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Applying blockchain to improve supply chain transparency, visibility and traceability in South African manufacturing sector

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Orientation: Manufacturing supply chains in South Africa face various challenges, including the lack of traceability, transparency and interoperability between supplier platforms. The use of innovations such as blockchain technology (BT) can help address these challenges due to its features, including decentralisation, transparency and immutability.

Research purpose: The study proposes a framework for manufacturing based on BT, which could offer an information platform for all stakeholders with transparency and information sharing.

Motivation for the study: Poor traceability, opaque supply chains, and counterfeiting continue to plague South Africa's manufacturing sector, undermining productivity and competitiveness in the global market. By increasing transparency and visibility throughout supply networks, blockchain's decentralised, tamper-resistant architecture presents a potential remedy. Therefore, the need to investigate how blockchain can help with these issues and promote more dependable and effective supply chain procedures is what spurred this study.

Research design, approach and method: The study employed a quantitative approach, distributing questionnaires to 287 purposively sampled respondents drawn from manufacturing firms in selected provinces of South Africa. Structural equation modelling, based on the smart partial least squares technique, was employed to test the hypotheses.

Main findings: The results reveal that BT practices (immutability and provenance) have a significant influence on supply chain transparency (SCT). However, security as a BT practice has an insignificant influence on SCT. Furthermore, SCT has a significant impact on both SC traceability and visibility. The study suggests that the implementation of BT practices is vital in influencing SCT.

Practical/managerial implications: Managers must dynamically foster cross-functional and cross-organisational collaboration. Because BT operates most effectively in a consortium-based environment, leadership should engage suppliers, customers, regulators and technology providers early in the implementation process to create a shared governance framework.

Contribution/value add: This study contributes to the digital transformation and supply chain management literature, as it is one of the groundbreaking studies focusing on BT practices, SCT, traceability, and visibility in South African manufacturing firms.

Keywords: small and medium enterprises; manufacturing; supply chain strategies; resilience; performance.

Introduction

In today's global village, supply chains (SCs) have become ever more complex, involving many stakeholders across diverse geographical regions in the world. Yet, this intricacy normally leads to challenges in warranting trust, traceability and transparency, within the SC (Kumar et al. 2025a). Problems such as counterfeiting, unethical sourcing practices, environmental concerns and fragmented data management systems have become persistent obstacles in the pursuit of a more efficient and sustainable SC ecosystem (Pooja, Chikhale & Dhir 2025). As a response to these challenges, blockchain technology (BT) has emerged as a transformative solution that holds the potential to revolutionise the global SC landscape (SC). Blockchain, initially introduced as the underlying technology behind cryptocurrencies such as Bitcoin, is a decentralised

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and immutable ledger system that allows secure and transparent recording of transactions and data (Zaman et al. 2025). The technology operates on a network of computers, or nodes, where each node holds a copy of the entire ledger, ensuring that any alteration to a record is evident across all copies, thus mitigating the risk of tampering and fraud (Kumar et al. 2025b). In recent years, the potential of BT to enhance SC transparency has gained significant attention from both industry players and regulatory bodies (Zaman et al. 2025). With its unique features of immutability, data integrity, security, provenance and stakeholder collaboration, blockchain offers a promising avenue to address the complexities and inefficiencies such as traceability and visibility that have inundated the global SCs.

One of the fundamental challenges that blockchain addresses is the need for end-to-end traceability and provenance of products (Zhan et al. 2025). Traditional SC systems often lack real-time visibility, making it difficult to track products from their origin to the final consumer. Blockchain's inherent ability to record every transaction and movement of goods allows for a transparent trail that can be accessed by all relevant parties, ensuring authenticity and quality assurance throughout the SC (Kumar et al. 2025b). Furthermore, data integrity is a crucial concern in supply chain management (SCM). Instances of data manipulation, whether intentional or accidental, can result in severe consequences and loss of trust (Al-Qudah, Al-Okaily & Yadav 2025). The BT utilises cryptographic techniques to ensure that data remain secure and tamper-proof. Any attempt to alter information within a block is immediately detected, thereby reinforcing the credibility and reliability of the SC data (Zhan et al. 2025).

In addition, blockchain's incorporation of smart contracts has the potential to revolutionise SC processes (Al-Qudah et al. 2025). These self-executing agreements automatically trigger actions when predefined conditions are met, reducing the need for manual interventions and intermediaries. Smart contracts can streamline processes such as payment settlements, compliance checks and quality assurance, thereby reducing administrative overhead and minimising the risk of errors and disputes (Raja et al. 2025).

Numerous real-world applications of BT in global SCs have already showcased its potential. In the food industry, for example, blockchain has been utilised to enhance food safety (Al-Qudah et al. 2025). Consumers can scan a product's QR code to access information about its journey through the SC, from farm to table, ensuring the authenticity and safety of the food they consume. Similarly, in the pharmaceutical sector, BT is being leveraged to combat the prevalence of counterfeit drugs by enabling patients and regulators to verify the authenticity of medications, thus ensuring patient safety (Raja et al. 2025). The growing emphasis on sustainability and ethical practices in business has also driven the adoption of blockchain in manufacturing firms' SC (Al-Qudah et al. 2025). Firms are using BT to transparently track and showcase the sustainability of their products, enabling consumers to make informed choices in favour of eco-friendly and socially responsible products (Raja et al. 2025).

Blockchain applications are currently evolving from pilot trials to real-world applications. A Report by GlobeNewsWire (2025) projected that global blockchain market is to surge to $306 billion by 2030. This is particularly relevant to SCM, as SC blockchains represent one of the most promising opportunities for the implementation of the distributed ledger technology (DLT) (Vern et al. 2025). In South Africa, various studies have been conducted on BT mostly in the cold SC (Chavalala et al. 2024; Khan, Singh & Kirti 2022; Mthimkhulu & Jokonya 2022). However, the lack of a thorough understanding of the technology, as well as the limited number of practical examples available from Africa, particularly from a South African perspective, warrants further investigation into precisely how BT impacts SC transparency, visibility and traceability.

The purpose of the study is therefore to understand the dynamics of BT in SCM, focusing on the role of BT practices on SC transparency, traceability and visibility in South African manufacturing firms. The proposed conceptual framework is based on a synthesis of the BT literature and the SCM literature. In addition, empirical evidence from different sectors of the economy is considered. The conclusion includes recommendations for future research into potential SC transparency, traceability and visibility issues associated with applications of BT practices across a network of relationships. The following research questions serve as a guide to this study:

RQ1. What is the relationship between BT and SC transparency in manufacturing firms' SCs?

RQ2. Which unique blockchain technological characteristic impact SC transparency and thus visibility and traceability?

Theories underpinning the study

The following are the theories underpinning this study.

Digital transformation theory

Digital transformation theory and Supply Chain Operations Reference (SCOR) model are the theories underpinning this study. The Digital Transformation (DT) theory describes how new digital technologies (such as blockchain, big data analytics and the Internet of Things [IoT]) change business structures, processes and value creation in networks and companies (Sharma et al. 2025). By utilising BT, digital transformation theory is essential to improving SC visibility, traceability and transparency in the South African manufacturing industry (Chavalala et al. 2024; Mthimkhulu & Jokonya 2022). The manufacturing industry in South Africa can improve SC visibility, traceability and transparency by utilising BT and digital transformation theory (Chavalala et al. 2024). This will boost competitiveness, efficiency and growth.

The Supply Chain Operations Reference model

A reference framework for supply-chain management, the SCOR model was first created by the Supply Chain Council and is currently maintained by American Production and Inventory Control Society (APICS). Its purpose is to offer common, standard definitions of processes, metrics and best practices (Nguyen 2024). Usually, the following are important process categories: Plan, Source, Make, Deliver, Return, and Enable. By facilitating communication, decision-making and problem-solving among suppliers, companies and customers, the SCOR model enhances SCM practices such as visibility, transparency and traceability. The SCOR theory has been used to benchmark performance, map supply-chain processes, find gaps and promote improvement (Wirda et al. 2025). In this study, the theory is applied to improve supply chain transparency (SCT), visibility and traceability by applying BT in the South African manufacturing sector' SC.

Literature review

The following sections discuss the literature review of the constructs used in this study. But first is the overview of the adoption of DT practices in manufacturing firms in South Africa.

The overview of the adoption of DT practices in manufacturing firms in South Africa

Manufacturing remains an important part of South Africa's economy (about 20% of Gross Domestic Product [GDP]) and is under pressure to improve competitiveness, resilience and sustainability (Langton & Mafini 2024). The push for digital transformation is driven by several structural and external factors such as the global competition and supply-chain disruption, requiring more agile, data-driven operations (Barnes, Sachs & Pelser 2024). Furthermore, the growing availability of 'Industry 4.0' technologies (cloud ERP [Enterprise Resource Planning], Industrial Internet of Things [IIoT], analytics, AI [artificial intelligence]) has made digital improvements more feasible in South African manufacturing firms' operations (Langton & Mafini 2024) In discrete manufacturing, one example is the Gibela Rail Manufacturing facility in Gauteng: according to reports, the site has leveraged automation, supplier development and workforce training to raise productivity and local content (Barnes et al. 2024). However, the adoption of DT practices has encountered its fare share of challenges such as a lack of capital and lack of digital infrastructure for many manufacturing firms (Willie & Mbongwe 2023). Moreover, a lack of skills has inhibited the full implementation of DT practices in manufacturing firms in South Africa. However, the pace of DT in South African manufacturing is accelerating. What was strategic in previous years is becoming progressively operational in the current period (Basir, Loukaides & Giannikas 2024). For example, the move from exploring cloud ER, IIoT to implementing retrofits, AI-automation and digital supply-chain integration is now a realistic in South African manufacturing firms. In sum, the environment for digitalisation in South African manufacturing is increasingly favourable but also urgent.

Blockchain technology

Blockchain technology, initially introduced in the well-known Bitcoin white paper, revolutionised electronic transactions, eliminating the need for trust using a peer-to-peer network and proof-of-work to record the public history of transactions (Zaman et al. 2025). It progressed from database technologies, incorporating a DLT that attaches records with timestamped transactions augmented by cryptographic systems and consensus tools to protect data integrity (Kumar 2025). Blockchain applications, initially considered as a new form of digital currency, have extended beyond monetary transactions (Sharma et al. 2025). As a DLT, a blockchain can update and validate end-to-end product traceability data in an SC (Igonor, Amin & Garg 2025). Cryptographic hash functions certify the integrity and completeness of records, with each network node verifying the accuracy of information (Zaman et al. 2025). Blockchain immutability permits for real-time, tamper-proof records, facilitating efficient communication in complex and fragmented SC (Hanafizadeh & Alipour 2025). The decentralised nature of blockchain enables instant data updates across all network participants, providing a shared data history and ownership of transactions (Zafar 2025), making it efficient and scalable (Hanafizadeh & Alipour 2025). Blockchains were initially designed as open distributed ledgers; however, differences in functionality exist between platforms such as Bitcoin and Ethereum. Blockchain ledgers can be private (closed, permissioned) or public (open, permissionless). In private ledgers, participation is restricted and is classically managed by a group of stakeholders (Sharma et al. 2025). Most blockchain trials in SCM use private ledgers, often using the 'proof of authority' algorithm consensus mechanism (Zaman et al. 2025). For instance, IBM's Food Trust implemented a private blockchain association for SC traceability with participants including Walmart, Nestle, Carrefour and Maersk (Kumar 2025), with database access controlled to ensure within-group privacy and control protocols. Conversely, public ledgers require substantial data processing capacity with all transactions publicly accessible and user anonymity maintained (Zafar 2025).

Another key benefit of BT in SC is its ability to prevent the infiltration of counterfeit products or ingredients (Sharma et al. 2025), improving public safety and facilitating faster detection of problems. Although collaboration and information sharing among SC partners are crucial, companies must protect their proprietary data from competitors. Hence, most favour private ledgers because of concerns regarding data exposure and the potential leakage of business intelligence to rival companies (Hanafizadeh & Alipour 2025). The decision to implement a private or public blockchain depends on the business environment and specific advantages companies seek over their competitors (Igonor et al. 2025). Organisations can evaluate the potential value of BT in minimising paper-based processes, improving traceability methods and securing provenance data (Kumar 2025). Blockchain technology is poised for further advances in proofs of concept, standardisation, collaboration and integration with other technologies over the next few years. These developments are expected to drive the broader adoption of blockchain in SCM and unleash its transformative impacts. Zafar (2025) predicts an increase in blockchain trialsfor food traceability and safety among top global grocers by 2025.

Supply chain traceability and visibility

Supply chain traceability is the capacity to track and trace the movement of products and materials across the entire SC, from raw materials to the end consumer (Blaettchen, Calmon & Hall 2025). It involves collecting and analysing data at each stage to ensure products are made safely, ethically and sustainably (Fabbe-Costes, Lechaptois & Shajari 2024). Supply chain visibility refers to the ability to track and monitor the movement of products, materials and information throughout the entire SC, from the sourcing of raw materials to the delivery of finished goods to the end customer (Peesapati 2024). It provides real-time insights into inventory levels, shipment status and other key data points, allowing businesses to optimise operations, improve decision-making and enhance overall SC resilience (Mwaiwa 2024).

Ensuring traceability and visibility in SCs is of paramount importance, particularly in sectors such as food and pharmaceuticals, where contamination or counterfeiting can have severe consequences for public health and safety. According to the World Health Organization (2022), approximately 5% – 10% of the world population contracts a disease, and more than 400 000 die from exposure to contaminated food. Such foodborne diseases affect public health, hinder socioeconomic progress, strain health-care systems and damage economies. Traditional computer systems often lack the necessary data security, leading to SC failures and difficulties in identifying the sources of contamination during outbreaks (Fabbe-Costes et al. 2024). Blockchain offers robust traceability capacities that can enhance food safety, combat food fraud and facilitate product recalls by auditing the entire chain of custody, which empowers brands to minimise SC risks and promptly trace and remove contaminated products from circulation (Mwaiwa 2024). Similarly, counterfeit medical goods pose a significant consumer risk and have a substantial economic impact on the pharmaceutical industry. By leveraging blockchain as an anti-counterfeiting solution (Lee & Cho 2025), the ownership and chain of custody of medical goods can be reliably tracked to mitigate the risks associated with fraudulent products (Fabbe-Costes et al. 2024), ensuring consumer safety and maintaining the integrity of the pharmaceutical SC.

Supply chain transparency

Supply chain transparency has emerged as a critical concern for businesses, governments and consumers in recent years. The concept refers to the degree to which a company discloses information about its SC practices, including sourcing, production and distribution (Kumar et al. 2025a). Research suggests that SC transparency can have numerous benefits, including improved risk management, enhanced brand reputation and increased customer trust (Lee & Cho 2025). For instance, a study by Park and Kim (2025) found that companies that prioritise transparency in their SCs are more likely to detect and mitigate risks related to labour exploitation, environmental degradation and corruption. However, achieving SC transparency can be challenging, particularly in complex global supply networks (Choi & Linton 2025). A study by Wang, Zhang and Tong (2025) highlighted the importance of technology, such as blockchain and AI, in enhancing SC transparency. Moreover, SC transparency can also have implications for sustainability and social responsibility. Research by Smith and Johnson (2025) found that transparent SC can contribute to the achievement of the United Nations' Sustainable Development Goals (SDGs), particularly those related to decent work, responsible consumption and climate action. Therefore, SC transparency is a multifaceted concept that can have far-reaching implications for businesses, governments and society. Further research is needed to explore the complexities of SC transparency and its impact on sustainable development.

Research model and hypotheses formulation

The research model considered in the present study is presented in Figure 1, followed by the formulation of hypotheses.

Blockchain technology and supply chain transparency

Blockchain technology has garnered significant attention over the past few years owing to its potential for enhancing SC transparency. The security-oriented, decentralised and immutable nature of the blockchain allows for product tracking and tracing in real time, thereby allowing stakeholders to make informed decisions. In this review,

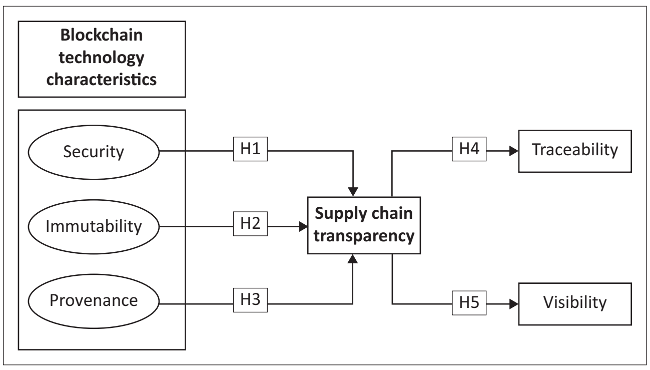


FIGURE 1: Research model for blockchain technology practices, supply chain transparency, traceability and supply chain visibility.

empirical studies on the nexus between BT and SC transparency will be consolidated. Studies have always proved that BT can be used to increase SC transparency by providing a tamper-resistant record of transactions (Kamble, Gunasekaran & Sharma 2025). For instance, a case study on the application of blockchain in the food SC confirmed that it allowed real-time tracking of products, which reduced contamination risk and improved food safety (Yi, Zhang & Li 2025). Another study on the use of blockchain in the pharmaceutical SC concluded that it increased transparency as it enabled tracing of medicines throughout the SC, rendering counterfeit products less likely (Miraz, Ali & Excell 2025). Similarly, in a survey of SC executives, BT was regarded as one of the significant enablers of SC transparency through improved visibility and accountability (Lee, Lee & Kim 2025). Blockchain technology provides a tamper-evident record of transactions, enabling stakeholders to track products throughout the SC (Kamble et al. 2025). It allows for real-time tracking and tracing of products, reducing the risk of contamination, counterfeit products and improving SC efficiency (Yi et al. 2025) and increases accountability for SC players, with improved transparency. While the empirical literature suggests that BT can lead to improved SC transparency, there are different challenges that have to be resolved. Blockchain technology should be scalable and interoperable with existing SC systems to have widespread adoption (Miraz et al. 2025). Clear regulatory frameworks are needed to oversee the use of BT in SCs (Kamble et al. 2025). The empirical evidence suggests that BT has the potential to significantly improve SC transparency. By offering a tamper-resistant history of transactions, enabling real-time tracing and tracking and promoting accountability among stakeholders, BT can increase SC trust and efficiency. Given the above discussion, the following hypotheses are formulated:

H1: Security has a positive and significant effect on supply chain transparency.

H2: Immutability exerts a positive and significant influence on supply chain transparency.

H3: Provenance has a positive and significant influence on supply chain transparency.

Supply chain transparency and supply chain traceability

The relationship between SC transparency and SC traceability has come under the limelight in recent years because of increasing consumer demand for ethical sourcing, regulatory requirements and the need to minimise risk in complex global SCs (Anastasiadis, Apostolidou & Tsolakis 2024). Supply chain transparency can be defined as the degree to which a firm makes known to stakeholders' information related to its SC operations, such as sourcing processes, labour practices and environmental imprints (Morgan, Gabler & Manhart 2023). On the other hand, SC traceability can be defined as the ability to track the origin, movement and ownership of products throughout the SC. Empirical evidence has established that traceability is positively related to transparency. For instance, Than (2024) established that companies implementing traceability systems are more transparent in their SCs. This is because traceability requires the capture and sharing of detailed information about products as they move through the SC, and this increases transparency (Essien et al. 2024).

Yet another study by Kim et al. (2024) examined how BT impacted SC transparency and traceability. Based on their results, blockchain can improve traceability as well as transparency significantly by creating a secure and tamper-evident history of transactions and movements throughout the SC (Garcia-Torres, Rey-Garcia & Sáenz 2024). Similarly, Anurag and Johnpaul (2025) in a study observed the role of digital technologies, including IoT devices and AI, in improving the traceability and transparency of SCs. Their research demonstrated that these technologies could provide real-time data and analysis, enabling companies to make informed decisions and improve their SC activities (Anurag & Johnpaul 2025). In short, the empirical relationship between traceability and transparency in SCs is one of complementary correspondence. Implementing traceability initiatives tends to drive up transparency and vice versa. Technologies including blockchain, IoT and AI play key roles in supporting both. Given the above discussion, the following hypothesis is formulated:

H4: Supply chain transparency influences supply chain traceability.

Supply chain transparency and supply chain visibility

Supply chain transparency and visibility are meticulously intertwined notions critical to modern SCM. While they are occasionally used interchangeably, they characterise different fundamentals (Li et al. 2025). Transparency classically refers to the disclosure of information to external stakeholders, while visibility narrates to the internal capacity to monitor and access data throughout the SC (Baycik 2024). Current empirical studies have investigated how improvements in one can influence the other and their combined influence on performance, trust and sustainability (Sunmola & Apeji 2024). Achieving effective SCM requires both transparency and visibility, as both terms relate, yet differ from one another. Li et al. (2025) reveal that internal visibility of product and process data significantly facilitates external transparency, particularly in quality assurance and sustainability labelling. Moreover, Kumar, Luthra and Mangla (2020) institute that the embracing and implementation of BT practices improved both visibility and transparency in SC, especially in activities with strict traceability requirements such as food and pharmaceuticals. Udeh et al. (2024) confirmed that SC visibility positively affects transparency, which in turn improves SC resilience and performance. Transparency mediated the relationship between visibility and trust among partners (Sunmola & Apeji 2024). Emerging technologies such as blockchain can serve as a powerful resource when it comes to improving visibility and transparency owing to its immutable history of transactions and movements throughout the SC

(Li et al. 2025). The empirical literature consistently supports a positive relationship between SC visibility and transparency. However, visibility is a necessary condition for transparency rather than a guarantee of it. Organisational culture, technological capability and stakeholder pressure determine whether visible data are made transparent. Given the above discussion, the following hypothesis is formulated:

H5: Supply chain transparency has a positive and significant influence on supply chain visibility.

Research methods and design

Research methodology refers to the specific procedures and techniques used to conduct research and gather information (Marra & Nielsen 2025). It outlines the systematic process a researcher follows to investigate a problem, collect data and analyse outcomes or findings (Kumar & Praveenakumar 2025). A quantitative research approach and a cross-sectional survey design were employed to collect, analyse and interpret the collected data. The motivation behind adopting the quantitative approach is that it is intended to make predictions, realise evidence and test the developed hypotheses. In addition, cross-sectional survey design is less expensive and time consuming (Marra & Nielsen 2025). This design can provide valuable insights and understandings into respondent's characteristics and reveal correlations for future studies (Kumar & Praveenakumar 2025).

Sampling method, population and sample size

In this study, the non-probability sampling method was used. It is a sampling technique where respondents are selected based on non-random criteria, meaning not every member of the population has an equal chance of being included in the sample (Marra & Nielsen 2025). Respondents were selected using the purposive sampling technique, to ensure that only those individuals who possessed the desired knowledge were included in the study. The target population included owners, managers and SCM professionals in manufacturing firms from Gauteng, Limpopo and North-West Provinces of South Africa. This target population (i.e. owners, managers and SCM practitioners) is largely responsible for handling logistics and SCM matters, formulating strategies and the implementation of BT practices, hence, were important to this study. A survey questionnaire was applied as the primary data collection instrument. A questionnaire is considered an inexpensive and efficient technique of gathering data in a properly designed and convenient form from a huge pool of respondents, which makes it suitable for this study (Kumar & Praveenakumar 2025). Self-completion survey questionnaires were made available online through Google Forms, some emailed and hand delivered, to purposely sampled respondents in manufacturing firms of the selected provinces. A final sample size of 287 (n = 287) adequately depicts the selected respondents. This sample size was regarded relevant, as recommended by Kumar and Praveenakumar (2025).

Measurement items, data collection

The measurement scales of the study were adapted from renowned scales in the previous studies. Blockchain technology practices were measured using five items each and were adapted from Lee et al. (2025). Supply chain transparency was measured using five items adapted from Anurag and Johnpaul (2025). Supply chain traceability and visibility were measured using five items and were adapted from Riaz et al. (2025). Self-administered survey questionnaires were used as data collection instruments. Data were collected between September 2024 and February 2025. The lengthy period of 6 months was attributed to a lot of questionnaires distributed. Measurement scales in the questionnaire were presented on a five-point Likert scale having options ranging from 1 = strongly disagree and 5 = strongly agree.

Data analysis

In this study, descriptive and inferential statistics were employed to analyse collected data. Structural equation modelling (SEM) and path analysis were also used to examine the linear correlations' strength and direction between the constructs. Hypothesis analysis was applied to determine the predictive relationships between the constructs. The Smart partial least squares (SMART PLS) were the software package used for data analysis.

Ethical considerations

Ethical clearance to conduct this study was obtained from the Vaal University of Technology Faculty Research Ethics Committee. The ethical clearance number is FRECMS-16042025-217/1. Moreover, respondents partook in the study at their expediency, and the study also informed consent, warranted privacy, anonymity and confidentiality of the respondents by not requiring names or other identities of the respondents on the questionnaire. At the end, the data were analysed according to the objectives, and the report on the results was done free of bias.

Results

Respondents' characteristics

In this study, 400 questionnaires were distributed, and 287 were considered suitable for further data analysis translating to a response rate of 71.75%. This response rate is supported by Babbie (2016) who regards a 60% response rate as 'good'. Black Africans formed most of the respondents (56.8%, n = 163). Regarding gender, 77.7% (n = 223) were males, and 22.3% (n = 64) were females. The most represented age group was between 36 and 40 years, translating to 38.68% (n = 111) of the survey respondents. Concerning the qualification level, most of the respondents achieved diplomas (35.2%, n = 101). In terms of experience at their workplaces, respondents with between 6 and 10 years of work experience were most represented (40.77%, n = 117). A total of 31.71% (n = 91) of respondents were drawn from firms with between

101 and 200 employees. Gauteng province was the most represented, comprising 65.85% (*n* = 189) of the respondents. Regarding the industry categorisation, the food and beverage industry had most respondents (62.37%; *n* = 179). Lastly, most of the respondents were working in the logistics and SC departments (49.13%, *n* = 141).

Measurement properties of the constructs

This section discusses the measures used to determine the psychometric properties of measurement scales.

Exploratory factor analysis

In multivariate studies, exploratory factor analysis (EFA) is a statistical technique applied to reveal the principal configuration (PC) of a practically large set of variable items. Mineiro et al. (2025) state that EFA is a process within factor analysis whose key objective is to notice the essential relationships between measured variables. From Table 1, it can be observed that after subjecting the measurement items to EFA, some of the items that is, S1, S3, S4, T4, T5 and V1 were discarded as they failed to meet the minimum score of 0.7 as recommended by Mineiro et al. (2025).

Multicollinearity

Multicollinearity refers to a condition where two or more independent variables are meticulously interconnected to each other. In addition, multicollinearity happens when there is a correlation between many predictor constructs in a multiple regression model (Salmeron-Gomez, García-García & Rodriguez-Sanchez 2025). In this study, variance inflation factor (VIF) was applied to find out whether collinearity was a problem in the collected data. Variance inflation factor is an indicator or measurement of multicollinearity in a group of multiple regression variables (Bergqvist 2025). The results in Table 1 indicate that VIF values for all constructs were less than 5, as recommended by Kalnins and Praitis Hill (2025), proving the non-existence of multicollinearity among the variables.

Analysis of reliability and validity

The validity and reliability of the items were tested using the average variance extracted (AVE), factor loading analysis. Cronbach's alpha and composite reliability (CR). Convergence validity was tested using the AVE. All the AVE scores were greater than the minimum of 0.5 as recommended by Alford and Teater (2025). The square root of AVE was used to ascertain discriminant validity. The items correlation coefficients between two latent constructs must be less than the square root of AVE. This is shown in Table 2. According to Noor and Fuzi (2025), discriminant validity exists if the items between latent construct are also less than one. Table 2 shows that all the latent item scores are less than one depicting that

TABLE 2: Correlation between constructs.

Construct	IM	P	S	SCT	T	V
IM	0.693	-	-	-	-	-
P1	0.731	0.725	-	-	-	-
S	-0.083	-0.119	0.801	-	-	-
SCT	0.689	0.794	-0.082	0.762	-	-
T	0.662	0.771	-0.071	0.810	0.823	-
V	0.846	0.848	-0.090	0.894	0.868	0.763

IM, immutability; SCT, supply chain traceability; P, provenance; S, security; T, supply chain transparency; V, supply chain visibility.

TABLE 1: Constructs and measurement items.

Construct	Item code	Mean	s.d.	Factor loadings	VIF	Cronbach's alpha	CR	AVE	$\sqrt{AVE}$
Security	S2	3.674	1.203	0.584	1.161	0.742	0.771	0.642	0.801
	S5			0.971					
Immutability	IM1	3.742	1.332	0.734	1.753	0.776	0.724	0.780	0.883
	IM2			0.623					
	IM3			0.548					
	IM4			0.834					
	IM5			0.855					
Provenance	P1	3.341	1.126	0.735	1.531	0.774	0.525	0.774	0.880
	P2			0.715					
	P3			0.691					
	P4			0.772					
	P5			0.708					
Supply chain transparency	T1	3.454	1.337	0.792	1.873	0.818	0.823	0.680	0.825
	T2			0.831					
	T3			0.844					
Supply chain traceability	SCT1	3.774	1.463	0.712	1.545	0.763	0.771	0.677	0.823
	SCT2			0.719					
	SCT3			0.800					
	SCT4			0.802					
	SCT5			0.769					
Supply chain visibility	V2	3.521	1.322	0.883	1.841	0.791	0.816	0.582	0.763
	V3			0.877					
	V4			0.877					
	V5			0.089					

VIF, variance inflation factor; CR, composite reliability; AVE, average variance extracted; SCT, supply chain transparency; s.d., standard deviation.

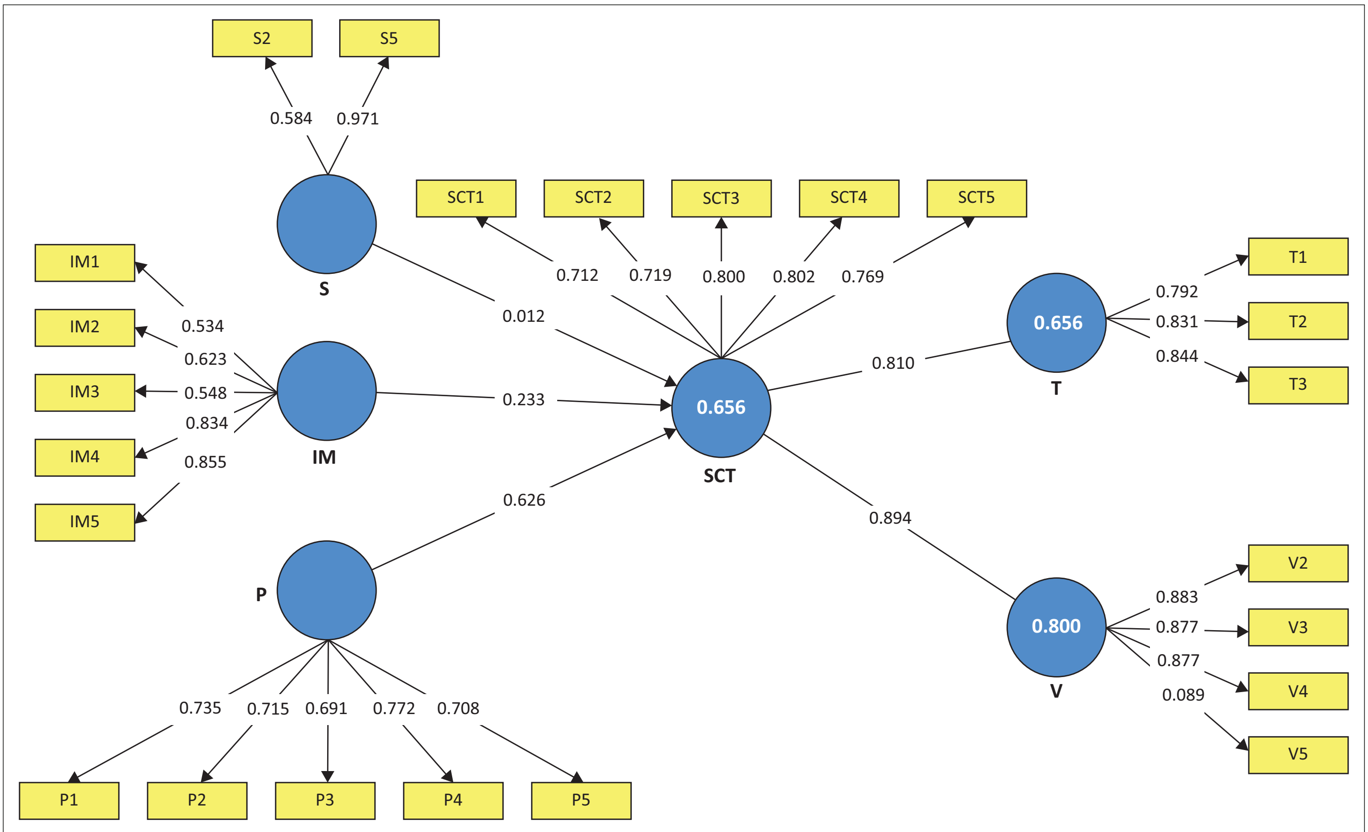
discriminant validity was ascertained. Cronbach's alpha scores for the constructs were all greater than 0.70, which confirmed the internal consistency and reliability were adequate for this study (Christou 2025). The item factor loadings were used to test construct reliability. All items factor loadings were more than 0.5 and were considered acceptable as suggested by Alford and Teater (2025). Correspondingly, CR scores were calculated to measure construct reliability. All CR values were greater than 0.80 implying that the variance captured by the factor is notably more than the variance implied by the error factors, thereby confirming construct reliability (Christou 2025). As shown in Table 1, all CR scores show that they were greater than 0.85, which confirm the construct reliability of all items under each construct.

Common method bias

Various measures were applied to minimise the effect of common method bias as led by Merkle (2025). Crucial among them is confirming anonymity in questionnaire administration in addition to refining survey items for the constructs. Mainly, anonymity was maintained in the survey questionnaires, and respondents were asked to be candid with their responses while ensuring them that there is no wrong or right answer. A valid and well-tested measurement scale aids in the eradication of item ambiguity (Podsakoff et al. 2024). Formerly tested scale items were used in the measurement of this study's variables. Furthermore, the measurement items were also improved by conducting a pilot study that managed to eliminate unclear and indistinct concepts, composite and unaccustomed terms, as well as multiple-barrelled questions (Merkle 2025). Initial EFA performed on the data used for pilot testing established the multidimensionality of the data. Lastly, common method bias becomes a problem or a challenge when a single concealed factor contributes to most of the variance explained (Polas 2025). In dealing with common method bias in this study, a Harman's one-factor test was applied. All scale items were loaded into a non-rotated single factor to determine the number of factors vital to account for the variance in the measurement items. Less than 42% of the variance in the model was accounted for by the single factor extraction, which is purposely less than the 50% threshold, in that way, signifying that common method bias was not a challenge in the study.

Path analysis

Path analysis is a statistical procedure used in quantitative research to examine the relationships between variables (Ashaduzzaman et al. 2022). It is a leeway of regression analysis that supports researchers to recognise the direct and indirect influences of study constructs on each other (Ashaduzzaman et al. 2022). In path analysis, a diagram (path diagram) is created to visualise the hypothesised relationships between constructs. The path analysis diagram in Figure 2 shows the causal paths between variables, including direct effects. Path analysis was employed to test hypotheses in this study. The analysis of this study accounted



PLS, partial least squares; IM, immutability; SCT, supply chain traceability; P, provenance; S, security; T, supply chain transparency; V, supply chain visibility.

FIGURE 2: Path coefficients.

for two assumptions of PLS model to accept or reject every hypothesis. The first assumption is based on the beta (β) measure to confirm the association between the variables. The beta value should be positive or negative and predominantly range between 0.1 and 1 for positive associations and between −0.1 and −1 for inverse associations (Deng & Yuan 2023). The second assumption applies to the values of significance denoted by *p*-values of the variables. The values of significance would be less than 5% or 0.05, that is $p < 0.05$. The results of path analysis appear in Figure 2.

The beta values in Figure 2 range between 0.012 and 0.894. Details on the analysis are discussed in the next section.

Discussion

This study addressed the following objectives by conducting a hypothesis testing on the study constructs:

- To establish the effect of BT practices on SCT
- To determine the influence of SCT on traceability in manufacturing firms in South Africa.
- To determine the influence of SCT on visibility in manufacturing firms in South Africa

The hypothesis testing results of the study are highlighted in Table 3.

The study examined the relationship between BT practices, SCT and SC performance of manufacturing firms in South Africa. The results in Table 3 indicate that four hypotheses (H2, H3, H4 and H5) were accepted, while H1 was rejected.

Blockchain technology and supply chain transparency

The results in Table 3 show that IM and P have positive and significant influence on SCT (β = 0.233; *t* = 4.057; *p* = 0.000; β = 0.626; *t* = 11.802; *p* = 0.000). The results concur with those of Gligor et al. (2022) who highlight the potential of BT in enhancing SCT, particularly in the agri-food and medical devices sectors. The results imply that BT is being implemented in manufacturing firms as the technology is observed to enable precise tracking of assets, ensuring authenticity and origin of products. Furthermore, it can be concluded that BT provides real-time visibility into SC operations of the surveyed manufacturing firms, enabling better management of disruptions and improving customer trust. Interestingly, the same table of results show that S has an insignificant influence on SCT (β = 0.012; *t* = 0.365; *p* = 0.715). This result contradicts the outcomes of Bai and Sarkis (2020) who established that security has a positive impact on SCT. Blockchain security may not have much of an impact on traceability because it depends on human factors like data accuracy and sharing willingness, is expensive, lacks proper infrastructure and digital literacy and is difficult to integrate with current systems. Employees may purposefully or inadvertently enter inaccurate data, as is the case in certain SC, but this does not guarantee that the data entering the system will be accurate and complete from the beginning for the blockchain to be effective.

TABLE 3: Results of partial least squares hypotheses testing analysis.

Hypothesis	Path	*B*-values	*T*-values	*P*	Remark
H1	S → SCT	0.012	0.365	0.715	Reject
H2	IM → SCT	0.233	4.057	0.000	Accept
H3	P → SCT	0.626	11.802	0.000	Accept
H4	SCT → T	0.810	18.759	0.000	Accept
H5	SCT → V	0.894	44.735	0.000	Accept

IM, immutability; SCT, supply chain traceability; P, provenance; S, security; T, supply chain transparency; V, supply chain visibility.

The positive and significant relationship between BT practices and SCT in South African manufacturing firms proposes that BT is an influential and powerful digital transformation mechanism for modernising SC, building solid trust and enhancing competitiveness. Nevertheless, for these benefits to be fully understood and attained, support from policy, infrastructure and organisational willingness must align with technological innovation. Furthermore, this empirical evidence provides a solid foundation for strategic investment and policy development in digital SC transformation in South Africa and similar emerging economies.

Supply chain transparency influences supply chain traceability

The outcomes in Table 3 depict that SCT has a significant effect on T (β = 0.810; *t* = 18.759; *p* = 0.000). The results concur with previous studies, which established that SCT relates to traceability particularly in food processing industries (Dubey et al. 2021; Kamble et al. 2025). This positive and significant relationship between SCT and traceability in South African manufacturing firms underlines an essential dynamic in refining operational performance and sustainability in the segment. Thus, SCT significantly influences traceability in South African manufacturing firms by affording and presenting a basis and ground work for tracking and monitoring supplies, materials and products throughout the SC. Transparency, which involves reporting, revealing and releasing SC data to stakeholders, is indispensable for fostering trust and integrity. Traceability takes transparency a step further by providing inclusive understanding into a product’s path from raw materials to the final product. In a nutshell, this result is both logical and strategic. Transparency turns to be an enabler for traceability by providing the data infrastructure, stakeholder cooperation and operational visibility desirable for tracking materials and products precisely. For South African manufacturing firms, this relationship strengthens not only internal management systems but also supports their international competitiveness and compliance position.

Supply chain transparency and supply chain visibility

The results in Table 3 highlight that SCT has a significant effect on V (β = 0.894; *t* = 44.735; *p* = 0.000). The results concur with previous studies, which established that SCT has a significant relationship with SC visibility particularly in manufacturing industries (Miraz et al. 2025; Lee et al. 2025). The results imply that SCT ensures that precise, appropriate and complete data are shared among all stakeholders. This candidness directly improves SC visibility, permitting South African manufacturers to track materials, trace products, monitor supplier performance and respond proactively to SC disruptions. This result is not just theoretical–it has practical implications for operational efficiency, risk management and global competitiveness. As transparency increases, so too does the firm's ability to see, understand and react to what's happening across its supply network, leading to more resilient and agile operations.

Linking results with digital transformation and Supply Chain Operations Reference theories

The DT theory states that SC can become more visible and transparent through digital technologies such as blockchain and the IoT. One of the main themes, according to a study, is 'enhanced visibility and transparency enabled by digital technologies' (Khan et al. 2024). Applying BT (as part of a digital transformation project) in the South African manufacturing sector can be thought of as a DT intervention. Improved SC visibility, transparency and traceability can be achieved through real-time data sharing, stakeholder information flows and immutable records. According to DT theory, to reap these benefits, manufacturing firms need to modify their governance (data sharing, trust), culture (partner transparency) and processes (material tracking, supplier collaboration, etc.). Manufacturing firm must, for example, dismantle silos, integrate blockchain data flows and establish partner networks that DT promotes closer cooperation traceability, transparency, visibility and information exchange in the whole SC.

The SCOR model provides a well-established framework for analysing and managing SC operations – covering processes, metrics, best practices and technologies (Plan, Source, Make, Deliver, Return, Enable) and more recently emphasising digital, network-based capabilities. Transparency and traceability are explicitly supported when businesses standardise processes and integrate cutting-edge technologies, according to the SCOR model, which places an emphasis on standardised SC processes (Plan, Source, Make, Deliver, Return, Enable) and metrics to drive improvement (Flevy Management 2025). According to recent industry statistics, approximately 75% of manufacturing firms in South Africa that have integrated BT into their SC report increased traceability and transparency, which is consistent with the expectations of SCOR frameworks and digital transformation for technology-driven performance improvement (Gitnux 2025). 'Thus, the SCOR Model significantly improves SCT and Traceability by standardising processes and metrics, facilitating benchmarking, integrating advanced technologies'.

Study limitations

While this study provides valuable insights into the potential of BT to enhance SCT, visibility and traceability in the South African manufacturing sector, several limitations must be acknowledged. The study was based on a relatively small sample of manufacturing firms, which may not completely embody the whole sector. The diversity of industries within manufacturing (e.g. automotive, textiles, food processing) means that the results may not be homogeneously valid throughout all sub-sectors. Because of the sensitive nature of SC operations and data privacy concerns, access to comprehensive working data was circumscribed. This limitation may have inhibited the profundity of empirical analysis and the capacity to authenticate BT adoption in real-world settings. Numerous South African manufacturing firms are still in the primary phases of considering or navigating BT solutions. As a result, the research outcomes are principally based on projected benefits and perceived challenges, rather than extensive, real-world blockchain implementations. The study did not expansively account for all infrastructural and technical limitations, such as electricity reliability, Internet connectivity and digital literacy, which may meaningfully disturb BT adoption in South Africa. South Africa's regulatory environment concerning DT and BT remains underdeveloped. The absence of clear legal frameworks may impact both the adoption rates and the overall effectiveness of BT integration.

In addition, South Africa's blockchain adoption is influenced by a mix of regulatory and infrastructure factors that both help and hinder progress. The legal framework, shaped by the Protection of Personal Information Act (POPIA) and the Cybercrimes Act, provides a solid foundation for data privacy and cybersecurity. However, it also brings compliance challenges, especially because of blockchain's immutability and cross-border nature. Uncertainty in digital asset and trade regulations slows down institutional uptake because of legal ambiguity and risk aversion. On the infrastructure side, unreliable Internet, ongoing load-shedding and low digital literacy outside urban areas limit the scalability of blockchain solutions. In addition, outdated IT systems complicate integration. Because of these factors, blockchain adoption in South Africa is likely to progress gradually, focusing on well-connected sectors such as finance and logistics, with a preference for permissioned networks over public ones. However, as broadband access, cybersecurity standards and digital skills improve, the regulatory stability and expanding connectivity could support gradual and sustainable blockchain growth.

Future research directions

To build upon the results of this study and address its limitations, the following areas are suggested for future research. Initially, future studies should encompass longitudinal studies tracking actual blockchain implementation developments within South African manufacturing firms. This would permit for more accurate assessment of real-world impacts on SCT, visibility and traceability. Furthermore, comparative studies across different sectors (e.g. agriculture, mining, healthcare) within

South Africa could provide wider intuitions and understanding into where BT can be most successfully positioned and what circumstantial issues influence its success. Moreover, further examination into the controlling and regulatory conditions, comprising how policy and legal changes could enable or hamper BT implementation in SC, would be valuable. This includes analysis of data trade regulations, privacy laws and standards for digital recordkeeping. In addition, more detailed studies on the economic feasibility and return on investment (ROI) of BT implementation in manufacturing SC are required to direct investors and decision-makers. Again, future studies could investigate how BT can be efficiently combined with other digital transformation practices such as the AI, IoTs and ERP arrangements to further enhance SC visibility, transparency and traceability in manufacturing firms. Lastly, further qualitative research involving broader stakeholder groups (including suppliers, logistics providers and regulatory bodies) can stipulate and present profound understandings into challenges to BT adoption.

Conclusion

This study employed a quantitative design and SEM method, with SMART PLS analysis tool, to examine how BT practices, SCT, traceability and visibility, in South African manufacturing firms relate to each other. The integration of BT in the South African manufacturing sector's SC has the potential to significantly improve transparency, visibility and traceability. By leveraging blockchain's decentralised and unassailable nature, businesses can create a tamper-proof record of every transaction, enable real-time tracking of materials and enhance trust among stakeholders. This can lead to increased efficiency, reduced risk and improved collaboration within the SC.

This study outspreads conventional SCM concepts by incorporating blockchain as a digital technological enabler of improved transparency, traceability and visibility. It validates how circulated ledger technology balances traditional models such as the SCOR model by allowing real-time visibility and traceability throughout all SCOR processes (plan, source, make, deliver, return). Furthermore, the study contributes to the literature on SC DT by empirically illustrating how BT lessens the requirement for arbitrators and qualifies robust SC visibility and traceability. It augments the understanding of how trust can be concocted through code (smart contracts) rather than exclusively built through long-term associations. By concentrating on South Africa, this study complements to the increasing body of DT work in developing markets. It underlines context-specific factors such as infrastructure limitations, regulatory frameworks and digital literacy that shape blockchain implementation and practice in SC external of developed countries.

South African manufacturing firms need to develop clear BT adoption roadmaps aligned with their DT strategies. This includes conducting feasibility assessments, cost-benefit analyses and piloting blockchain in high-risk or high-value SC areas. Managers must dynamically foster cross-functional and cross-organisational collaboration. Because BT operates most effectively in a consortium-based environment, leadership should engage suppliers, customers, regulators and technology providers early in the implementation process to create a shared governance framework.

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The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

CRediT authorship contribution

Irvine Langton: Conceptualisation, Formal Analysis. Chengedzai Mafini: Data Curation, Formal Analysis. Mpho Tlale: Investigation, Methodology. All authors reviewed the article, contributed to the discussion of results, approved the final version for submission and publication and take responsibility for the integrity of its findings.

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Data availability

The authors confirm that the data supporting this study and its findings are available within the article and its listed references.

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References

Al-Qudah, A.A., Al-Okaily, M. & Yadav, M.P.P., 2025, 'The growth of FinTech and blockchain technology in developing countries: UAE's evidence', *International Journal of Accounting & Information Management* 33(2), 383–406. https://doi.org/10.1108/IJAIM-02-2024-0065

Alford, S. & Teater, B., 2025, 'Quantitative research', in M. Alston, P. Buykx, W. Foote & D. Betts (eds.), *Handbook of research methods in social work*, pp. 156–171, Edward Elgar Publishing, Cheltenham.

Anastasiadis, F., Apostolidou, I. & Tsolakis, N., 2024, 'Challenges and opportunities of supply chain traceability: insights from emergent agri-food sector', *Supply Chain Management: An International Journal* 30(1), 106–126.

Anurag, A.S. & Johnpaul, M., 2025, 'Security, Transparency, and Traceability: Role of Blockchain in AI-Powered Supply Chain', in *AI-Powered Business Intelligence for Modern Organizations*, pp. 181–206, IGI Global, Hershey, PA.

Ashaduzzaman, M., Jebarajakirthy, C., Weaven, S.K., Maseeh, H.I., Das, M. & Pentecost, R., 2022, 'Predicting collaborative consumption behaviour: A meta-analytic path analysis on the theory of planned behaviour', *European Journal of Marketing* 56(4), 968–1013. https://doi.org/10.1108/EJM-07-2020-0563

Babbie, E., 2016, *The practice of social research*, 14th edn., Cengage Learning, Boston, MA.

Bai, C. & Sarkis, J., 2020, 'A supply chain transparency and sustainability technology appraisal model for blockchain technology', *International Journal of Production Research* 58(7), 2142–2162. https://doi.org/10.1080/00207543.2019.1708989

Barnes, J., Sachs, W. & Pelser, T., 2024, 'The challenges of digital technology adoption within a group of South African manufacturing SMEs', in S. Van der Merwe (ed.), *International Business Conference*, 22–15 September 2024, Cape Town, South Africa.

Basir, M., Loukaides, E. & Giannikas, V., 2024, 'Consolidating perspectives on digitalization: A structured review of factors influencing technology implementation in manufacturing', in *31th European Operations Management Conference (EurOMA)*, 29 June – 03 July 2024, Barcelona, Spain.

Baycik, N.O., 2024, 'A quantitative approach for evaluating the impact of increased supply chain visibility', *Supply Chain Analytics* 6, 100065. https://doi.org/10.1016/j.sca.2023.100065

Bergqvist, E., 2025, 'Relations between mathematics self-efficacy and anxiety beliefs: When multicollinearity matters', *The Journal of Experimental Education* 93(3), 565–585. https://doi.org/10.1080/00220973.2024.2338545

Blaettchen, P., Calmon, A.P. & Hall, G., 2025, 'Traceability technology adoption in supply chain networks', *Management Science* 71(1), 83–102. https://doi.org/10.1287/mnsc.2022.01759

Chavalala, M.M., Bag, S., Pretorius, J.H.C. & Rahman, M.S., 2024, 'A multi-method study on the barriers of the blockchain technology application in the cold supply chains', *Journal of Enterprise Information Management* 37(2), 745–776. https://doi.org/10.1108/JEIM-06-2022-0209

Choi, T.M. & Linton, J.D., 2025, 'Global supply chain transparency: Challenges and opportunities', *Journal of Supply Chain Management* 61(1), 1–15. https://doi.org/10.1111/jscm.12298

Christou, P.A., 2025, 'Rigour in qualitative and quantitative studies that make use of tools: Reliability, validity, credibility, transferability, dependability and confirmability issues', in P.A. Christou (ed.), *Artificial intelligence (AI) in social research*, pp. 127–136, CABI, GB, Oxfordshire.

Deng, L. & Yuan, K.H., 2023, 'Which method is more powerful in testing the relationship of theoretical constructs? A meta comparison of structural equation modeling and path analysis with weighted composites', *Behaviour Research Methods* 55(3), 1460–1479. https://doi.org/10.3758/s13428-022-01838-z

Dubey, R., Gunasekaran, A., Childe, S.J. & Papadopoulos, T., 2021, 'The impact of blockchain technology on supply chain transparency and performance: An empirical study', *International Journal of Production Economics* 231, 107929. https://doi.org/10.1016/j.ijpe.2020.107929

Essien, A., Chukwukelu, G.O., Kazantsev, N. & Subramanian, N., 2024, 'Unveiling the factors influencing transparency and traceability in agri-food supply chains: An interconnected framework', *Supply Chain Management: An International Journal* 29(3), 602–619. https://doi.org/10.1108/SCM-02-2023-0083

Fabbe-Costes, N., Lechaptois, L. & Shajari, B., 2024, 'Measuring and assessing supply chain environmental performance through digitalization: The need to consider SC traceability, visibility and transparency', in P. Evangelista, J. Hallikas & M.Y. Jaber (eds.), *Environmentally responsible supply chains in an era of digital transformation*, pp. 165–188, Edward Elgar Publishing, Cheltenham.

Flevy Management, 2025, *What is the SCOR model in supply chain management?*, viewed 02 December 2025, from https://flevy.com/topic/scor-model/question/understanding-scor-model-supply-chain-success?srsltid=AfmBOormtNUuXWdzSZ44i1Z5OUq9nihRbL-Pa94Fe9Q7qjmEfqrLWgw7&utm.

Garcia-Torres, S., Rey-Garcia, M. & Sáenz, J., 2024, 'Enhancing sustainable supply chains through traceability, transparency and stakeholder collaboration: A quantitative analysis', *Business Strategy and the Environment* 33(7), 7607–7629. https://doi.org/10.1002/bse.3759

Gitnux, 2025, *Supply chain in the supply chain industry statistics: Supply chain digitization and automation crucial for future growth, resilience*, viewed 02 December 2025, from https://gitnux.org/supply-chain-in-the-supply-chain-industry-statistics/?utm.

Gligor, D.M., Davis-Sramek, B., Tan, A., Vitale, A., Russo, I., Golgeci, I. et al., 2022, 'Utilizing blockchain technology for supply chain transparency: A resource orchestration perspective', *Journal of Business Logistics* 43(1), 140–159. https://doi.org/10.1111/jbl.12287

GlobeNewsWire, 2025, *Blockchain technology market outlook 2025-2030*, viewed 02 December 2025, from https://www.globenewswire.com/news-release/2025/03/05/3037648/0/en/Blockchain-Technology-Market-Outlook-2025-2030-with-Blockchain-Market-Case-Studies-for-Honeywell-Aerospace-SGX-Zug-Digital-ING-Group-and-more.html.

Hanafizadeh, P. & Alipour, M., 2025, 'Theory borrowing in emerging technology-oriented research contexts: On the example of blockchain technology', *Review of Managerial Science* 19(1), 105–155. https://doi.org/10.1007/s11846-024-00736-2

Igonor, O.S., Amin, M.B. & Garg, S., 2025, 'The application of blockchain technology in the field of digital forensics: A literature review', *Blockchains* 3(1), 5. https://doi.org/10.3390/blockchains3010005

Kalnins, A. & Praitis Hill, K., 2025, 'The VIF score: What is it good for? Absolutely nothing', *Organizational Research Methods* 28(1), 58–75. https://doi.org/10.1177/10944281231216381

Kamble, S.S., Gunasekaran, A. & Sharma, R., 2025, 'Blockchain technology for supply chain transparency: A systematic review', *International Journal of Production Research* 63(1), 1–18. https://doi.org/10.1080/00207543.2023.2236789

Khan, T., Emon, M.M.H. & Rahman, M.A., 2024, 'A systematic review on exploring the influence of Industry 4.0 technologies to enhance supply chain visibility and operational efficiency', *Review of Business and Economics Studies* 12(3), 6–27.

Khan, S., Singh, R. & Kirti, K., 2022, 'Critical factors for blockchain technology implementation: A supply chain perspective', *Journal of Industrial Integration and Management* 7(4), 479–492. https://doi.org/10.1142/S2424862221500111

Kumar, A. & Praveenakumar, S.G., 2025, *Research methodology*, Authors Click Publishing, Bilaspur, Chhattisgarh.

Kumar, A., Luthra, S. & Mangla, S.K., 2020, 'Evaluating the influence of blockchain adoption on supply chain transparency and performance', *Technological Forecasting and Social Change* 162, 120370. https://doi.org/10.1016/j.techfore.2020.120370

Kumar, D., 2025, 'From tradition to technological advancement: Embracing blockchain technology in family businesses', *Journal of Family Business Management* 15(2), 278–296. https://doi.org/10.1108/JFBM-04-2022-0057

Kumar, N., Kumar, K., Aeron, A. & Verre, F., 2025a, 'Blockchain technology in supply chain management: Innovations, applications, and challenges', *Telematics and Informatics Reports* 18, 100204. https://doi.org/10.1016/j.teler.2024.100204

Kumar, V., Holt, D. & Ghobadian, A., 2025b, 'Supply chain transparency: A systematic review and future directions', *International Journal of Production Economics* 261, 108732. https://doi.org/10.1016/j.ijpe.2023.108732

Langton, I. & Mafini, C., 2024, 'The influence of supply chain strategies on performance of South African manufacturing SMEs: The mediating effects of supply chain resilience', *Abstract Book of the International Conference on Management and Economics* 1(1), 15–38. https://doi.org/10.33422/icmeconf.v1i1.824

Lee, S. & Cho, J., 2025, 'The impact of supply chain transparency on customer trust and loyalty', *Journal of Business Research* 133, 113–124. https://doi.org/10.1016/j.jbusres.2021.12.009

Lee, S.M., Lee, D. & Kim, B., 2025, 'Blockchain adoption in supply chain management: A survey of professionals', *Supply Chain Management Review* 29(2), 149–162.

Li, L., Liu, Y., Jin, Y., Cheng, T.E. & Zhu, X., 2025, 'The interplay between supply chain transparency and visibility: Implications for firm performance in manufacturing and service sectors', *Journal of Business Logistics* 46(3), e70016. https://doi.org/10.1111/jbl.70016

Marra, M. & Nielsen, B.B., 2025, 'Research methodology: Best practices for rigorous, credible, and impactful research', *Journal of International Business Studies* 56, 950–952. https://doi.org/10.1057/s41267-025-00774-2

Merkle, A.C., 2025, 'Item level correction: Detecting, removing, and reporting common methods variance', *Journal of Marketing Analytics* 13(2), 405–423. https://doi.org/10.1057/s41270-025-00399-2

Mineiro, K.M.L., Laurett, R., Nossa, V. & Nossa, S.N., 2025, 'Management accountant skills: An exploratory factor analysis', *The International Journal of Management Education* 23(3), 101209. https://doi.org/10.1016/j.ijme.2023.101209

Miraz, M.H., Ali, M. & Excell, P.S., 2025, 'Blockchain-based supply chain management: A systematic review and future directions', *Journal of Cleaner Production* 319, 132927. https://doi.org/10.1016/j.jclepro.2021.132927

Morgan, T.R., Gabler, C.B. & Manhart, P.S., 2023, 'Supply chain transparency: Theoretical perspectives for future research', *International Journal of Logistics Management* 34(5), 1422–1445, https://doi.org/10.1108/ijlm-02-2021-0115

Mthimkhulu, A. & Jokonya, O., 2022, 'Exploring the factors affecting the adoption of blockchain technology in the supply chain and logistics industry', *Journal of Transport and Supply Chain Management* 16, 750. https://doi.org/10.4102/jtscm.v16i0.750

Mwaiwa, S.W., 2024, 'Supply chain visibility and performance of distribution firms in Nairobi City County, Kenya', *International Journal of Social Sciences Management and Entrepreneurship* 8(1), 910–925.

Nguyen, T.T.H., 2024, 'Measuring supply chain performance using the SCOR model', *SN Operations Research Forum* 5(2), 1–23. https://doi.org/10.1007/s43069-024-00314-y

Noor, N.H.M. & Fuzi, A.M., 2025, 'Assessment of validity, reliability, and normality in quantitative study: A survey instrument analysis with IBM SPSS', in *8th ASNet International Multidisciplinary Academic Conference*, pp. 27–43, February 2025, Kuala Lumpur.

Park, J. & Kim, S., 2025, 'Supply chain transparency and risk management: An empirical study', *Supply Chain Management Review* 29(2), 147–159.

Peesapati, S.R.Y., 2024, 'Enhancing supply chain visibility in large enterprises: A literature review', *International Journal of Supply Chain Management* 13(3), 20–27. https://doi.org/10.59160/ijscm.v13i3.6246

Podsakoff, P.M., Podsakoff, N.P., Williams, L.J., Huang, C. & Yang, J., 2024, 'Common method bias: It's bad, it's complex, it's widespread, and it's not easy to fix', *Annual Review of Organizational Psychology and Organizational Behaviour* 11(1), 17–61. https://doi.org/10.1146/annurev-orgpsych-110721-040030

Polas, M.R.H., 2025, 'Common method bias in social and behavioural research: Strategic solutions for quantitative research in the doctoral research', *Journal of Comprehensive Business Administration Research* 11, 17–61. https://doi.org/10.47852/bonviewJCBAR52024285

Pooja, P., Chikhale, M.M. & Dhir, S., 2025, 'Uncovering the strategic potential of blockchain technology adoption: A systematic literature review', *Strategic Change* 34(2), 151–180. https://doi.org/10.1002/jsc.2677

Raja, J., Ashish, A., Boianapalli, S. & Rashid, S.Z., 2025, 'Blockchain technology in supply chain management enhancing transparency and efficiency', *ITM Web of Conferences* 76, 02011. https://doi.org/10.1051/itmconf/20257602011

Riaz, A., Rehman, H.M., Sohail, A. & Rehman, M., 2025, 'Industry 4.0 supply chain nexus: Sequential mediating effects of traceability, visibility and resilience on performance', *Asia Pacific Journal of Marketing and Logistics* 37(4), 842–860. https://doi.org/10.1108/APJML-02-2024-0202

Salmeron-Gomez, R., García-García, C.B. & Rodriguez-Sanchez, A., 2025, 'Enlarging of the sample to address multicollinearity', *Computational Economics* 48(1), 1–23. https://doi.org/10.1007/s10614-025-10920-5

Sharma, R., Samad, T.A., Chiappetta Jabbour, C.J. & De Queiroz, M.J., 2025, 'Leveraging blockchain technology for circularity in agricultural supply chains: Evidence from a fast-growing economy', *Journal of Enterprise Information Management* 38(1), 32–67. https://doi.org/10.1108/JEIM-02-2021-0094

Smith, J. & Johnson, K., 2025, 'Supply chain transparency and sustainable development: A systematic review', *Journal of Cleaner Production* 394, 135802. https://doi.org/10.1016/j.jclepro.2023.135802

Sunmola, F.T. & Apeji, U.D., 2024, 'Modelling supply chain visibility: A framework with considerations for manufacturing and business', *Journal of Manufacturing Technology Management* 35(7), 1354–1374. https://doi.org/10.1108/JMTM-09-2023-0375

Than, L.L., 2024, 'Enhancing transparency through Blockchain and Internet of Things technology in supply chain', *SSRN Electronic Journal*, viewed 02 December 2025, from https://ssrn.com/abstract=4894197.

Udeh, E.O., Amajuoyi, P., Adeusi, K.B. & Scott, A.O., 2024, 'The role of IoT in boosting supply chain transparency and efficiency', *Magna Scientia Advanced Research & Reviews* 12(1), 178–197. https://doi.org/10.30574/msarr.2024.11.1.0081

Vern, P., Panghal, A., Mor, R.S. & Kamble, S.S., 2025, 'Blockchain technology in the agri-food supply chain: A systematic literature review of opportunities and challenges', *Management Review Quarterly* 75(1), 643–675. https://doi.org/10.1007/s11301-023-00390-0

Wang, Y., Zhang, Y. & Tong, L., 2025, 'Enhancing supply chain transparency with blockchain technology: A case study', *International Journal of Production Research* 63(4), 1024–1039.

Willie, M.M. & Mbongwe, N.A., 2023, 'Assessing the impact of digitalisation on SME policy: A comparative analysis of approaches to support the manufacturing sector in the digital age–South Africa', *Journal of Public Administration* 58(2), 337–350. https://doi.org/10.53973/jopa.2023.58.2.a8

Wirda, B., Irwandi, P., Muflikh, Y.N. & Nurmalina, R., 2025, 'The use of supply chain operations reference (SCOR) in measuring the performance of supply chain management in agribusiness sector', *Agromix* 16(1), 71–91. https://doi.org/10.35891/agx.v16i1.5742

World Health Organization (WHO), 2022, Food safety, World Health Organization, Geneva, viewed 02 December 2025, from https://www.who.int/news-room/fact-sheets/detail/food-safety.

Yi, J., Zhang, Y. & Li, F., 2025, 'Blockchain-based food supply chain management: A case study', *Journal of Food Science* 90(2), S388–S398. https://doi.org/10.1111/1750-3841.17001

Zafar, A., 2025, 'Reconciling blockchain technology and data protection laws: Regulatory challenges, technical solutions, and practical pathways', *Journal of Cybersecurity* 11(1), tyaf002. https://doi.org/10.1093/cybsec/tyaf002

Zaman, A., Tlemsani, I., Matthews, R. & Mohamed Hashim, M.A., 2025, 'Assessing the potential of blockchain technology for Islamic crypto assets', *Competitiveness Review: An International Business Journal* 35(2), 229–250. https://doi.org/10.1108/CR-05-2023-0100

Zhan, Y., Yeung, A.C., Tan, K.H., Xiong, Y., Xing, X. & Ye, F., 2025, 'Success and failure of blockchain technology providers: Founders' power, beyond-blockchain exploration and centralized decision-making', *Journal of Operations Management* 71(7), 893–916. https://doi.org/10.1002/joom.1364