Journal of Transport and Supply Chain Management
ISSN: (Online) 1995-5235, (Print) 2310-8789

Advancing sustainable supply chain management through digitalisation: Insights from the South African automotive industry

Authors:
Megan Kirsten[1]
Simelwe Mthethwa[1]
Thuli Sitsha[1]
Wesley Niemann[1]

Affiliations:
[1]Department of Business Management, Faculty of Economic and Management Sciences, University of Pretoria, Pretoria, South Africa

Corresponding author:
Wesley Niemann,
wesley.niemann@up.ac.za

Dates:
Received: 06 Aug. 2025
Accepted: 09 Sept. 2025
Published: 23 Oct. 2025

How to cite this article:
Kirsten, M., Mthethwa, S., Sitsha, T. & Niemann, W., 2025, 'Advancing sustainable supply chain management through digitalisation: Insights from the South African automotive industry', *Journal of Transport and Supply Chain Management* 19(0), a1221. https://doi.org/10.4102/jtscm.v19i0.1221

Background: Automotive manufacturing organisations are major contributors to carbon emissions, creating social, environmental and economic challenges. Adopting holistic sustainability can provide a competitive advantage. In developing countries like South Africa, digitalisation remains in its early stages, and few studies have explored the role of Industry 4.0 technologies in supporting sustainable supply chain management (SSCM). Many firms continue to rely on traditional supply chain practices because of barriers such as limited infrastructure and skills shortages.

Objective: The purpose of this generic qualitative study is to explore the role of digitalisation in SSCM in the South African automotive industry.

Method: A generic qualitative approach was employed using semi-structured interviews with 12 senior managers from automotive organisations. Purposive sampling ensured participants had relevant experience in digitalisation and sustainability.

Results: The findings show that digitalisation significantly enhances SSCM by improving operational efficiency, increasing supply chain visibility, reducing carbon emissions and supporting sustainability optimisation. Participants acknowledged digital tools as enablers for more proactive and transparent supply chains although adoption is constrained by resource limitations and resistance to change by employees.

Conclusion: Digitalisation is a key driver for SSCM in the automotive sector, offering pathways to reduce emissions and improve supply chain performance. Overcoming adoption barriers through investment, training and policy support is essential to unlocking its full potential.

Contribution: This study contributes to the limited body of knowledge on digitalisation and SSCM in developing countries. It provides practical insights for managers and policymakers aiming to leverage digital tools to advance sustainability in automotive supply chains.

Keywords: digitalisation; industry 4.0; sustainable supply chain management; carbon emissions; automotive industry.

Introduction

Environmental protection is vital for sustaining life and ensuring access to natural resources (Harivelo & Harifidy 2022:513–514). Human production and consumption are major contributors to emissions, with manufacturing accounting for one-fifth of global carbon emissions and 54% of energy use (Liang & Zhong 2023:2; World Economic Forum 2023). The automotive industry is among the most carbon-intensive sectors because of its high energy consumption and fossil fuel reliance (Chen, Sharma & Liu 2023:3; Liu, Xin & Li 2022:36352; Lu et al. 2018:371; Matthess et al. 2023:1; Palea & Santhià 2022:2). Growing environmental awareness and pressure from the United Nations' sustainable development goals (SDGs) are pushing manufacturers to adopt sustainable supply chain management (SSCM) practices (Lenort, Wicher & Zapletal 2023:2; Liu, Song & Liu 2023:1). Legislative requirements and sustainability assessments are also key motivators (Chauhan et al. 2023:1; Jasiński, Meredith & Kirwan 2021:1123; Lukin, Krajnović & Bosna 2022:5). Sustainable supply chain management integrates environmental goals into supply chain processes to reduce emissions and improve performance (Lee 2021:3).

Digitalisation and Industry 4.0 (I4.0) technologies support SSCM by enabling automation, smart systems and data-driven decisions (Horvat, Kroll & Jäger 2019:887; Kumar et al. 2023:10; Ma & Lin 2023:1). I4.0 tools such as Enterprise Resource Planning (ERP), Electronic Data Interchange

(EDI) and computer-aided systems enhance supply chain visibility and responsiveness (Bai et al. 2020:3; Liu et al. 2023:1; Nikishina 2023:1). These technologies reduce resource use and emissions while improving sustainability reporting and transparency (Chari et al. 2022:2501; Xu, She & Liu 2022:11). Despite their potential, early digital adoptions often prioritised profit over environmental outcomes (Liu et al. 2023:4–5). However, advanced I4.0 applications now enable more efficient SSCM integration (Tseng et al. 2021:13). In South Africa, I4.0 adoption faces obstacles such as limited infrastructure, technological resistance because of a lack of knowledge in I4.0 and social inequalities (Luthra et al. 2020:1508; Maisiri, Van Dyk & Coeztee 2021:2). Nevertheless, competition and the need for process efficiency drive adoption (Horváth & Szabó 2019:120).

The global automotive industry plays a crucial role in sustainable development but remains a major pollution source (Opazo-Basáez, Vendrell-Herrero & Bustinza 2018:2; Palea & Santhià 2022:1). Although technological advances improve efficiency and environmental performance, research on low-carbon supply chains is still developing (Chen & Jin 2023:1–2; Moshood et al. 2021:1). Most studies focus on developed regions, whereas developing countries like South Africa often face greater sustainability challenges (Baig et al. 2020:1; Xu et al. 2022:13; Yang et al. 2024:1). The automotive supply chain requires further research on digitalisation's role in SSCM transitions (Yi et al. 2023:3). Empirical studies from developing regions remain limited, creating a gap in understanding how digital tools can reduce environmental impact in such contexts (Chauhan et al. 2023:1; Luthra et al. 2020:1507). Identifying the drivers and barriers of digital SSCM adoption is crucial for guiding sustainable transformation (Narimissa, Kangarani-Farahani & Molla-Alizadeh-Zavardehi 2020:248).

This generic qualitative study explores how digitalisation supports SSCM in reducing carbon emissions within South Africa's automotive industry. It examines the key drivers and barriers to digital adoption and investigates the digital tools used to promote sustainability. During this investigation, semi-structured interviews were conducted with senior managers employed by South African automotive organisations.

The proposed study aimed to answer the following questions:

- *How does digitalisation contribute to SSCM in the South African automotive industry?*
- *What are the drivers for adopting digitalisation for SSCM in South African automotive supply chains?*
- *What are the barriers to adopting digitalisation for SSCM in South African automotive supply chains?*
- *What digital tools are being used to advance SSCM in the South African automotive industry?*
- *How are digital tools used to advance SSCM in the South African automotive supply chains?*

This study offers two key contributions. Firstly, it provides an academic contribution by examining the adoption of advanced digital tools such as artificial intelligence (AI), the Internet of Things (IoT) and robotics to enhance SSCM in the South African automotive industry. It offers novel insights into how digitalisation can support SSCM in a developing country context, an area that remains underexplored. Secondly, the study delivers practical value by guiding South African automotive managers on leveraging digital tools to improve supply chain transparency, monitor carbon emissions and reduce waste. The findings encourage managers to make strategic investments in digital technologies to advance sustainability objectives and address key operational challenges.

Literature review

An overview of the South African automotive industry

The South African automotive sector plays a key role in the country's economy by contributing to Gross Domestic Product (GDP), exports and job creation (Sharma & Naude 2021:443). It comprises seven major manufacturers, with 64% of production allocated for export (Redda & Surujlal 2021:209), and contributes 18.7% to national manufacturing output, making it the largest manufacturing segment (Modise, Mpofu & Adenuga 2021:3). It ranks as the fourth largest industry in manufacturing sales and the fifth largest in exports (Govender 2022:14). Globally, South Africa is the 23rd largest vehicle producer (Arthur et al. 2021:2).

Over 450 component manufacturers operate within the industry, with Gauteng, KwaZulu-Natal, Eastern Cape and Western Cape producing around 70% of total output (Worku 2018:2). These suppliers play a critical upstream role by producing parts for vehicle assembly, many of which are exported across Africa for aftermarket use (Mngadi 2019:11; Qhogwana 2017:26). Dealerships connect manufacturers to consumers by offering vehicles and replacement parts (Govender 2022:15; Majola 2020:13; Makgopa 2016:34). Despite its importance, the industry faces challenges such as outdated infrastructure, high emissions and coal-reliant energy use (Modise et al. 2021:3–4). To stay competitive and reduce environmental impact, manufacturers must embrace digital technologies and transition to SSCM (Ikome et al. 2022:1170; Monaco & Wuttke 2023:1).

Sustainable supply chain management

Sustainability is increasingly gaining attention and is becoming an important topic in operations management (Chen, Despeisse & Johansson 2020:2). According to the Brundtland Report, sustainability is the development that satisfies current demands without compromising the capacity of future generations to satisfy their own needs (Chen et al. 2020:2). The automotive industry is focusing on incorporating sustainability into its practices and is more mindful of how its processes and systems impact the environment as it is the key industrial sector that influences the sustainability of the

global economic system (Szász, Csíki & Rácz 2021:1). Focusing on sustainability is critical because supply chains now play an important role in a sustainable global economy making SSCM essential (Park & Li 2021:1). Sustainable supply chain management is the management of capital, material and information flow and the collaboration of supply chain partners that consider economic, social and environmental sustainability objectives derived from stakeholders (Jia, Zuluaga-Cardona, Bailey & Rueda 2018:1). The automotive industry significantly impacts society and the environment because they contribute to climate change, posing a threat to the environment (Mathivathanan, Kannan & Haq 2018:1). Therefore, the industry has adopted SSCM practices because of the external and internal pressures it experiences from regulation and stakeholders (Mathivathanan et al. 2018:1). Manufacturing industries are encouraged to use I4.0 to interact with their supply chain networks and improve sustainable development (Li, Dai & Cui 2020:1–3).

Pillars of sustainable supply chain management

Organisations' performance and engagement in environmental, social and governance matters are encapsulated by the three pillars of sustainability (Park & Li 2021:1). The United Nations' 2030 Agenda for sustainable development consists of 17 SDGs, which integrate economic, social and environmental sustainability as vital facets of sustainable development. To achieve the UN SDGs, it is essential to enhance supply chain sustainability (Asche et al. 2018:1; Chams & García-Blandón 2019:1; Park & Li 2021:1). Additionally, there is a significant interrelationship between the SDGs and digital technologies, as digitalisation can considerably advance the realisation of these goals by offering faster and more effective solutions to pressing global challenges such as poverty, climate change and inequality (Kumar et al. 2023:1).

Economic sustainability refers to the economic values that organisations contribute to the environment to support and ensure prosperity for future generations (Nogueira, Gomes & Lopes 2022:6). This incorporates social equity with environmental integrity principles and facilitates innovation, productivity and wealth creation (Söylemez & Yangil 2017:113). Supply chains benefit from successful economic sustainability in the long run because it can strengthen organisations' competitive advantage, achieve transparency and healthy corporate management, boost profits and support the development of the two other pillars (Park & Li 2021:8).

Social sustainability is the responsibility of considering the rights of stakeholders and refraining from irresponsible practices that may harm them (Nassar et al. 2020:467). To maintain a healthy society and environment, social sustainability is concerned with how organisations affect workers, customers and local communities (Park & Li 2021:8). Social sustainability in supply chains explores the social and economic circumstances surrounding the workers, manufacturers and suppliers, including human rights and workplace safety (Park & Li 2021:8). Social sustainability involves making sure that organisations and their supply chain partners manage their operations in a way that supports labour and human rights, health and safety and initiatives to improve moral workplace behaviour (Najjar, Small & Yasin 2020:1). Social sustainability is linked to factors such as labour conditions, diversity, well-being, quality of life, equality and connectedness inside and outside the community (Jia et al. 2018:1).

Environmental sustainability relates to the equitable distribution of benefits from natural and environmental resources across generations (Park & Li 2021:7). Environmental sustainability issues develop when raw materials are used in the production and consumption process and when pollution from activities is released into the environment (Park & Li 2021:7). SDG 13's objective is to combat climate change as sustaining the environment is a global priority. Environmental sustainability plays an important role in SSCM by reducing carbon emissions and energy consumption and encouraging environmentally friendly practices to promote the development of green supply chains (Yu 2024:195–196). Green supply chain management (GSCM) helps solve environmental issues and enhance organisational performance, and it requires cutting waste and pollution while using renewable and non-renewable resources (Rupa & Saif 2022:141). Environmental sustainability within supply chains can be achieved through implementing optimal environmental management and protection policies and practices for managing natural resources and by the effective allocation of resources by utilising digitalisation (Li et al. 2020:1; Park & Li 2021:7). Environmental regulations and protection policies drive supply chain sustainability by enforcing accountability and transparency while also fostering innovation and long-term resilience.

The automotive industry uses the life cycle assessment (LCA) to assess the environmental performance of vehicles (Bicer & Dincer 2018:142). Life cycle assessment is recognised as the most common technique for assessing environmental impact in manufacturing (Chen et al. 2020:3). Life cycle assessment is used to determine and examine organisations' environmental impact by identifying the natural resources and energy inputs that are used (Sutawidjaya, Nawangsari & Nor 2021:180). Life cycle assessment obtains data on environmental issues, which may be utilised to reorganise supply chains to enhance environmental performance (Sutawidjaya et al. 2021:180).

The importance of sustainable supply chain management

Sustainable supply chain management practices have been encouraged by organisations that need to achieve sustainability and enhance supply chain performance (Sánchez-Flores et al. 2020:4). There are various internal and external motives behind adopting SSCM principles. The internal drivers include achieving long-term profitability, brand differentiation benefits, streamlining operations, productivity improvement, competitive opportunities and lowering organisational risk (Gao et al. 2022:698; Zimon, Tyan & Sroufe 2020:222).

Other SSCM benefits are improvements in environmental performance and operational efficiency, improved brand image and reputation and expanded customer base and market share, which can lead to a competitive advantage and stronger stakeholder relationships (Gao et al. 2022:698; Paulraj, Chen & Blome 2017:246). External drivers include societal, market and regulatory pressures, including enhancing customer expectations, keeping positive supplier relationships, obeying rules, avoiding penalties and obtaining social acceptance (Gao et al. 2022:698; Shamseldin & Shendy 2021:23). Sustainable supply chain management can help facilitate the implementation and execution of supply chain integration using digital tools (Kumar et al. 2023:1).

Digitalisation

Digitalisation is the process of adopting I4.0 tools and technologies in the supply chain to improve internal and external supply chain capabilities by enabling organisations to reduce costs, increase revenue and gain a strategic competitive advantage (Pathak 2023:122). Digitalisation transforms traditional supply chains into interconnected systems that function flawlessly by integrating the processes at the societal, organisational and individual levels through information sharing, collaboration and communication using digital technologies (Tseng et al. 2021:3–4). Digitalisation allows manufacturing processes to be integrated, automated and optimised for a more efficient production flow (Chen et al. 2020:5).

Digitalisation reduces carbon emissions by promoting sustainable practices and the use of renewable energy (Xu et al. 2022:5). The adoption of digital technologies improves the environmental performance of products and reduces pollution during production (Chu et al. 2023:176). Reduction of carbon emissions through digitalisation can provide ways for traditional supply chains to become green supply chains (Chen & Jin 2023:2). To achieve SSCM, supply chains should be enhanced to include digital tools (Tseng et al. 2021:4). Traditional supply chain processes and systems can be transformed by digital tools, leading to improvements in efficiency, flexibility and environmental awareness (Peng et al. 2023:2). Digital tools can help organisations share information about product life cycle statuses and manufacturing processes while taking environmental implications into account (Liu et al. 2023:2). Digital tools enable the exchange of important information between downstream and upstream supply chain members to build a collaborative environment to improve sustainability (Liu et al. 2023:9).

I4.0 technologies create cyber-physical systems on the assembly line that provide real-time data regarding the actions performed on manufacturing processes and make that data available within the organisation (Braccini & Margherita 2018:3). Cyber-physical systems are information technology systems incorporated into the physical world to monitor and control it (Humayed 2017:1803). One goal of I4.0 is to maximise efficiency and productivity while utilising fewer resources (Jamwal et al. 2021:1). I4.0 provides a more efficient manufacturing process that adopts sustainability, remanufacturing tools, environmental procedures and reuse programmes (Haleem et al. 2023:208). Some I4.0 benefits include enhanced competitiveness and performance, improved flexibility and resilience and higher profitability (Haleem et al. 2023:204).

Drivers for adopting digitalisation for sustainable supply chain management

Pressures from external stakeholders such as customers, government and shareholders in adopting sustainability practices and digital technologies can motivate manufacturing organisations to implement these elements into their supply chains (Oubrahim & Sefiani 2023:311; Rebs et al. 2019:899). Key drivers that enable the adoption of I4.0 tools for SSCM typically include public funding for digital infrastructure, innovation that enhances environmental performance, secure cloud services and private investments in digital platforms (Samper et al. 2022:648). Public and private support structures can enable the transfer of assistance from digitally mature organisations to those less developed (Samper et al. 2022:648). A legal and political environment that promotes sustainable supply chains is also important, as governments and public institutions exert pressure on supply chain members (Samper et al. 2022:648). Pressure to adopt sustainable practices is put on organisations and supply chains by national regulators and trade organisations (Saeed & Kersten 2019:11). Government regulations and incentives help enforce laws that hold organisations responsible for the environment, thereby encouraging organisations to work towards sustainability through strict rules (Harikannan, Vinodh & Gurumurthy 2021:363). Environmental laws encourage organisations to improve their environmental performance to avoid trade barriers and fines that result from non-compliance (Liu et al. 2021:624; Saeed & Kersten 2019:11). The government interacts with stakeholders and offers tools that support SSCM (Jia et al. 2018:269).

Larger organisations that face reputational risks are more committed to sustainable practices than smaller firms (Jia et al. 2018:265). Campaigns that expose bad practices made by organisations and harm their reputation drive the adoption of sustainable practices (Jia et al. 2018:269). Proactive sustainability activities are driven by societal pressures and awareness of external and internal customers on environmental issues (Harikannan et al. 2021:363). As people become aware of green manufacturing and I4.0 benefits, governments and industries are likely to prioritise sustainable practices (Harikannan et al. 2021:363).

Improvement of the working environment and the health and safety conditions for employees are important drivers (Jia et al. 2018:269–270). To maintain high employee morale and loyalty, organisations should ensure proper working conditions and promote employee health and well-being (Dubey et al. 2017:1121). Pressure and increased awareness of sustainability from society and the media influence organisations to change their health and safety approaches

towards employees and the environment (Jia et al. 2018:265; Neri et al. 2018:459). As employee welfare and social reputation are necessary when competing for skilled labour, health and safety drivers have motivated organisations to engage in sustainable practices (Jia et al. 2018:270; Phatak & Sople 2018:21).

Barriers to adopting digitalisation for sustainable supply chain management

Change resistance and I4.0 technologies are key barriers to adopting digitalisation for SSCM (Durmaz & Budak 2022:6667; Maisiri et al. 2021:9). The resistance comes from unknown benefits and a need for knowledge of novel skills (Sharma et al. 2023:5). This resistance also comes from labour unions' concerns about I4.0 potentially reducing or even eliminating low-skilled and semi-skilled jobs (Maisiri et al. 2021:9). Employees resist changing from traditional practices to embracing innovation because of fear of failure and opposition to necessary changes (Menon & Ravi 2021:5).

There is a lack of political support for the implementation of SSCM, especially in developing countries (Jia et al. 2018:270). This relates to the government not implementing industry-friendly policies towards SSCM (Muchaendepi et al. 2019:495). Governments may delay implementing sustainable supply chain practices and I4.0 technology as policymakers struggle to agree on a common goal to determine what regulations need to be set (Durmaz & Budak 2022:4; Jia et al. 2018:270). Manufacturing organisations in South Africa were concerned that policies and regulations do not support large-scale I4.0 adoption as they were not able to address the rapid I4.0 technology-related changes (Maisiri et al. 2021:10). Rapid advances in Industry 4.0 technologies such as automation, AI and advanced manufacturing outpace governmental policies, risking job losses for low-skilled workers while creating demand for digitally skilled roles that the current workforce is often unprepared to fill. Without adaptive regulation and investment in skills and innovation, developing countries may remain a technology consumer rather than an innovator.

Financial constraints pose a substantial hurdle in I4.0 adoption, particularly when it comes to developing modern infrastructure and innovating sustainable processes (Ghadge et al. 2020:674). Transitioning to production with intelligent machines can create high energy and capital investments (Durmaz & Budak 2022:6667). This includes costs of installing technologies, engineering services and mechanical equipment, maintenance and labour (Sharma et al. 2023:6). Organisations in developing countries may find the initial costs of going green too expensive, and the benefits may not materialise or occur quickly (Jia et al. 2018:270). Emerging technologies pose a significant risk to organisations' investments as there is a possibility of financial loss (Kamble, Gunasekaran & Sharma 2018:110).

Digitalisation requires a workforce that is capable of using digital technologies (Agrawal, Narain & Ullah 2019:303). There is a lack of knowledge of which I4.0 technology to use in sustainable supply chain processes, causing a deficiency in SCM (Durmaz & Budak 2022:6668). The lack of knowledge of the latest technology and management of global data increases the resistance to adopting I4.0 technology (Ghadge et al. 2020:674). Another barrier to adopting I4.0 is youth unemployment coming from their lack of basic technology skills (Maisiri et al. 2021:9). Enhancing skills and training is needed to align competencies for I4.0 (Sharma et al. 2023:5).

Top management support presents clear visions and values for digital transformation; therefore, the lack of top management support will lead to resistance to change (Agrawal et al. 2019:303). The lack of top management commitment and leadership prevents the adoption of I4.0 sustainability practices (Durmaz & Budak 2022:6668). The adoption of I4.0 can be delayed because of a lack of contributions or knowledge from senior officials; therefore, management acceptance, support and involvement are important (Sharma et al. 2023:5).

In addition, the lack of technology and infrastructure facilities is a barrier to SSCM (Narayanan, Sridharan & Ram Kumar 2019:950; Rahman et al. 2020:689), resulting in system failures and disruptions (Durmaz & Budak 2022:6668). The lack of technical infrastructure is a significant barrier in developing countries (Kumar, Mangla & Kumar 2024:405). In South Africa, the lack of access to advanced technology and a reliable electricity supply is an infrastructure barrier (Maisiri et al. 2021:11).

Organisations can experience issues when integrating new technologies or systems with legacy systems (Koca & Erdoğan 2024:133). Adopting digitalisation poses system integration difficulties and high integration costs (Menon 2024:245). Data security and privacy are major concerns for organisations moving towards digitalisation (Agrawal et al. 2019:303). Data security concerns like hacking, confidentiality breaches and reliability have become common because of the inflow and outflow of data (Weerabahu et al. 2023:3051).

Digital tools

Artificial intelligence and machine learning: Artificial intelligence is the application of human intelligence in machines to carry out tasks creatively and autonomously, without human intervention (Moro-Visconti, Cruz Rambaud & López Pascual 2023:2). Artificial intelligence systems analyse large volumes of data to identify trends, forecast outcomes and make decisions more efficiently and accurately (Moro-Visconti et al. 2023:2–3). Through the analysis of production data to identify inefficiencies and recommend improvements, AI can improve the sustainability of production by maximising resource use, reducing energy and eliminating waste (Rakha 2023:3). Organisations utilise AI to automate repetitive tasks and carry out difficult calculations, which increases productivity and flexibility,

minimises waste and lowers the carbon emission index for products (Ghobakhloo 2020:8; Moshood et al. 2021:9).

Machine learning (ML) is a subset of AI that is an algorithm or programme that can learn with minimal or no additional assistance (Amruthnath & Gupta 2018:355). Machine learning algorithms optimise and minimise resource usage by utilising the amount of data that organisations have access to (Varriale et al. 2023:8). For organisations, any differences between the ordered volume and actual consumption can result in significant losses (Varriale et al. 2023:8). Consequently, by using predictive models, ML approaches could support supply chain activities by making accurate and efficient decisions (Moro-Visconti et al. 2023:3; Varriale et al. 2023:8). Machine learning identifies buying patterns, streamlines inventory and warehousing processes and enhance forecasting (Moshood et al. 2021:9).

Internet of Things: Internet of Things is a network of intelligent, interactive and connected objects that allow real-time status information transfer and sensing, bridging processes, data and people to develop intelligence more effectively and create new business opportunities (Liu et al. 2023:8). Machines and product components can exchange real-time data, which facilitates the ongoing monitoring and control of processes (Beier, Niehoff & Xue 2018:1). Internet of Things facilitates real-time inventory management, automated stock replenishment and delivery tracking (Moshood et al. 2021:1).

Internet of Things provides access to information about manufacturing components and processes across supply chains (Beier et al. 2018:2). As IoT makes real-time data accessible, it may foster transparency and help organisations manage and report environmental impacts thoroughly (Ali et al. 2023:3; Beier et al. 2018:2). Internet of Things can improve supply chain transparency through real-time process monitoring of resource usage (Chen et al. 2020:5; Moshood et al. 2021:8). Complementary technologies such as Radio Frequency Identification (RFID) enhance IoT applications by enabling accurate identification and tracking of products throughout the supply chain, while digital twins create virtual replicas of physical systems that allow predictive analysis, performance optimisation and improved decision-making based on real-time data (Tao et al. 2019:158).

Big data analytics: Organisations frequently lack comprehensive information about the impact of their supply chains on the environment when conducting environmental assessments (Dubey et al. 2019:535). Big data analytics (BDA) may be able to address these problems, which go undetected because supply chains lack transparency (Dubey et al. 2019:535). Big data analytics evaluates massive volumes of data to provide insights and meaning to the underlying data (Bai et al. 2020:3).

Supply chain operations' data can be utilised to assess overall sustainability (Raut et al. 2019:12). Sustainable supply chain management uses BDA to enhance performance and sustainability by improving process control and enabling processes to act independently (Liu et al. 2023:7; Raut et al. 2019:12). Big data analytics enables processes to be environmentally friendly by identifying opportunities to minimise waste and improve energy efficiency (Peng et al. 2023:3). Big data analytics rapidly analyses data to minimise potential expenses such as carbon emission penalties and maintain low environmental cost (Liu et al. 2023:5).

Additive manufacturing: Additive manufacturing (AM), also known as 3D printing, involves using several layered or additive development frameworks for three-dimensional (3D) solid items (Bai et al. 2020:3). Additive manufacturing reduces shipping costs by producing components on demand at locations (Haleem et al. 2023:172). Three-dimensional prototypes can be produced more rapidly and affordably than traditional methods (Chen et al. 2020:17; Haleem et al. 2023:172). Additive manufacturing has the potential to reduce energy usage in production by decreasing material waste and allowing customisation in manufacturing (Sun et al. 2021:2). Developing customised parts and products results in lower material consumption and waste, which lowers environmental impact (Chen et al. 2020:17; Ribeiro et al. 2020:2).

Blockchain technology: Blockchain technology is a decentralised database that all users of a blockchain network can access and contains shared public and private ledgers of all digital activities conducted (Praveenadevi et al. 2023:234). Supply chain participants have access to comprehensive information in real time (Park & Li 2021:2). Blockchain emphasises intelligent execution, audibility, security and decentralisation (Praveenadevi et al. 2023:234). Blockchain enables supply chains to identify products that have been counterfeited more readily and unethical suppliers by limiting data recording to those who are authorised (Praveenadevi et al. 2023:234). Blockchain ensures transparency and reliability of data produced in SSCM because the immutable blocks eliminate the possibility of false reputation records among stakeholders through continuous monitoring (Liu et al. 2023:7; Varriale et al. 2023:9).

Autonomous robotics: Autonomous robotics replicate human behaviours in manufacturing processes to enhance operational efficiency and support emerging sustainable practices (Bai et al. 2020:3; Varriale et al. 2023:14). They are designed to operate accurately and reliably, which minimises errors and waste (Liu et al. 2024:1). Organisations can automate repetitive, manual processes to accelerate process completion, minimise errors and reduce delays (Peng et al. 2023:3). They can also operate continuously without the need for breaks or sleep, which increases production with less energy consumption (Liu et al. 2024:1). Robots should perform repetitive activities such as sorting, counting and fetching products, while employees focus on more difficult and strategic tasks (Peng et al. 2023:3).

Cloud computing: Cloud computing provides resources and services on demand by utilising distributed computer networks, including data centres and servers (Chauhan et al. 2023:7). Cloud computing reduces the need to operate large, expensive on-site computer equipment while providing simplicity, scalability and global accessibility (Moshood et al. 2021:8). Cloud computing can provide better energy efficiency strategies, lower carbon emissions and reduced equipment requirements (Radu 2017:4). Cloud computing can function alongside and enhance on-premises supply chain applications by providing an enhanced user interface, greater capability and instant access to new updates and features (Moshood et al. 2021:8). Cloud computing services offer continuous platforms for global networking real-time data sharing and access to network information (Bermejo & Juiz 2023:42; Chauhan et al. 2023:7).

Methodology

Research design

A generic qualitative research design was most suited to this study because it allows researchers to explore real-world experiences, uncover meaningful themes and deepen understanding of a specific issue without aiming to develop new theory (Jahja, Ramalu & Razimi 2021:5; Mihas 2019:1). This approach was ideal for investigating how South African automotive organisations adopt digital tools in their transition towards SSCM, particularly from the perspectives of industry participants (Kennedy 2016:1373). Semi-structured interviews with open-ended questions enabled the collection of rich, experience-based data (Kennedy 2016:1372), which was analysed thematically to identify patterns and insights.

Sampling

The units of analysis consisted of automotive organisations operating in South Africa, regardless of whether they have manufacturing plants in the country. The units of observation were the individual participants from automotive organisations who are knowledgeable and involved with the adoption of digital tools and sustainability. Twelve automotive organisations participated in the study, allowing for 12 semi-structured interviews. One participant per organisation was interviewed.

Purposive sampling was used to sample participating organisations. Purposive sampling is strategic as information-rich participants are sought out to optimally address the research questions (Mweshi & Sakyi 2020:190). The researchers purposefully selected relevant organisations to address the research questions and provide rich information. Criterion sampling was used to recruit organisations that met the eligibility criteria, specifically, automotive organisations operating in South Africa that use digitalisation to achieve SSCM.

Criterion sampling was also used to select participants who met pre-determined criteria (Moser & Korstjens 2018:10). Participants had to operate in the supply chain or logistics department and be in a middle to senior position. Participants were required to have at least 2 years of industry experience and have been working for at least 6 months in the organisation. Snowball sampling was used to access the participants with the desired eligibility criteria (Mweshi & Sakyi 2020:191; Naderifar, Goli & Ghaljaie 2017:2). These sampling methods ensured that the topic of interest was investigated from the viewpoints of participants involved with digitalisation and SCM in the South African automotive context. Table 1 provides the details of the participants.

Data saturation was used to determine the final sample size. Data saturation occurs when additional data reveal redundant information and no new information emerges (Moser & Korstjens 2018:11). The researchers experienced data saturation after the ninth interview, as no new information emerged. Sample sizes are flexible, with the recruitment of participants continuing until data saturation is achieved (Chisela 2022:45). Three additional interviews were conducted to confirm saturation, totalling 12 interviews.

TABLE 1: A profile of this study's participants.

Pseudonym	Job title	Organisation	Role of the organisation	Gender	Employment duration	Years of experience	Interview duration (min)
P1	General manager	O1	Dealer	Female	2 years	11	58
P2	Chief executive officer	O2	Second-hand dealer	Male	8 months	30	34
P3	Logistics manager	O3	Component supplier	Male	10 months	15	39
P4	Distribution manager	O4	Dealer	Female	6 years	24	61
P5	Supply chain manager	O5	OEM	Male	10 years	10	70
P6	Supply chain manager	O6	OEM	Male	6 years	12	61
P7	Managing director	O7	Vehicle finance and sales	Male	12 years	16	54
P8	Logistics manager	O8	Assembler	Male	6 years	27	46
P9	Supply chain planning manager	O9	OEM	Female	2 years	18	60
P10	Chief operating officer	O10	Consultants	Male	12 years	20	27
P11	Logistics manager	O11	Component supplier	Male	6 months	15	54
P12	Managing director and chief executive officer	O12	Component supplier and dealer	Male	15 years	30	46

Note: Average interview duration was 50.83 min.
OEM, Original Equipment Manufacturer.

Data collection

Data were collected through semi-structured interviews, which allowed the researchers to understand the participants' experiences and perspectives on the phenomenon (Adeoye-Olatunde & Olenik 2021:1360). Open-ended questions were used to focus on specific topic areas, allowing the development of many themes (Judith 2020:22). Open-ended questions allowed participants to provide their unique perspectives. A combination of face-to-face and online video conferencing was conducted with participants to accommodate their preferences. Ten face-to-face interviews were conducted at the participants' offices. Microsoft Teams was used to conduct online video conferences with three participants who were not based in Gauteng.

A discussion guide was designed around the research questions and literature review to get the participants' perspectives on the phenomenon. The discussion guide was pre-tested with an experienced automotive general manager who met the inclusion criteria. Based on feedback, a few adjustments were made to improve the discussion guide. The pre-test data were included in the final sample. The 12 semi-structured interviews lasted between 27 and 70 min, with an average of 50.83 min. The face-to-face interviews were audio-recorded, whereas online video conferencing interviews were video-recorded. The researchers collaboratively transcribed all 12 interviews. The researchers listened to each recording while reading the transcripts and made the necessary adjustments to guarantee the accuracy of the transcripts.

Data analysis

Thematic analysis was used to analyse the data, which is an approach to identify codes and then develop themes (Clarke & Braun 2017; Hardy 2019). Codes are words and brief phrases that represent the researcher's interpretation of meaningful patterns in the data (Byrne 2022:1393; Neuendorf 2018:212). Themes are patterns that answer research questions and are derived from data collection (Kiger & Varpio 2020:846). Initially, the researchers observed the transcripts, sought patterns in the transcripts and then theorised the patterns by coding the transcripts using Atlas.ti 24 software, using descriptive tags for the relevant data extracts. Thereafter, related codes were grouped into sub-themes, which were then refined and organised into main themes that aligned with the research questions.

Trustworthiness

Trustworthiness is the degree of confidence in data, interpretation and methods applied to assure the quality of research (Connelly 2016:1). The trustworthiness of this study was assessed using four criteria: credibility, dependability, confirmability and transferability (Adler 2022:599). Triangulation and peer debriefing were used to ensure credibility. Data were collected from multiple participants who met the eligibility criteria, offering a variety of perspectives. Credibility was further improved by having in-depth discussions during peer debriefing sessions. The dependability of the data was enhanced by keeping an accurate audit trail and documenting all changes. The researchers transcribed the participants' responses verbatim to refrain from interfering with the findings with their perspectives. Therefore, confirmability was achieved by linking the gathered data to the literature through thematic analysis, identifying main themes and sub-themes to ensure the participants' true perspectives and experiences were represented, not the researchers. Transferability was achieved by providing a detailed description of participants, data collection methods employed and by documenting the discussion guide used to allow other researchers to follow the same framework to collect insights.

Ethical considerations

The Research Ethics Committee of the Faculty of Economic and Management Sciences at the University of Pretoria approved the study before data collection (Group 23/2024) on 31 July 2024. All participants were required to read and sign an informed consent form before commencing with the interviews. The form outlined the study's purpose, emphasised that participation was voluntary and assured anonymity and confidentiality. Pseudonyms were used for participants and organisations in both the transcripts and final data presentation to protect the identities of those involved.

Results

The study identified five main themes directly related to the research questions. The main themes include digitalisation's contribution to SSCM, drivers for adopting digitalisation for SSCM, barriers to adopting digitalisation for SSCM, digital tools for SSCM and the application of digital tools for SSCM. The following section discusses the main themes and related sub-themes with supporting raw data extracts. Table 2 illustrates a summary of the research questions, main themes and sub-themes.

Theme 1: Digitalisation's contribution to sustainable supply chain management

Theme 1 identified digitalisation's contribution to SSCM in the South African automotive industry. The study identified 12 contributions of digitalisation, categorised into four sub-themes: improved operational efficiency, carbon emission reduction, enhanced sustainability and waste reduction.

Improved operational efficiency

Improved operational efficiency occurs when organisations utilise their resources effectively to enhance profitability. Participants experienced reduced errors when adopting digitalisation. Digitalisation reduces the need for human intervention, which reduces errors as demonstrated in the following:

TABLE 2: A summary of the research questions with their related main themes and sub-themes.

Themes	Sub-themes	Outcomes
1 Digitalisation's contribution to SSCM	1.1 Improved operational efficiency	1.1.1 Reduced errors
		1.1.2 Quick task completion
		1.1.3 Quick customer response
		1.1.4 Improved lead time
	1.2 Carbon emission reduction	1.2.1 Carbon emissions
		1.2.2 EVs and hybrids
	1.3 Optimised sustainability	1.3.1 Sustainability reporting
		1.3.2 Sustainable investments
	1.4 Waste reduction	1.4.1 Reduced waste
		1.4.2 Reduced paper
		1.4.3 Increased productivity
2 Drivers for adopting digitalisation for SSCM	2.1 Stakeholder influence	2.1.1 Customer influence
		2.1.2 Competitor influence
		2.1.3 OEM and Head office influence
		2.1.4 Shareholder influence
		2.1.5 Government influence
	2.2 Customer engagement	2.2.1 Customer satisfaction
		2.2.2 Customer experience
		2.2.3 Convenience
	2.3 Competitive advantage	2.3.1 Customer service
		2.3.2 First-mover
	2.4 Cost reduction	2.4.1 Cost savings
		2.4.2 ROI
		2.4.3 Saving space
3 Barriers to adopting digitalisation for SSCM	3.1 Skills gap	3.1.1 Skills shortage
		3.1.2 Hindered skills development
	3.2 Cost constraints	3.2.1 Digitalisation cost
	3.3 Resistance to change	3.3.1 Employee
		3.3.2 Top management
		3.3.3 Older generation
		3.3.4 Investment
	3.4 Infrastructure limitations	3.4.1 Poor infrastructure
		3.4.2 Loadshedding
	3.5 Data security concerns	3.5.1 Confidentiality
		3.5.2 Trust in digitalisation
	3.6 Systems integration difficulties	3.6.1 Systems compatibility issues
		3.6.2 Legacy systems constraints
		3.6.3 Integration costs
4 Digital tools for SSCM	4.1 Automation	4.1.1 Automated guided vehicles
		4.1.2 Robotics
	4.2 Advanced analytics	4.2.1 Power BI
		4.2.2 Blockchain
		4.2.3 Artificial intelligence
	4.3 Internet of Things	4.3.1 Sensors
		4.3.2 Tracking devices
		4.3.3 RFIDs
		4.3.4 Tablets
	4.4 Enterprise software	4.4.1 SAP
		4.4.2 EDI
		4.4.3 Customised software
5 The application of digital tools for SSCM	5.1 Supply chain visibility	5.1.1 Tracking and monitoring
		5.1.2 Earlier awareness
		5.1.3 End-to-end supply chain visibility
		5.1.4 Accountability
		5.1.5 Information accuracy
	5.2 Decision-making	5.2.1 Improved stock control
		5.2.2 Improved decision-making
	5.3 KPIs	5.5.1 Accuracy
		5.3.2 Profitability
		5.3.3 Quality control
	5.4 Improved accuracy	5.4.1 Production planning
		5.4.2 Inventory accuracy
		5.4.3 Order accuracy
	5.5 Collaboration and communication	5.5.1 Collaboration
		5.5.2 Information sharing
		5.5.3 Collaborative planning

Table 1 continues on the right side →

TABLE 2 (Continues...): A summary of the research questions with their related main themes and sub-themes.

SSCM, sustainable supply chain management; BI, business intelligence; EDI, electronic data interchange; RFID, radio frequency identification; ROI, return on investment; OEM, orginal equipment manufacturer; EV, electrical vehicle, SAP, systems applications and product; KPIs, key performance indicators.

> 'But that includes now the robots, less human intervention, which means less human error of all that.' (P3, Logistics manager, Male)

Digitalisation enables quick task completion by automating processes and providing users with immediate access to information, as identified by participants. This can be seen in the following quote:

> 'I'd say turnaround times of how quickly transactions can be conducted and concluded.' (P7, Managing director, Male)

Furthermore, participants indicated that customers want products on demand and digitalisation enables these participants to fulfil customer demand quicker, as seen in the following quote:

> 'Speed to market. So that's definitely gone up. We are in that era where everybody wants everything on demand. So I think obviously they need to be considerate of that as well.' (P5, Supply chain manager, Male)

Improved lead time was identified by participants. Digitalisation enhanced planning, allowing organisations to reduce lead times and deliver more vehicles or components. This finding is supported by the following quote:

> 'So if a carrier gets delivered, it makes its time. I think it takes like a day or depending where it is, a day back to the depot. So with regards to that, we could have actually delivered more vehicles within a week than previously.' (P4, Distribution manager, Female)

Carbon emission reduction

Carbon emission reduction refers to reducing CO2 and other greenhouse gases emitted during operations and vehicle production. Participants highlighted that digitalisation reduced carbon emissions. Digitalisation optimises capacity and route planning by utilising real-time data to determine the number of trucks and trips, track to identify high carbon emission vehicles and design environmentally friendly vehicles. The following quote supports this:

> 'From a logistics perspective is you don't want trucks with two cars on the road, so being more efficient with the transparency and digitisation and trigger points from us to carriers with their planning and more efficient route calculations. I think that is the important part because you're reducing the carbon footprint, you're reducing the number of trucks that need to go down, you're reducing the number of.' (P5, Supply chain manager, Male)

Digitalisation monitors and reports emissions, which encouraged organisations to build electric vehicles (EVs) and hybrids to reduce emissions, as mentioned by participants. Digitalisation may encourage organisations to develop EVs and hybrids to meet customer demand and achieve SDGs as described in the following:

> 'Ourselves will go over to EV vehicles, right? So, meaning there's going to be a lot of digitalisation when it comes to EV vehicles, because you need to fit the right battery for the right vehicle as well. So, meaning we have to adopt as quickly as possible because in 2030 they need some EV vehicles on South African roads.' (P8, Logistics manager, Male)

Optimised sustainability

Optimised sustainability involves improving processes to use resources more efficiently and effectively, with emphasis on reducing environmental impact. A participant indicated that digitalisation has encouraged them to utilise digitalisation to incorporate sustainability reporting and Environmental, Social, and Governance (ESG) metrics to track their carbon footprint, as illustrated in the following:

> 'So in that project also, there's another factor which we're working on, which is the sustainability side. So we're also looking for the ESG metrics or reporting to be reported out there so that we can also see what our carbon footprint is in the supply chain, working with all the shipments and supply partners, etc.' (P9, Supply chain planning manager, Female)

Investments in sustainable practices contribute to a more sustainable adoption of digitalisation, as highlighted by one participant. Digital tools can be charged sustainably by investing in sustainable practices such as solar power to reduce energy consumption, as seen in the quote that follows:

> 'And then with the solar, charging those assets because it doesn't help you get all the battery powered and you don't have a sustainable way of recharging them.' (P5, Supply chain manager, Male)

Waste reduction

Waste reduction is the practice and strategy used to minimise waste, thereby reducing environmental impact. Adopting digitalisation helped participants reduce waste. Digitalisation helps control stock levels and availability of the correct stock at the right time, reducing waste associated with overstocking and delays as illustrated in the following:

> 'Now with digitalation digital technologies, it's a lot easier to control stock holding and the right part at the right time at the right place, which reduced a lot of waste…' (P10, COO, Male)

Digitalisation enabled organisations to be more efficient by using digital systems to store information. This is supported in the following:

> 'So instead of printing all this documentation, everything is listed on the computer.' (P1, General manager, Female)

Digitalisation increased productivity, as pointed out by participants. Digital tools increase productivity by automating processes and providing real-time information to make informed production decisions. This is highlighted in the following quote:

> 'But ever since they brought in the robots, they now cut the time in half, which has made it more efficient and which results in more production.' (P3, Logistics manager, Male)

The findings are consistent with the current literature as one goal of digitalisation is to maximise efficiency, which can be done through the optimisation of manufacturing processes for more efficient production (Chen et al. 2020:5; Jamwal et al. 2021:1). Organisations can utilise digital tools that encourage them to adopt sustainable practices to reduce their carbon emission (Xu et al. 2022:5). Organisations can use their digital capabilities for sustainable reporting, as digital tools can assist in better management and reporting of environmental impacts (Ali et al. 2023:3; Beier et al. 2018:2). Digital tools can reduce waste in production and operations as they are designed to operate accurately and reliably (Liu et al. 2024:1).

Theme 2: Drivers for adopting digitalisation for sustainable supply chain management

Theme 2 discusses the drivers for adopting digitalisation for SSCM. The study identified 13 drivers categorised into 4 sub-themes: stakeholder influence, customer engagement, competitive advantage and cost reduction.

Stakeholder influence

Stakeholder influence refers to individuals or groups that can have an impact on organisations' decisions and outcomes. Participants emphasised how customers' influence impacts their decision to adopt digitalisation for SSCM. Digitalisation enables organisations to meet environmentally conscious and digitally proficient customers' expectations by providing efficient, sustainable solutions and enhancing transparency. This is demonstrated in the following quote:

> '… so customers does play a big role. I'm going to go back to it. The newer generation wants to know that when they're purchasing a car, not just for themselves, that they're trying to save emissions.' (P1, General manager, Female)

Competitors influence organisations to adopt digitalisation for SSCM and maintain competitiveness, as indicated by seven participants. Digitalisation equips organisations with capabilities to meet customer demands and remain competitive in changing markets, as described by the following quote:

> 'So I think in order to actually keep up with the market, because motor-industry is a very tough market, there's a lot of brands, they've got new features and stuff. So I think in order for you to digitalise and keep up with advancements, you actually need to. Yeah. Because it's really competitive. And currently we feel it, because especially now with Chinese brands that's coming in as well.' (P4, Distribution manager, Female)

Original Equipment Manufacturer (OEM) and head office's decisions influenced organisations to adopt digitalisation for SSCM. OEMs and head offices determine when organisations should adopt digitalisation by evaluating the costs and benefits as indicated in the following:

> 'Headquarters, they will always want to push efficiency, speed, cost savings, less overheads, more money you save.' (P3, Logistics manager, Male)

Shareholders influence digitalisation adoption for SSCM, as they aim to achieve strong returns on investments, long-term value creation and sustainable growth. Digitalisation enables organisations to maximise profitability by optimising processes. This is highlighted by the following quote:

> 'So first of all from a look at a shareholder perspective, a shareholder will always require a return on investment or capital.' (P2, CEO, Male)

The government's rules and regulations influenced organisations to adopt digitalisation for SSCM by implementing policies and regulations that motivated them to invest in digitalisation to meet sustainability standards. This is seen in the following quote:

> '… these days the government push the OEMs to reduce carbon neutral footprint and you also get points. The more points you get, the more money rebate you get from the government.' (P11, Logistics manager, Male)

Customer engagement

Customer engagement is the continuous development of long-term relationships between organisations and customers. According to participants, customer satisfaction motivated them to adopt digitalisation as it streamlined processes and gained better insights into customer needs through real-time data. This is indicated in this quote:

> 'Customer satisfaction. It goes back to that. So we want everyone, all stakeholders, internally, externally, to be sufficient, efficient, and longevity of every business that we touch base with.' (P5, Supply chain manager, Male)

Digitalisation enhances customer experience by providing integrated platforms and streamlining interactions to be more responsive, as seen in the following:

> 'You want to engage with that customer before that service is due or before the customer realises that I should be in the market for a new vehicle. So, they use different systems and technologies and marketing tools that's integrated within the internal systems to, you know, to serve that customer.' (P7, Managing director, Male)

Convenience for customers played a role in the adoption of digitalisation as it can offer customers convenience by allowing them flexibility and easier access in interacting with the organisation at their comfort, as illustrated in the following:

> 'It's a virtual showroom, that type of virtual showroom. So yes, you have cars, but it's actually just the order taker. You sit there, you see a big screen, this is new cars. You choose your specifications and your colours.' (P1, General manager, Female)

Competitive advantage

Competitive advantage is the capabilities that enable organisations to offer superior products or services compared to competitors. Participants emphasised that improved customer service played a crucial role in the adoption of digitalisation by offering real-time information to customers, as seen in the following:

> 'It gives us the competitive advantage by utilising the system and getting to the customer first and providing that information back to that customer.' (P7, Managing director, Male)

Furthermore, participants mentioned that being a first-mover influenced digitalisation adoption. Digitalisation gave organisations features and strategic benefits that enabled them to stay ahead of competitors, supported by the following quote:

> 'And if we are the first to do that, I think we will be the game changers in this industry.' (P1, General manager, Female)

Cost reduction

Cost reduction is the practice used to minimise costs to maximise profitability. Participants experienced cost savings with the adoption of digitalisation by reducing manual labour, improving resource management and automating processes. See the quote that follows:

> 'Cost saving. It's only cost savings. The logistics cost in vehicle manufacturing is by far the highest component of vehicle cost, especially in South Africa and Africa, because we're far from the rest of the world, and there's lots of cost savings to be had by optimised supply chain and that's what we need that digitalisation for.' (P10, COO, Male)

A return on investment influences organisations to adopt digitalisation because of the potential financial benefits they can experience, such as profitability. This is illustrated in the following:

> 'So if you can do it within your industry or within your company, you don't even have to, because in that sense, you will actually be more profitable. Say for instance, if you've got an idea and that actually takes off, there will be more sales basically, so there's more profit. So your investor or your stakeholder will actually benefit from it.' (P4, Distribution manager, Female)

Saving space influenced digitalisation adoption, as the need for physical storage was reduced. This is demonstrated in the following:

> 'Where previously it's like, you need to have that specific car on the floor, and this is this one. So that's saving space, obviously. Not building so much, not having so many cars, not paying too much rent, not having too many staff.' (P1, General manager, Female)

The literature review links with the findings that stakeholders influence organisations to adopt digitalisation to improve sustainability (Oubrahim & Sefiani 2023:311). Customer engagement drives organisations to incorporate and expand sustainability across their supply chains (Najjar et al. 2020:5). Successful adoption of sustainability can strengthen supply

chains and provide organisations with a competitive advantage (Park & Li 2021:8). By adopting digital tools in the supply chain, organisations can experience cost reductions (Pathak 2023:122).

Theme 3: Barriers to adopting digitalisation for sustainable supply chain management

Theme 3 discusses the barriers that hinder organisations from adopting digitalisation for SSCM. The study identified 14 barriers categorised into six sub-themes: skills gap, cost constraints, resistance to change, infrastructure limitations, data security concerns and systems integration difficulties.

Skills gap

Skills gap is the difference between what an organisation requires and the abilities that employees possess. Skills shortages hindered digitalisation adoption by limiting their ability to effectively implement, manage and optimise new digital tools as illustrated:

> 'Another challenge could also be the tech skills. Yeah, I think in South Africa specifically, there is definitely a room as well to improve the tech skills available.' (P9, Supply chain planning manager, Female)

Hindered skills development can prevent the adoption of digitalisation, as organisations may prioritise adopting new digital tools over upskilling existing employees as described:

> 'But then the more you're pushing less human intervention, it means there's no skill sharing, there's no skill transfer.' (P3, Logistics manager, Male)

Cost constraints

Cost constraints are the financial limitations preventing organisations from investing or pursuing projects. High digitalisation costs can hinder digitalisation adoption. Digitalisation costs limit organisations' ability to invest in the initial and maintenance expenses required for successful digital transformation, as highlighted:

> 'Cost is always a big factor and these IT systems … These [*Information Technology*] IT systems and so on is, it can become very expensive and especially the bigger the system and the more powerful the system is, the more expensive it can become.' (P10, COO, Male)

Resistance to change

Change resistance is the reluctance of individuals to accept and adapt to new conditions. According to participants, employees' resistance to digitalisation can hinder or impact the pace of adoption by opposing new digital tools or delaying adoption. This resistance may stem from a lack of understanding of the benefits or job security concerns. This is illustrated in the following:

> 'I would say it's more a human, because us as humans are so used to doing things a certain way. And that's where we get stuck, because this is how the previous person did it, this is how I was taught it, and this is how I am doing it.' (P4, Distribution manager, Female)

In addition, participants mentioned that top management's resistance can hinder the adoption by not providing the necessary support and resources for digital transformation. They tend to be more inclined to the old organisational culture or old ways of operating, as seen in the following:

> 'Resistance to change, and organisational culture, you know, some people might not want to change, and that's actually a big, big, big thing. You know, some management is, they've set in the old ways, they don't want to change, such kind of things, and culture also, you know, they believe just this way.' (P11, Logistics manager, Male)

The findings indicate that older generations' resistance can hinder adoption because of their discomfort or unfamiliarity with new technologies. They may prefer familiar processes, which then slows down the adoption as demonstrated in the following:

> 'Impact on people, number one. You'll have, sure, I'm going to keep on. It sounds like I'm hammering you on the older generation, but I'm really not. But that is a factor. I've dealt with a lot of older generation people that's not used to change. They don't want to change it.' (P1, General manager, Female)

Investors' reluctance to invest in digitalisation hinders adoption. This can be a lack of willingness to allocate funds towards digitalisation because of uncertainty. This is described in the following:

> 'Because of the reluctance to spend money, it takes some time now to convince and to prove that it needs to be implemented.' (P10, COO, Male)

Infrastructure limitations

Infrastructure limitations are the inadequate physical or organisational structures that limit organisations' ability to adopt new technologies or processes. Participants indicated that poor infrastructure, such as unreliable networks, inconsistent electricity supply and high electricity costs, could impede adoption. Poor infrastructure restricts organisations' ability to support advanced technologies, as demonstrated in the following:

> 'Which we all want to drive the high technology and obviously, like our infrastructure is not set up correctly to have that high standard technology. So you cannot have a high standard technology with a lower infrastructure.' (P3, Logistics manager, Male)

Load shedding can impede adoption by causing power disruptions that interfere with digital operations and limit the ability to fully utilise digital tools, as mentioned by some participants. Power disruptions can impact the charging of digital tools that rely on electricity, leading to delays. Refer to the following quote:

> 'But loadshedding has actually impacted our flow a lot, especially with the movement of the vehicles because if they don't keep the scanners on charge, yes, then the scanners don't work. Then we have to basically divert back to doing it manually.' (P4, Distribution manager, Female)

Data security concerns

Data security concerns are the potential threats and risks related to safeguarding sensitive information from unauthorised access. According to participants, concerns about confidentiality can impede adoption because of fears of access to sensitive information, as described in the following:

> 'And then the other one is obviously making sure that from a confidentiality, from a cyber security, you have all those checks and balances in place as well.' (P2, CEO, Male)

A lack of trust in digitalisation can hinder adoption, as concerns about insufficient security and the potential risks of data breaches can occur. This can be seen in the following quote:

> 'I'm using AI as an example or a robot as an example. I don't know how secure some of those things are. If you're dealing with sensitive information, how secure is that?' (P1, General manager, Female)

Systems integration difficulties

Systems integration difficulties are difficulties encountered while integrating different systems, software applications or technologies. Participants stated that compatibility issues can hinder adoption as integrating different systems can be challenging, leading to inefficiencies, data inconsistencies and workflow disruptions as seen in the following:

> 'So, there's lots of integrations that need to take place within your system and that system operates in our ecosystem. So, obviously, if that integration fails or something doesn't work as it should, you know, that creates the challenges and it can be a counterproductive result.' (P7, Managing director, Male)

The findings show that legacy systems' constraints can impede adoption by making it difficult to integrate new systems with outdated ones. Legacy systems frequently lack flexibility or scalability to support more advanced systems, as mentioned by participants and demonstrated in the following:

> 'So you need new technologies to adapt into different systems in a way where that system was never, or sometimes never created to adapt to the newest technology that we want to integrate into it.' (P5, Supply chain manager, Male)

Integration costs can impede adoption by creating financial obstacles, leading to higher costs. Organisations may incur technical expertise and systems upgrade expenses associated with integrating systems, as detailed in the following:

> 'For me, so integration is one of the bigger issues where a lot of systems don't integrate with each other, and then you need to develop some sort of interface between those systems, which the next problem is it then adds costs.' (P10, COO, Male)

The findings are consistent with the literature review as a lack of technology skills is a barrier to adopting digitalisation (Maisiri et al. 2021:9). Transitioning production to include digital tools requires significant capital investments (Durmaz & Budak 2022:6667). Change resistance arises from a lack of understanding of digitalisation benefits (Sharma et al. 2023:5). A lack of infrastructure to support digitalisation can lead to disruptions and system failures (Durmaz & Budak 2022:6668). With the increased movement of data, data security concerns such as confidentiality, breaches and reliability issues have become prevalent (Weerabahu et al. 2023:3051). Integration challenges can hinder adoption when organisations encounter difficulties in integrating new systems with legacy systems (Koca & Erdoğan 2024:133).

Theme 4: Digital tools for sustainable supply chain management

Theme 4 identified different digital tools used by organisations for SSCM. The study identified 12 types of digital tools, categorised into four sub-themes: automation, advanced analytics, IoT and enterprise software.

Automation

Automation is using technology to carry out operations with little to no human intervention. Automated guided vehicles (AGVs) are used to transport parts to the assembly line. Automated guided vehicles can lower energy use through accurate routing, minimise human errors as correct parts are picked and optimise the movement of parts. See the quote that follows:

> 'We've gone one step further, taken away the tow motor and made it automated guided vehicles, AGVs. So, basically, they would drive themselves to the line.' (P6, Supply chain manager, Male)

Participants noted that they are using robotics to automate tasks, which reduces manual handling during production as highlighted in the following:

> 'Robots actually putting cars together where they actually took the man-made out of it…' (P1, General manager, Female)

Advanced analytics

Advanced analytics uses methods to analyse information from multiple data sources. A participant indicated that Power BI provides visualisation and analytics capabilities to monitor real-time performance as described in the following:

> 'Power BI, the function that once you understand it, it opens doors for many, many things. It can constantly visualise things. Let's say, yeah, we can constantly see what's happening in the warehouse.' (P11, Logistics manager, Male)

Blockchain enables organisations to track and trace products' movement across the supply chain, as stated and illustrated by a participant in the following:

> 'Live tracking, I would say. Blockchain, you know, timestamps. Let's say areas where you can have multiple references from the client's reference to your reference so that they can link together. So order numbers, outbound numbers.' (P11, Logistics manager, Male)

According to participants, AI identifies strategic opportunities to improve areas such as marketing, feature optimisation and decision-making. This is explained in the following:

> 'Because AI helps you to make your decisions faster, delivery to the right places in the market at the right time.' (P5, Supply chain manager, Male)

Internet of Things

Internet of Things refers to interconnected devices and software that communicate and share information with other devices over the Internet. Sensors monitor performance and provide real-time data, as emphasised by a participant. Sensors can detect and prevent errors related to inefficiencies in production, as supported in the following:

> 'So an engine has got a computer that kind of has all the sensors that measures it. So if you just near the steering wheel, there's normally, it looks like the back of a [*television*] TV. And it's got a whole bunch of pins in it. What you do is we then have a reader that goes in there. And what it'll do, it'll tell you what the vehicle, what all the error codes are in the vehicle. So one of the error codes that it could come up with is the air and oxygen intake and combustion engine aspects of it.' (P2, CEO, Male)

Tracking devices provide real-time information about the location and status of products, as illustrated in the following:

> 'And then once we ship the goods, we add a tracking device, and that tracking device is linked to your order. And then you can track in Africa. You can type in your order number, and that order number is linked to your shipment.' (P11, Logistics manager, Male)

In addition, by using RFIDs, participants experienced an improvement in inventory management by capturing the real-time movement:

> '… the operator just scans where the vehicle is, there's a barcode on each parking area, so he would scan the barcode to the vehicle and marry, so that means that the vehicle is in this location, and then you know where the vehicle is at all times …' (P6, Supply chain manager, Male)

Furthermore, by using tablets, participants are reducing paper usage and gaining immediate access to real-time information. This can be seen in the following:

> 'So it's no longer an actual paper that the dealer signs once he receives the vehicle. It's on a tablet, he checks damages, he checks that all of the, like the spare wheel and the aerial and stuff that's loose in the vehicle is actually there. He can check it, he can tick it off and he signs it off.' (P4, Distribution manager, Female)

Enterprise software

Enterprise software is designed to assist and automate essential functions. Systems Applications and Product offers participants insight into the flow of products and components, along with up-to-date information as demonstrated in the following:

> 'We are we're going to implement SAP now for for scanning facility now in our plant. So that is now another supply chain digitalisation as well SAP they will. It will see your component movement, your parts movement as well.' (P8, Logistics manager, Male)

Electronic Data Interchange facilitates the exchange of information between supply chain partners, leading to reduced paper use. EDI provides real-time access to information, enabling organisations to identify areas for improvement as seen in the following:

> '… EDI it's a different system, so EDI is basically between us and our supplier and network in terms of plant performance or what happens within the four walls that we have a different system for.' (P9, Supply chain planning manager, Female)

In addition, participants indicated that customised systems can seamlessly integrate with supply chain partners' systems, leading to streamlined processes and easier data accessibility. These systems are tailored to the organisations' needs. See the quote that follows:

> 'So, obviously, our main system that we utilise is (x) and that delivers our [*Customer Relationship Management*] CRM, [*Document Management System*] DMS, our financial reporting and it's integrated into all the participating stakeholders.' (P7, Managing director, Male)

The literature links with the findings that automating repetitive tasks allows employees to concentrate on more strategic tasks (Peng et al. 2023:3). Advanced analytics enables transparency and reliability of data through continuous monitoring and provides real-time information (Liu et al. 2023:7; Park & Li 2021:2; Varriale et al. 2023:9). Internet of Things provides real-time information on components, products and processes across the supply chain (Beier et al. 2018:2). Organisations can leverage digitalisation to transform traditional supply chain processes and systems, enhancing efficiency, flexibility and environmental awareness (Peng et al. 2023:2).

Theme 5: The application of digital tools for sustainable supply chain management

Theme 5 discusses how digital tools are applied in SSCM. The study identified 16 applications of digital tools categorised into five sub-themes: supply chain visibility, decision making, key performance indicators (KPIs), improved accuracy and collaboration and communication.

Supply chain visibility

Supply chain visibility is to manage the flow of products, materials and information in real time as they move through the supply chain. Participants stated that digital tools enable real-time tracking and monitoring of parts and products. Tracking and monitoring provide real-time data on inventory and production processes, which enhances transparency across the supply chain as per the following quote:

> 'But I think it's critical in digitalisation, ensuring the tracking and monitoring of where parts and suppliers generate their resources from.' (P2, CEO, Male)

Digital tools provided early awareness of potential problems. Earlier awareness can enable proactive decision-making and optimise resource usage. Organisations can anticipate disruptions and efficiently manage inventory as described in the following:

> 'You have more time to develop contingencies because now you see far out there's a issue coming at you.' (P9, Supply chain planning manager, Female)

Digital tools provide organisations with end-to-end supply chain visibility through a centralised system. End-to-end visibility provides an in-depth view of each stage in the supply chain, allowing for more responsive, efficient and sustainable practices as demonstrated in the following:

> 'Everything in one. So that's what digitalisation has also done. It's actually allowed us to collaborate all of the different functions or parts, departments into one system actually. (P4, Distribution manager, Female)

The data show that digital tools enhance accountability across the supply chain by enabling organisations to accurately identify where and when problems occur, as mentioned by participants. Digital tools create audit trails with every transaction and process. This can be seen in the following:

> 'And especially to pinpoint exactly what happens to the vehicle. Say for instance, a vehicle gets damaged within our holding yard. I can go back and then track where exactly that vehicle was at a particular time to see if it was maybe the driver or the negligence.' (P4, Distribution manager, Female)

Digital tools improve information accuracy by providing reliable, quality data throughout the entire supply chain. This is evident in the following quote:

> 'We have seen improvements in terms of loading shipments on the system and improving on the quality of the data that is on the system now. So the system can kick out any errors without sending it to the next person.' (P3, Logistics manager, Male)

Decision-making

Decision-making entails choosing strategies and processes to effectively manage supply chain operations, inventory, sourcing and transportation. Participants mentioned that digitalisation can accurately predict the stock needed, ensuring that they have the right inventory at the right time to prevent overstocking or stockouts. This is explained in the following:

> 'And also to ensure things like just-in-time holding, that if your digitalisation is up to scratch, then you would know how much stock you need to hold.' (P2, CEO, Male)

In addition, participants noted that digital tools improve decision-making throughout the supply chain by providing real-time information and data analysis, allowing for more informed and strategic choices. This is highlighted in the following:

> 'So yeah, it's very important that you are reducing time spent manually checking things by having something check it for you, and have more on-demand reporting, which can help you steer better decision-making.' (P5, Supply chain manager, Male)

Key performance indicators

Key performance indicator metrics measure overall supply chain performance and the effectiveness of the organisation's strategies towards its objectives. Accuracy KPIs are used by participants to assess the effectiveness of digital tools by measuring their reliability and accuracy. Digitalisation provides organisations with accurate real-time data, which enables precise performance reporting and gives accurate information on supply chain operations as illustrated in the following:

> 'So, we measure it in terms of how fast we can send vehicles through and how accurately, in terms of is it. So, we have a strict threshold where we need to make sure we deliver all vehicles at 98% on time.' (P6, Supply chain manager, Male)

Profitability KPIs are used to measure the impact of digital tools by assessing how they contribute to financial performance. Profitability KPIs can encourage cost-effective practices. The following quote supports this:

> 'It's all about the profitability that your company can actually go through. And with profitability, of course, comes sustainability. And the profit and sustainability that you are getting is because of the correct technologies that you have invested in.' (P12, Managing director and CEO, Male)

In addition, quality control KPIs are used by participants to assess how effectively digital tools improve quality and minimise defects. Digital tools help to identify where improvements are needed in production. This is evident in the following:

> 'We have very good quality control after production as well that is digitised to talk straight back into the plant so that we know exactly when to cut off.' (P5, Supply chain manager, Male)

Improved accuracy

Improved accuracy is an organisation's ability to reduce mistakes and optimise resources by aligning its information and operations with real-time needs and conditions. Digital tools enable more accurate production planning by leveraging real-time data. Digital tools provide accurate insights into production timelines, helping organisations to make better use of resources as seen in the following:

> 'From outside we measure it by your planning your your buffer stock. How do you plan your production? Meaning that you can see how many units you can build for the for for the month or how many units you can build, not to dry up your buffer stock, meaning you don't have to dry up your whole supply or your whole logistics or your whole supply of of parts going through to the line side.' (P8, Logistics manager, Male)

Digital tools improve inventory accuracy by providing real-time data and accessible information. Digital tools offer continuous inventory monitoring and better demand forecasts. This is illustrated in the following:

> 'So it's imperative, more so imperative to have information available at your fingertips to better manage the demand of the finished products as well as the supply of the raw material.' (P9, Supply chain planning manager, Female)

Furthermore, digital tools improve order accuracy as they can ensure that orders are fulfilled correctly and on time, thus reducing the need for returns. This can be described in the following:

> 'So it's critical that the parts are not late and that the right parts are supplied. I remember years ago when we supplied when we supplied automotive industry without this technology, we often supplied the wrong parts.' (P10, COO, Male)

Collaboration and communication

Collaboration and communication occur when individuals or organisations exchange information and ideas and work together by combining skills and resources to achieve a common goal based on shared understanding. Digitalisation enhances collaboration within participants' supply chains by enabling real-time connectivity, which allows stakeholders to align efforts more effectively. As a result, collaboration is improved, and supply chain partners can make more informed, aligned decisions. This is demonstrated in the following:

> 'Collaborating with stakeholders. If our system is collaborating with theirs, we can see vice versa. Example is we've got a dealer management system. They can order stock on that system. If they're out of stock, they can see who's got stock the nearest around them. So collaborating with your stakeholders, not just your dealers, but with head office.' (P11, Logistics manager, Male)

Digital tools facilitate information sharing by providing stakeholders with real-time access to information. Digitalisation enables the exchange of real-time data by integrating different systems, which provides a centralised platform for the sharing of information as seen in the following:

> 'So SAP sale templates, we have those systems that need to talk to each other. And then from those systems, we have additional, we call them smaller systems that needs to feed into a centralised system.' (P5, Supply chain manager, Male)

In addition, participants emphasised that digital tools enable collaborative planning across the supply chain through integrated platforms. Digital tools help stakeholders to work together effectively by optimising the planning of shared resources, production and logistics. This is described in the following:

> '… collaboration and the ease of uh strategic planning in terms of what is necessary with demand and forecast from the retail side right up to us uh where we where we are all selling and manufacturing absolutely crucial.' (P12, Managing director and CEO, Male)

Previous literature aligns with the findings that digitalisation provides visibility by making information available to supply chain partners (Varriale et al. 2023:2). Digital tools support supply chain activities through accurate and efficient decision-making (Moro-Visconti et al. 2023:3; Varriale et al. 2023:8). Digital tools can improve accuracy as they are designed to operate with high accuracy and reliability (Liu et al. 2024:1). Organisations will measure the benefits of digital tools by using profitability and quality metrics (Haleem et al. 2023:204). Digitalisation transforms a traditional supply chain into an interconnected system by integrating processes through information sharing, collaboration and communication enabled by digital tools (Tseng et al. 2021:3–4).

Conclusion

Summary of findings

This study aimed to explore the role of digitalisation in South African automotive organisations for SSCM. Furthermore, the study also explored the drivers and barriers to adopting digitalisation, along with the digital tools that can be utilised.

The first research question explored how digitalisation contributes to SSCM in the South African automotive industry. The study identified that digitalisation contributes to SSCM through improved operational efficiency, carbon emission reduction, optimised sustainability and waste reduction. Some participants noted that digitalisation reduces errors as organisations require less human intervention. Digitalisation enables quick task completion by automating processes and providing immediate access to information. Organisations can respond to and fulfil customer demand more quickly through digitalisation. A few participants indicated a reduction in lead time as digitalisation enhances planning. Digitalisation helps to reduce carbon emissions by optimising capacity and route planning through real-time data. Digitalisation enables carbon emission reporting, encouraging the development of EVs and hybrids to reduce emissions. Digitalisation motivates organisations to use digital tools for sustainability reporting by incorporating ESG metrics to track carbon footprint. By investing in sustainable practices such as solar to reduce energy usage, organisations can charge digital tools more sustainably. Digitalisation helps reduce waste by controlling stock levels and ensuring the correct stock is available at the right time. Organisations reduce their paper usage by using digital systems to store information. The automation of processes through digitalisation has increased productivity by providing real-time information for informed production decisions.

The second research question explored the drivers for adopting digitalisation for SSCM. Stakeholders, particularly customers, competitors, OEM and head office, shareholders and the government, influence organisations to adopt digitalisation to meet demand, sustainability standards and expectations. Customer engagement, specifically customer satisfaction, customer experience and convenience, influenced digitalisation adoption. Digitalisation streamlines processes, improves transactions, provides real-time insights into customer needs and offers greater convenience with easy access at their comfort. Competitive advantage in terms of customer service and first-mover advantage drives organisations to adopt digitalisation. Digitalisation provides real-time information to customers, improving customer services. Organisations leverage digitalisation for strategic benefits and features to maintain a competitive advantage. Cost savings from digitalisation stemmed from reduced manual labour, improved resource management and process automation. Financial benefits such as profitability and return on investment influenced digitalisation adoption. Digitalisation reduces the need for physical storage, saving space.

The third research question explored the barriers that hinder the adoption of digitalisation for SSCM. The lack of skills among employees hinders the effective adoption of digital tools. Hindered skills development can hinder digitalisation adoption, as organisations may prioritise adopting digitalisation over upskilling existing employees. The high initial and maintenance costs associated with digital tools hinder organisations from adopting digitalisation. Resistance to change from employees, top management, older generations and investors can impact digitalisation adoption. Employees may resist because of a lack of understanding or job security concerns while older generations may prefer familiar processes. Top management often follows the old organisational culture and may not provide the necessary support. Investors can be reluctant to fund digitalisation because of uncertainty. Infrastructure limitations, such as poor infrastructure and load shedding, limit organisations' ability to support advanced technologies, while power disruptions hinder the charging of digital tools, causing delays. Data security concerns, particularly confidentiality and trust in digitalisation, can hinder adoption because of fears of access to sensitive information and potential data breaches. Systems integration difficulties, including compatibility issues, legacy system constraints and high integration costs, hinder adoption by causing inefficiencies, limiting flexibility and increasing costs for technical expertise and upgrades.

The fourth research question explored the digital tools used to advance SSCM. Automation, particularly AGVs and robotics, is used to efficiently transport parts and automate tasks, optimising movement and reducing manual handling. Advanced analytics such as Power BI, blockchain and AI provide organisations with real-time insights, visualisation, analytics and transparency. Organisations use IoT technologies like sensors, tracking devices, RFIDs and tablets to gain real-time data for error detection, movement tracking and decision-making. Enterprise software, specifically SAP, EDI and customised software, enhances SSCM by providing real-time information, improving information exchange and enabling seamless integration.

The fifth research question explored the application of digital tools to enhance SSCM. Digital tools improve supply chain visibility by enabling real-time tracking and monitoring, early problem detection and end-to-end visibility. Accountability is strengthened by audit trails, and information accuracy is improved through reliable data. Digital tools accurately predict inventory needs, which improves stock control while also improving decision-making by providing real-time data to make more strategic choices. Organisations use KPIs to evaluate the effectiveness of digital tools like accuracy to measure real-time performance, profitability to assess cost-effectiveness and quality control to improve quality and identify improvements. Digital tools improve accuracy in production planning, inventory and ordering by providing real-time data for better resource utilisation, continuous monitoring and accurate demand forecasts, thus reducing returns. Digital tools enhance collaboration and communication by improving coordination, information sharing and collaborative planning. They provide real-time connectivity and access to information, while integrated platforms facilitate information exchange and planning.

Theoretical implications

The study identified five theoretical implications. Firstly, the findings confirm the existing literature highlighting digitalisation's role in improving operational efficiency and sustainability within supply chains. The use of digital tools to reduce waste during production and report environmental impacts more accurately with sustainability reporting aligns with previous research (Ali et al. 2023:3; Beier et al. 2018:2; Liu et al. 2024:1). The study's findings expand on existing literature by providing examples of how digitalisation contributes to SSCM in the South African automotive industry. Secondly, the study corroborates existing literature that identifies stakeholder influence, customer engagement, cost savings and competitive advantage as significant drivers for adopting digitalisation for SSCM (Najjar et al. 2020:5; Oubrahim, Sefiani & Happonen 2023:311; Park & Li 2021:8; Pathak 2023:122; Rebs et al. 2019:899). The findings indicate that organisations are motivated to adopt digitalisation and improve sustainability if they are aware of the benefits (Harikannan et al. 2021:363).

Thirdly, the findings are consistent with the literature, highlighting the barriers to adopting digitalisation for SSCM such as change resistance, financial constraints, infrastructure limitations and the lack of technical skills (Ghadge et al. 2020:674; Kumar et al. 2024:405; Maisiri et al. 2021:9; Menon & Ravi 2021:5). These barriers can impact the pace of adoption of digitalisation. Furthermore, the study confirms that digital tools like AI, robotics, blockchain and IoT technologies can optimise production and operations to be more efficient and transparent (Chen et al. 2020:5; Moshood et al. 2021:8). Digital tools can lead to be better decision-making (Moro-Visconti et al. 2023:2–3). Finally, the study's findings confirm existing literature that emphasises the use of digital tools to track and monitor products, parts and processes (Liu et al. 2023:2). Digital tools facilitate collaboration and communication by improving information sharing and collaborative planning among supply chain partners (Liu et al. 2023:9). The study adds to the existing literature by indicating how digital tools are specifically applied within the South African automotive industry for SSCM, which can be valuable insights to automotive organisations in other developing countries.

Managerial recommendations

The study provides valuable insight for automotive organisation managers to make informed decisions regarding the adoption of digitalisation for SSCM. This study identifies the key drivers, barriers and contributions of digitalisation that enable managers to develop strategies

for successfully adopting digitalisation and enhancing their sustainability. If organisations understand the challenges associated with digitalisation, managers can develop effective strategies to overcome them. To address the skills gap identified in the study, managers should prioritise and invest in employee training to enhance employees' technical skills. This will enable employees to effectively utilise and manage digital tools, leading to quicker adoption. Managers should promote a culture that embraces digitalisation change. This can be achieved by clearly communicating the benefits of digitalisation and providing support to employees during the adoption of digitalisation. The study can assist other organisations by emphasising that the adoption of digitalisation for SSCM should be based on strategic reasons, rather than simply following industry and competitor trends. Organisations must identify their needs and align digital investments with long-term goals. This will help avoid unnecessary investments in digital tools that will be idle and ineffective.

Limitations and directions for future research

The study was conducted in a single industry, the South African automotive industry, which may not fully capture the distinct challenges and opportunities encountered by organisations in other industries. The findings may not be directly relevant to other industries as they may have different drivers, barriers and contributions of digitalisation for SSCM. Future research could be conducted in other industries, such as retail, healthcare or agriculture, to provide a broader perspective on the role of digitalisation in contributing to SSCM.

The study's findings are based on a limited number of participants from the South African automotive industry. Future research can include a larger and more diverse sample of automotive organisations from different regions. The findings only mentioned the immediate impacts of digitalisation, such as reduced errors, waste reduction and quick task completion. The long-term implications of digitalisation were not considered in this study. Future quantitative longitudinal research can be conducted to understand these impacts, as digitalisation and its impact on SSCM may shift over time.

Given that this study focused solely on the context of a singular developing country, future research would benefit from exploring the role of digitalisation in SSCM across other developing countries. This can provide a comprehensive understanding of how digitalisation impacts SSCM in other developing countries. Future research could adopt a quantitative approach to test the nature and strength of the relationships among the key variables mentioned, such as the drivers, barriers and impacts of digitalisation on SSCM. Quantitative studies can be employed to evaluate the effectiveness of digital tools, providing organisations with data-driven insights that inform digitalisation decision-making.

Acknowledgements

Competing interests

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

Authors' contributions

M.K contributed to the methodology, formal analysis, investigation and writing. S.M contributed to the methodology, formal analysis, investigation and writing. T.S. contributed to the methodology, formal analysis, investigation and writing. W.N. contributed to the conceptualisation, methodology, formal analysis, investigation, writing, review and supervision.

Funding information

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

Data availability

The data that support the findings of this study are available on request from the corresponding author, W.N. The data are not publicly available due to privacy requirements of the research participants.

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