implementation if they perceive a positive outlook in the political situation and global competition.

The adoption and implementation of blockchain in supply chains is experiencing significant growth, contributing to the pursuit of sustainability goals. Blockchain technology leverages distributed ledger technology, providing a digital system and database for recording transactions within supply chains. What sets it apart from other IT systems is its unique characteristic of allowing all participants to verify the data. This feature makes blockchain an explicitly transparent tool, giving it a distinct role in the industrial and academic spheres.

The integration of blockchain in supply chains has primarily been explored in terms of reducing fraud risks, achieved through enhanced visibility and precise tracking of supply chain activities. The utilization of smart contracts further streamlines purchasing processes and improves control over the shipment processes, fostering increased trust within the supply chain.

In the technological signification, participants emphasized the importance of adopting and implementing BT and its integration with other technologies such as the Internet of Things (IoT) and Artificial Intelligence (AI). While some 3PL companies were already utilizing specific digital technologies alongside BT, they recognized the existence of other technologies they had yet to explore and implement. Moreover, participants stressed the significance of integrating these technologies to enhance decision-making and address challenges in BT implementation, underscoring the need to combine BT and other emerging technologies with managerial skills within the organization.

Furthermore, managers from selected BT-based 3PL corporations emphasized the pivotal function of blockchain service providers involves assisting and streamlining the process of implementing blockchain technology. They also recognized the government's regulatory



function as a chance or advantage that contributes to the successful implementation of BT in the supply chain. However, participants unanimously agreed that the macroeconomic landscape of societies is significantly influenced by government-imposed regulations, directly impacting the sustainability of BT-based SSCs.

In the environmental, social, and economic significations, all participants acknowledged the vital and crucial benefits BT-based SSC brings, including Circular Economy (CE), human rights protection, and significant earnings or substantial revenue generation. These advantages contribute to achieving competitive edges by reducing time and costs and enhancing quality.

CONCLUSION

The study identifies six key aspects of blockchain implementation in a blockchain-driven sustainable supply chain (BT-driven SSC) in the form of one refined framework and sheds new light on the role of blockchain in sustainability in the supply chain. The study results contribute to theory by linking all aspects and adding one new theme, the external environment, with existing aspects in the supply chain namely to use the unique features of blockchain to achieve its benefits it is necessary to overcome blockchain implementation challenges via management skills, connection to other technologies and external environment cooperation. The author also demonstrates that blockchain-based services of 3PLs enhance sustainability. Reliance on data from just accessible managers and firms is a major limitation in this study. The six aspects identified in BT implementation and their relationship or dependence on each other in this study as a proposed framework are recommended for managers of various supply chain echelons to promote sustainability in BT-based SSC. To the best of our knowledge, this is the first study to link all elements of blockchain implementation in the BT-based SSCM to enhance sustainability. Moreover, the author obtains empirical evidence from managers in international 3PLs corporations.

According to the statements of company managers as interview participants of this qualitative research, I reflect that to modify the framework and improve the literature, one more theme can be added to the framework resulting from the literature review in such a way that uses the unique features of blockchain in the supply chain, as much as the internal factors of the organization, such as excellent management and the skill of linking with other emerging technologies, are involved in overcoming the challenges of blockchain implementation efficiently, but the external factors of the organization, namely government laws, interaction with external partners, professional providers of Blockchain services and support, and role of competitors cannot be ignored and these factors under the name of the external environment, theme sixth, play a substantial role in the final efficiency of blockchain implementation in the supply chain.

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