Managerial approaches to blockchain technology adoption in the rail freight sector: An emerging market perspective

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Abstract

Modern supply chains demand adaptability driven by the globalization of production and markets, the fourth industrial revolution (4IR) and recent events such as the unexpected closure of the Suez Canal, the Russia-Ukraine war, and the Covid-19 pandemic. Investing in digital supply chain technologies boosts end-to-end visibility, mitigates risk, and improves the resilience of supply chains. Many disruptive technologies are currently changing the business landscape in Africa. However, Africa has traditionally been an adopter rather than a pioneer of technologies for business development. Although there has been an increase in the use of blockchain technology in various industries, there is still a challenge of understanding how the technology can be applied in the South African rail supply chain context. Thus, it is crucial to investigate how managers perceive the technology and how this understanding affects the decision to use the technology in the rail freight Container Corridor. A gap exists between the understanding, organizational support and benefits of the technology and its application within the corridor.

A case study approach was utilized to collect primary data obtained through a structured self-administered survey questionnaire. The main findings of the study were that the understanding of blockchain influenced managers perceptions and willingness to adopt the technology. While the railway operator was committed to implementing blockchain, other operational constraints and inefficiencies still present on the corridor were impediments to further investigation. Furthermore, potential benefits and challenges, costs and resources required as well as the impact on current operations and workings were highlighted by management as important decision-making factors.

The study provides valuable insights into disruptive technologies applications within the transport supply chains. It substantiates the significance of how managers view blockchain as a technology to address various challenges as well as enhance operations within the South African freight rail sector.

Introduction

The transportation sector in South Africa plays a fundamental role in economic development, contributing 6,5 percent to the country's Gross Domestic Product (GDP) in 2022 (Labour Research Service, 2022). The rail network in South Africa spans to around 31000 track kilometer (KM) and is primarily utilized for domestic passenger transportation, with an occasional usage for international connections (Transnet, 2021; African Development Bank, 2015). The South African rail system provides a vital link, connecting major cities and stands out as the most advanced and sophisticated rail network on the African continent (Zote, 2022).

An essential link between the economic hub of Gauteng to the port of Durban is the Container corridor, representing South Africa's largest rail corridor. The corridor facilitates the transportation of diverse commodities including fuel, containers, coal, and automotive products (Transnet, 2022). However, losses stemming from various inefficiencies such as limited processes and collaboration, inadequate rail infrastructure as well as continued security concerns favor the use of road transport as an alternative. These inefficiencies have resulted in losses of billions of Rands in various industries and threaten the country's regional and domestic trade (International Trade Administration, 2021)

A road-to-rail strategy proposed by Havenga, de Bod, Simpson, Swarts and Witthöft (2021), revealed the lack of reliable and timely services as a main issue with South Africa's intermodal rail freight terminal. Furthermore, various factors such as the spatial and modal interfaces influence the freight logistics networks interaction between the port and rail users (Pieterse, Farole, Odendaal & Steenkamp., 2016). Enhancing the efficiency and effectiveness of the Container corridor can be done by implementing new operating models at ports and terminals to manage increased cargo volume and offer improved services to their customers. Moreover, the deployment of technology can also be used to improve the daily operations of the corridor. The advent of fourth industrial revolution (4IR) technologies, such as Internet of Things (IoT), Artificial Intelligence (AI), Big Data and Blockchain has opened new possibilities for the operations and management of the railway industry (Veitch, 2022).

Blockchain is a technology that provides security, transparency, and immutability (Deshmukh and Saxena, 2023). Blockchain has emerged as a transformative solution in addressing the various challenges within the context of the Container Corridor. However, the successful implementation of these technologies demands considerable expertise and willingness. Several studies on blockchain across various industries including that of Almekhlafi and Al-Shaibany (2021), Jena (2022), and Shrestha, Vassileva and Deters (2020), emphasize that the users' willingness to adopt new technology plays a crucial role in the rate of adoption. Additionally, social influences which encompass support from superiors and colleagues has been identified as an important factor influencing blockchain adoption (Sharma, Sharma, Singh & Bhatia, 2023). As such, it is essential to examine managers' understanding of the technology and assess how their perception influences their decision to employ the technology in the rail freight Container corridor.

Literature Review

Rail Transport in Africa

Railway lines in Africa span approximately 70 000 kilometers, with an operational rate of around 84% in various regions (Bullock, 2009:4). Rail freight within Africa constitutes only 7% of the global total, while passenger rail contributes to a mere 2% (Wangai, Rohacs, & Boros, 2020). Although African governments have embarked on various initiatives to develop rail transport infrastructure, rail transport still suffers from neglect, marked by insufficient support systems, a lack of financial aid, inadequate strategic planning, and a disregard for the environmental impact (Wangai et al., 2020). Most railway lines in Sub-Saharan Africa are in a state of disrepair, though there are exceptions, such as those in Northern Africa and South Africa, which exhibit better performance (African Development Bank, 2015).

Despite the contribution of transport to the South African GDP, Venter (2022:1) states that sectors such as the iron-ore, coal, manganese mining and chrome sector experience yearly losses ranging between R39 billion and R50 billion in export earnings. The losses, in part, can be attributed to the failure of the South African freight rail system to transport larger volumes of these commodities to different ports. Moreover, as per Venter (2022:1), rail traffic volumes in South Africa have experienced a decline of around 2.9% compared to previous years, while road transport has witnessed an increase of 16.8%. In 2017, South Africa's primary railway operator transported over 230 million tons of cargo (Daniel, 2022:1). Subsequently, freight volumes have steadily declined year-on-year, reaching a record low of 179 million tons in 2021 (Daniel, 2022:1). This downward trajectory continued into early 2022, with a 4% volume decrease compared to the previous year, a trend partially attributed to the impacts of the COVID-19 pandemic and the gradual recovery of economies (Daniel, 2022:1; Grater & Chasomeris, 2022:2).

The diminishing freight volumes are exacerbated by factors such as the deterioration of the rail network and diminishing rail infrastructure (Daniel, 2022:1; (Venter, 2022:1). Consequently, inefficiencies in rail transport have prompted a noticeable shift towards road transport as the preferred modal choice (Daramola, 2022:62). This shift is underscored by the poor performance of the country's largest transport provider Transnet, which has contributed to a myriad of logistics inefficiencies and increased costs. The use of digital technologies to improve the efficiency of rail transport is essential (Popova et al., 2021). Currently, digital technology employed by the South African railway operator directly transmits information about train operations and communicates with drivers through a centralized system (van der Merwe, 2018). However, the centralized system has not addressed the ongoing challenges of the operator

such as increased theft, vandalism and sabotage of the network infrastructure and rolling stock, continued contractual disputes, poor cost recovery and increasing maintenance backlogs. Acknowledging the challenges mentioned, the South African railway operators are actively working on modernizing its rail infrastructure by embracing advanced technologies (Transnet, 2023).

Blockchain technology and its application in supply chains

Blockchain is "a type of distributed ledger which can record transactions securely and transparently" (IBM, 2020:1). Sherman, Javani, Zhang and Golaszewski (2018:1) stated that "blockchain is a shared, immutable ledger that facilitates the process of recording transactions and tracking assets in a business network". Parizo, 2021; Iansiti & Lakhani (2017) confirm the technology as a shared and immutable structure while adding that it provides members with control over information and decision-making processes. It provides transparency, equity and trust while expediting essential information transfer and storage security, ultimately providing innovative solutions and increased interest from various industries (Sharif and Ghodoosi., 2022; Weking, Mandalenakis, Hein, Hermes, Bohm, & Krcmar., 2019).

The implementation of blockchain technology can significantly transform and improve supply chains by ensuring transparency, traceability, and security. This ultimately addresses inherent challenges in global supply chains (Saberi, Kouhizadeh, Sarkis, & Shen., 2018). Transparency and traceability within the supply chain can be achieved by the technology's ability to monitor and record social and environmental conditions across different tiers of the supply chain (Pournader, Shi, Seuring & Koh., 2019). Furthermore, the technology improves security in supply chains by enhancing information and transaction management (Wannenwetsch et al., 2023).

The initial application of blockchain technology was an electronic peer-to-peer payment system Bitcoin which enabled merchants to accept cryptocurrencies for transactional purposes (Hamukuaya, 2021). This paved the way for the integration of the technology across diverse industry sectors contributing to substantial business value (Iansiti & Lakhanil, 2017; Paliwal, Chandra, & Sharma, 2020). The use of blockchain technology within the financial sector has enhanced operational efficiency by expediting banking transactions and lowering costs (Chang, Baudier, Zhang, Xu, Zhang & Aramis, 2020). In the healthcare industry, blockchain technology is employed to securely transfer patient medical records (Jabbar, Lloyd, Hammoudeh, Adebisi & Raza, 2021), while its use in the pharmaceutical sector has the potential to track and trace serial numbers, aiming to reduce costs, enhance security, instill trust, and foster transparency across supply chains (Rayome, 2018).

Within the logistics sector, blockchain technology has been used to manage inventory, track shipments, secure and manage billing and payments, reduce counterfeit trade, and effectively govern contracts (Martynov, 2023). The incorporation of blockchain technology in the transport industry has enabled companies to enhance their payment and billing systems, reduce commissions, and accelerate transactions, while simultaneously facilitating real-time tracking of vehicle movement and providing more accurate trip information (Martynov, 2023). A notable example is that of IBM and A.P. Møller – Mærsk which together launched the TradeLens platform in 2018, aimed at assisting companies to enhancing their supply chain efficiency by providing users with real-time data on freight movement (Musienko, 2023). Similarly, Kuehne + Nagel has created a cloud-based platform, empowering partners to oversee their supply chains to minimize costs and enhance operational efficiency thereby addressing concerns related to fraud prevention and ensuring information security by mitigating errors and inconsistencies (Musienko, 2023).

Within the rail sector, operators such as the Russian Railways (RZD), Thailand's State Railway (STR) and Germany's Deutsche Bahn AG have created innovative applications that have the potential to augment efficiency of business operation (Zasiadko, 2020; Robinson., 2022). Despite many of these applications being in the experimental phase, Morant (2018) suggests, aim to address diverse railway systems management challenges, including signaling, passenger information systems, and ticketing.

The use of blockchain in railway transport

Blockchain technology has the potential to decentralize railway infrastructure management, enabling trains to autonomously make decisions and oversee their routes in a transparent and efficient manner

(Kuperberg, Kindler & Jeschke, 2020). Robinson (2022), highlighted Germany's application of blockchain technology in rail, illustrating how trains can automate their communication. This innovative approach eliminates the requirement for centralized control, empowering trains to make informed decisions autonomously. The implementation of blockchain-based railway control systems in Germany is aimed at not only improving safety but also enhancing operational efficiency, ultimately creating an automatic traffic management system (Kuperberg et al., 2020).

Furthermore, blockchain technology, coupled with sensors, promotes the adoption of predictive maintenance operations, enabling components to autonomously register their requirements (Dutta, Choi, Somani & Butala., 2020). An illustrative example is the ongoing testing of blockchain on locomotives by the Italian railway company Trenitalia (Perasole, 2020). The integration of blockchain and sensor technology empowers the company to improve operational efficiency and safety. Through the utilization of blockchain, the company can proactively safeguard its network against potential failures (Perasole, 2020). Further blockchain initiatives have been the creation of intelligent ticketing systems aimed at reducing reliance on paper tickets for passengers (RSSB, 2020). The United Kingdom (UK) is working on leveraging blockchain for the development of smart ticket system that seeks to be established universally by all train operators in the region (Preece & Easton, 2019).

International collaborations as seen in the partnership between China and Laos, aims to establish blockchain-based trade platforms to facilitate cross-border business transactions (Global Times, 2022). The objective of such an initiative is to offer a secure cost-effective means to engage in business transactions ultimately improving the country's transportation system. While blockchain technology is finding value in global rail industries, its development and utilization in the African and South African railway sectors are currently limited or nonexistent. Only Transnet, South Africa's leading transport operator, has initiated projects to pilot blockchain solutions (Mackenzie, 2018)

Drivers influencing the adoption of blockchain technology.

The most prevalent drivers in blockchain adoption have been technology innovation (Gaur & Gaiha., 2020; Kuperberg., 2021; Xie, Chen, Qu, Fan, Tang, Zhu & Wang., 2020), fraudulent transactions (Ye & Zeng., 2021; Saberi et al., 2018; Xu., 2016; Cai & Zu., 2016), pressure from customers (Lukrozo., 2020; Tan & Sundarakani., 2021; Sharedo, Patil & Madaan., 2020) and pressure from internal and external stakeholders (Geroni., 2021; Jardim, Pranto, Ruivo & Oliviera., 2021). Technological innovation has revolutionized the supply chain, optimizing goods delivery, financial access, traceability, and partner relationships (Gaur & Gaiha., 2020). Countries like China, Australia, and Russia are exploring blockchain to enhance railway systems, addressing issues from value transportation to administrative authentication (RSSB, 2020; OECD, 2018; Fraga-Lamas, Fernandez-Carames & Castedo., 2017; Kuperberg, 2021). The introduction of blockchain in railway freight transportation holds potential for modernization and improved stakeholder connectivity, addressing the industry's need for innovation (Xie et al., 2020).

The surge in fraudulent transactions amid increased digitization has fueled the adoption of blockchain technology across several sectors (Javaid, Haleem, Singh, Suman, Khan, 2022). Leveraging its immutability and security features, blockchain can effectively prevent unauthorized activities (Ye & Zeng, 2021; Saberi et al., 2018), offering a secure and transparent means for businesses to conduct transactions and combat fraudulent activities (Swan, 2015). While studies by Cai, et al., (2016) showcase blockchain's potential in preventing objective information fraud, research by Xu (2016) highlights the need for further research to address vulnerabilities.

The rail industry in South Africa boasts Mediterranean Shipping Company (MSC), Maersk, Ford Motor Company, Toyota Motor Corporation, Puma Energy, Shell Global, Total Energies and Engen Petroleum as some of its most valued customers (Transnet, 2022). However, its popularity amongst these and other customers has declined due to unreliable services (Lukrozo, 2020. The implementation of blockchain technology is driven by customers who demand competitiveness and sustainability in rail freight operations, providing transparent and flexible services to their business objectives (Tan & Sundarakani, 2021; Sharedo, et al., 2020). Railway operators often engage with a range of stakeholders, including the Government, employees, management, labor unions, suppliers, media, customers, and credit rating agencies, to respond promptly to concerns and to integrate stakeholder inputs into their

business plans. Jardim, et al., (2021) emphasize that blockchain technology's ability to track and trace company activities is a crucial incentive for implementation while Geroni (2021) highlights its potential for real-time asset tracking and executing smart contracts.

Toth, Padayachee, Mahlatji and Vilakazi (2022), reported that the industrial sector's acceptance of new technologies such as the blockchain, centers on factors such as reliability, certainty and economic value associated with the technology for its intended applications. This often prevents innovative advancements from realizing their full potential, primarily due to absences in skills, knowledge, market access, and a comprehensive understanding of the economic advantages the technology could bring (Chua, Wong and Yeong., 2017). Additionally, factors such as the maturity, relative advantage and organizational readiness is also considered in the decision-making process when it comes to adopting blockchain technology (Wang, Liu, Liu & Huang, 2022:1). Aside from the drivers and potential benefits to enhance the supply chain, blockchain adoption is also influenced by the actual user's perception of the technology. A study by Dehghani et al. (2022) indicated that while data quality and interoperability were drivers to adopting blockchain, technological volatility, regulatory uncertainty, standardization uncertainty and the perceived lack of technological knowledge were barriers.

The incorporation of blockchain technology into supply chain practices stands as a promising avenue for organizations to elevate their supply chain management (SCM). The utilization of blockchain-based systems for automating routine tasks empowers supply chain professionals to focus on critical aspects of their roles, fostering improved decision-making and overall performance (Oracle, 2022). To fully leverage the advantages of blockchain technology in SCM, organizations must develop a comprehensive understanding of the technology and its implementation in the organization's operational context. This research investigates how managers on the South African rail Container Corridor perceive the technology and how this understanding affects the decision to adopt blockchain technology.

Despite the transformative potential and indications to pilot blockchain solutions, no research exists on the actual implementation and impact of the technology on the Container corridor operations. The study aims to provide valuable insights to the South African rail transport industry, facilitating informed decision about blockchain technology to optimize supply chain operations and enhance overall competitiveness in the transport sector.

Research Methodology

A quantitative, exploratory case study approach was used to explore the understanding of blockchain technology by managers on the Container Corridor. Specifically, the study attempted to determine how the technology is understood in a fright rail context, what the planned and current use of the technology was and what drivers to adopt the technology could be identified. The respondent organization (name withheld due to confidentiality) is a multimodal transport operator in South Africa. The respondents were managers of different levels across various departments within the Container Corridor. Management work experience was important as their knowledge of issues and processes influence the implementation of innovative solutions. Cross-departmental analysis provided insight into the current and possible applications of blockchain technology while the level of management influenced their perception and willingness to adopt or further develop the technology. Data was collected using a closed-ended survey questionnaire, distributed to 115 managers during the first quarter of 2022 of which 100 responses were received. The sample size of 100 responses is justified by their representativeness and statistical power. A high response rate ensured in-depth exploration and analysis of blockchain technology adoption within context of the Container corridor. Furthermore, the large sample size provided statistical power for meaningful analysis to align with the study objectives. The survey instrument consisted of multiple 5-point Likert-scale items related to the understanding, utilization, and drivers of blockchain technology within the freight rail Container Corridor. The results of the study were analyzed using IBM SPSS Statistics 28.0. Various descriptive statistics were calculated such as means, standard deviations, frequency distribution, and reliability analysis. Mean scores and standard deviation were used to describe the level of understanding and planned utilization of blockchain technology along the corridor. By generating frequency distributions, the researchers were able to analyze the support initiatives and drivers influencing technology adoption. SPSS further assisted with a reliability analysis using Cronbach's

alpha which assesses the internal consistency of measurement scales within the questionnaire. As all constructs indicated values greater than or equal to 0.70, the internal consistency and reliability of measurement scales related to blockchain understanding and adoption are acceptable.

Findings and results

Managers perceived understanding of blockchain technology

How managers understand blockchain technology was deemed an important measure in their willingness to adopt or further develop the technology along the corridor. The results investigated the understanding as perceived by all other managers as well as executive managers only. Executives greatly influence the adoption of technology based on various attitudes, subjective norms and perceived control (Riemenschneider et al., 2003). From the results, there appears to be a high level of understanding of blockchain technology as a "software protocol" and "system of recording information" and this is indicative of the broader and basic understanding of the technology. Executive alone showed a slightly higher understanding of these definitions although in context of the operations of the Container Corridor, these are marginal.

Blockchain technology concerning its "enhancement to supply chain" (mean 4.06) and "providing all parties….with access to information" (mean 3.68) was less understood as the technology is usually associated with financial and cryptocurrency application which are not the core focus of operational activities on the Container Corridor. The difference between other managers and executive managers is marginal and may be attributed to the corridors ongoing commitment to implementing various technologies.

The degree of understanding of blockchain technology	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Mean – other managers	Mean score for executive managers
Blockchain is a software protocol for the secure transfer of unique instances of value (e.g., money, property, contracts, and identity credentials) via the internet without requiring a third-party intermediary such as a bank or government.	0%	0%	40%	30%	30%	3.90	4.53
Blockchain is a system of recording information in a way that makes it difficult or impossible to change, hack, or cheat the system	0%	0%	19%	45%	36%	4.17	4.18
Blockchain technology enhances supply chain management through process tracking, regulatory compliance, and reporting.	0%	0%	18%	58%	24%	4.06	4.06
Blockchain is an unchangeable distributed digital ledger with many uses beyond cryptocurrencies	0%	8%	44%	20%	28%	3.68	4.06
Blockchain provides all parties within a respective supply chain with access to the same information, potentially reducing communication or transfer data errors.	0%	8%	22%	50%	20%	3.82	3.94

Table 4.1: Respondents understanding of blockchain technology.

Current use of blockchain technology on the Container Corridor

Table 4.2 indicates that 40% of all departments "are developing prototype applications" for the use of blockchain. Departments such as Infrastructure (73%), Operations (41%) and Risk and Safety (64%) were at the forefront of this development consistent with blockchains ability to automate processes, safeguard rail consignments, enhance transparency and address data and information management issues. A

further, 28% "expect to have blockchain applications in production within the next 12-24 months", while 12% indicated that they were "experimenting" or currently have "blockchain applications" in production. Interestingly 20% of respondents indicated that they "did not know". Most of the respondents were from departments that are not directly related to blockchain activities although this may also indicate that they do not understand how and where the technology is currently employed. This reinforces the need to properly and fully understand how the technology works in a specific operational context.

The use of blockchain	Operations (%)	Infrastructure (%)	Risk and Safety (%)	Strategic Projects (%)	Other (%)	Total Percentage
We are developing prototype applications.	41	73	64	26	20	40
We expect to have Blockchain applications in production within the next 12-24 months.	15	27	36	35	40	28
Do not know	35	0	0	12	40	20
We are currently experimenting with Blockchains	9	0	0	15	0	8
We now have blockchain applications in production	0	0	0	12	0	4

Table 4.**2**: Current use of blockchain technology (N = 100).

Following the current use of blockchain technology, respondents were asked about their planned implementation of the technology. Executive management believed blockchain implementation was inevitable while almost a quarter of other management were more reserved stating that it would not be adopted unless it proved beneficial (14%), that they did not need blockchain (5%) or that it was unlikely to be adopted (5%). Blockchain is a relatively new technology and has not been explored in all sectors and applications. The need to wait for the "right time and required capability" is driven by the technology meeting specific business requirements and the difficulty in switching to different technological infrastructure. The need to "clarify some queries and justify adopting blockchain" can be attributed to the various adoption drivers, both technical and non-technical, that influence management decisions. Furthermore, the "need to get solutions" could be explained by the poor performance of the railway operator and thus, a major hinderance to adopting blockchain technology.

Planned implementation of blockchain technology	Executive management (%)	Other management (%)
Will not adopt blockchain unless it proves beneficial for us.	0	14
Will wait for the right time and required capability to adopt blockchain.	24	23
Needs to clarify some queries and justify adopting blockchain.	24	29
Needs to get solutions for some of our complaints/objections before adopting blockchain.	53	24
Does not need blockchain.	0	5
Is unlikely to adopt blockchain in the near future.	0	5

Table 4.3: Planned implementation of blockchain technology (N = 100).

To explore the drivers of blockchain technology.

The drivers of blockchain technology	Not probable	Somewhat improbable	Neutral	Somewhat probable	Very probable	Mean
Technology innovation	0%	0%	24%	40%	36%	4.12
Pressure from external stakeholders	0%	8%	28%	36%	28%	3.84
Pressure from customers	4%	8%	24%	40%	24%	3.72
Fraudulent transactions	4%	12%	40%	36%	8%	3.32
Pressure from Railway operator internal stakeholders	8%	12%	36%	36%	8%	3.24

Table 4.4: Drivers for the implementation of blockchain technology on the Container Corridor (N = 100)

The most significant driver for adopting blockchain technology on the Container Corridor was "technology innovation" (mean 4.12). Blockchain can improve the decision-making process for cargo owners seeking increased volume demands. The use of smart sensors and drones to monitor railway tracks address cable theft, derailments and cargo theft which have been persistent problems along the corridor. Other significant drivers were "pressure from external stakeholders" (mean 3.84) and "corridor customers" (mean 3.72). External stakeholders and customers such as shipping lines and cargo owners from the mining and minerals, automotive and petroleum industries value improved tracking and tracing of shipments to ensure faster turnaround times and improve the efficiency of various automated processes. The supply chain visibility benefits that blockchain affords, could incentivise the movement of cargo from road to rail transport. "Fraudulent transactions" (mean 3.32) and "pressure from internal stakeholders" (mean 3.24) were less likely to drive blockchain adoption although in principle, these could address many of the inefficiencies of the railway operator.

The adoption of blockchain technology will enhance supply chain management practices	Extremely Unlikely	Unlikely	Neutral	Likely	Extremely Likely	Mean
Real-time information sharing	0%	0%	12%	36%	52%	4.40
Visibility	0%	0%	16%	36%	48%	4.32
Cyber security	0%	4%	12%	40%	44%	4.24
Transparency	0%	0%	28%	28%	44%	4.16
Reliability	0%	0%	12%	60%	28%	4.16
Traceability	0%	0%	16%	52%	32%	4.16

Table 4.5: The likelihood of blockchain to enhance supply chain practices.

Despite indicating less understanding of blockchain in a supply chain context (Table 4.1), respondents viewed all features of blockchain as 'likely to extremely likely" to enhance supply chain management practices. Each of these features addresses key strategic risks in the South African freight rail sector. Real-time information sharing drives predictive maintenance of infrastructure which ensures a reliable service and may increase the rail market share. Visibility can improve the financial sustainability of the railway operator and enhance contract management. Cyber security not only facilitates cargo security, but the overall lack of ICT infrastructure has been a major impediment to achieving the business objectives of the railway operator. Transparency was cited as an important factor for enhanced customer collaboration and partnerships. Reliability is strategically important as the railway operator as unavailability, underinvestment and obsolesce has continually affected the operator's capacity to meet customer demands. Lastly traceability mitigates the procurement risk as current procurement practices have hindered the efficiency of the operator.

Discussion and conclusions

Managers across various departments and experience level within the Container Corridor were targeted for this research due to their pivotal and influential role in decision-making. Table 4.1 highlights the various definition of blockchain technology with notable recognition for blockchain as a software protocol or a system of recording information. However, definitions related to the supply chain, such as blockchain enhancing supply chain management and providing information to all parties, were less understood particularly by executive managers. This lack of understanding may have influenced responses to other questions, and this was considered in the analysis of the data.

Consistent with studies by Falcone, Steelman, and Aloysius (2020), Saberi et al. (2018) and Wang, Han and Beynon-Davies (2019) managers' perceptions and willingness to adopt blockchain, play a significant role in its implementation, while a barrier to adoption in the supply chain is posed by a lack of knowledge and expertise; this knowledge gap can lead to misconceptions, impeding the technology's widespread

adoption. Despite the prevalent use of blockchain technology, supply chain managers, as highlighted by Saberi et al. (2018), remain unaware of its potential to enhance operations. This lack of awareness may hinder management on the Container Corridor from fully embracing the technology, indicating a necessity for increased training and education on blockchain use in the Container corridor. Such efforts could promote technology adoption and enhance the overall efficiency of the rail supply chain.

Pournader et al (2019), emphasised that blockchain adoption needs to be aligned with the organisational goals and objectives. Findings of this study indicated that various departments are in different stages of blockchain implementation along the corridor which is consistent with the respondent organization's goal to enhance technological capabilities. Surprisingly, some managers in the same department indicated different stages of blockchain development. While this emphasises the lack of understanding and use of the technology, its greater implication as suggested by McKenzie et al. (2011) is that knowledge management contributes to better decision making. Previous research by Gurcan (2021) and Broni and Owusu (2020) mentions that the adoption of blockchain technology is conditional and similar results were found in this study.

Technological innovation was stated as the most significant driver of adopting the technology, and this is related to research by Olnes, Ubacht, and Janssen (2017) and Jena (2022). "Pressure from railway operator internal and external stakeholders," was an important finding in this study and resonates with Balci and Surucu-Balci (2021) emphasis that stakeholders may influence blockchain technology adoption. Similarly, "Pressure from Container Corridor customers" aligns with Saberi et al.'s (2018) suggestion that customers demand transparency. The influence placed by stakeholders and customers highlights their significant role in shaping the functioning of the corridor, often leading to the adoption of new technologies. Blockchain may have a significant impact on supply chain management practices and comparable results were stated by Khurshid, Zahid, and Rehman (2023); Liu, Xiang, and Sun (2022); Osmani, El-Haddedeh, Hindi, Janssen, and Weerakkody (2020); Shafay, Ahmad, Salah, Yaqoob, Jayaraman, and Omar (2022); Polyviou, Velanas, and Soldatos (2019); Yu (2022); Kumar, Lahza, Sreenivasa, Shawly, and Alsheikhy (2023). This study aligns with previous findings that highlight the enhancement in supply chain practices with the adoption of blockchain technology. Since the study did not specifically address the use of blockchain technology on the Container Corridor, the impact and operational performance of the technology cannot be determined.

The research undertaken, highlights the diverse understanding of and adoption attitudes of blockchain technology amongst managers from various departments and experience level within the Container corridor. Managers influential role in decision making processes makes their perceptions and willingness to adopt blockchain crucial for successful implementation. This study further revealed the lack of understanding regarding blockchains application in the supply chain, such as enhancing supply chain management and providing information to all parties. This lack of awareness may have influenced responses to other questions and poses a potential barrier to the widespread adoption of blockchain technology within the Container Corridor.

Consistent with prior studies by Molla et al. (2016) and Riemenschneider et al. (2003), the success of blockchain implementation is underscored by the significance of managers perceptions and knowledge. A knowledge gap can lead to misconceptions and hinder the technology's adoption. Therefore, there is a clear need for increased training and education on blockchain use in the Container Corridor, aimed at enhancing the overall efficiency of the rail supply chain.

The study also highlighted that blockchain adoption should align with organizational goals and objectives. Various departments within the Container Corridor are at different stages of blockchain implementation, reflecting the organizations' goals to enhance technological capabilities. However, the disparity in stages of blockchain development within the same department emphasizes the need for better understanding and application of the technology.

Technological innovation emerged as a significant driver for adopting blockchain, with pressure from internal and external stakeholders, as well as customers, influencing the decision-making process. Stakeholders and customers play a crucial role in shaping the functioning of the corridor, highlighting the impact of their demands on the adoption of new technologies. Despite the study's alignment with previous findings by Pournader et al. (2020), Saberi et al. (2019) and Wannenwetsch et al. (2023) regarding

the positive impact of blockchain on supply chain practices, the ongoing deterioration of the railway operator's operational and financial performance remains and will remain the major obstacle to any technological advancement on the Container Corridor.

Limitations and directions for future research

As a singular case study limited to the Container corridor, the study's findings cannot be generalized and applied to the broader sector. The study did not consider the viewpoint of other key stakeholders such as customers, cargo owners, and freight forwarders which are key for understanding how the technology works and identifying future growth opportunities. Importantly, the study did not formulate a blockchain model that can be used as a framework for logistics development in the rail freight sector.

Future research should consider the use of other data and digital technologies within the railway industry and the influence this has on the potential adoption of blockchain technology. Research into the practical implications of blockchain adoption in specific context of the Container Corridor will provide a more comprehensive understanding of its effects on operational efficiency and supply chain management. While the current study focused on rail freight transport, there is greater potential for the application of the technology in passenger rail services. Lastly, there is a need to further understand the recurring challenges within the South African rail freight sector and explore how blockchain and other such technologies can mitigate the problem.

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