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Application of Fourth Industrial Revolution technologies to enhance supply chain sourcing: A systematic literature review

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Background: In an era marked by rapid technological advancements, the manufacturing sector is increasingly adopting Fourth Industrial Revolution (4IR) technologies to streamline sourcing processes within supply chains. Sourcing and supplier management are crucial to achieving competitive advantages, cost reductions and sustainable practices.

Objectives: The study examines the application and the integration of various 4IR technologies in sourcing activities to achieve improved supplier selection, cost control, on-time delivery and supply chain resilience.

Method: A systematic literature review (SLR) was conducted, following a structured methodology across five stages: database selection, keyword generation, application of filters (inclusion and exclusion criteria), search area selection and final document review. The Scopus database was used for data collection, and VOSviewer was employed for keyword co-occurrence analysis.

Results: Out of 1530 documents, 16 relevant studies were identified, highlighting the usage of specific 4IR technologies in the sourcing process. Simulation, Internet of things (IoT), machine learning (ML), additive manufacturing and radio frequency identification (RFID) were found to be critical technologies.

Conclusion: Fourth Industrial Revolution technologies are pivotal in optimising sourcing Key Performance Indicators (KPIs), although gaps exist in the literature around ethical sourcing, augmented reality and cybersecurity. Moreover, the study identifies emerging trends such as crowdsourcing and IoT, which indicate a shift towards data-driven decision-making in sourcing.

Contribution: This study serves as an eye-opener to unveil appropriate 4IR technologies that could be deployed by supply chain managers to ensure effective manufacturing sourcing operations. The study also unveils further research on ethical sourcing and cybersecurity.

Keywords: 4IR technologies; sourcing; supply chain; manufacturing; systematic literature review.

Introduction

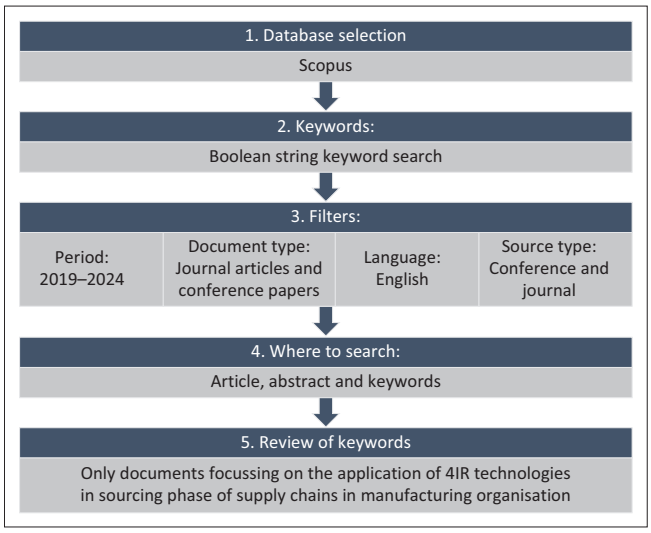
The effective management of supply chain processes in conjunction with the support and collaboration of all stakeholders, is a key priority for manufacturing organisations seeking to strengthen their competitive edge and maximise profits (Jermsittiparsert & Rungsrisawat 2019). Hence, inefficiencies within the sourcing phase, including poor supplier relationships, affect organisational profits in terms of increased costs and hinder brand image, thereby weakening the organisations' competitiveness leverage (Charles & Ochieng 2023). Therefore, the sourcing, selection and management of suppliers have become essential to operational effectiveness and organisational sustainability, thereby prompting organisations to adopt strategic sourcing practices (Mubarik, Kazmi & Zaman 2021). Strategic sourcing in manufacturing aims to maximise value in acquiring raw materials, enhancing environmental sustainability and fostering collaboration with suppliers (Van Hoek & Thomas 2021). Ekechukwu (2024) emphasises that sourcing aims to align an organisation's supplier network with its operational needs to increase productivity, lower costs, maintain quality standards, meet delivery deadlines and comply with legal requirements. Literature has highlighted that concepts such as ethical sourcing, green strategic sourcing, sustainable sourcing, green supplier selection and sustainable supplier selection improve the triple bottom line of people, planet and profits (Liu, Chen & Zhu 2023).

Accordingly, to achieve key strategic performance objectives in sourcing, organisations are increasingly incorporating Fourth Industrial Revolution (4IR) technologies into the sourcing phase of the supply chain. The adoption of 4IR technologies in supply chain systems has gained momentum, with studies examining the benefits of these technologies for supply chains, including optimisation, digital visualisation, information integration, data security, enhanced research and development, and green supply chain practices (Ali 2022; AlMulhim 2021; Nasiri et al. 2020; Wu et al. 2016; Zhao, Hong & Lau 2023). Hence, the aim of the study is to examine industry 4.0 technologies adopted to improve the supply chain sourcing phase in manufacturing organisations.

Key 4IR technologies, on the one hand, include advanced robotics, which involves using robots for various tasks that replicate human actions (Jindal & Kaur 2021); artificial intelligence (AI) and machine learning (ML), which enable machines to learn and make decisions, perform tasks and predict outcomes based on data analysis (Rai et al. 2021); and big data, which focusses on predicting future outcomes rather than merely reporting past ones (Belhadi et al. 2019). On the other hand, it includes augmented reality (AR), which enhances real-world experiences through computer-generated visuals, sounds and other effects (Bai et al. 2020); simulation technology, which allows for the recreation of real-world processes or systems in controlled, repeatable environments (Mourtzis 2020); system integration which can be described as a process that combines various computing systems and software to produce a larger system (Wang et al. 2021); and additive manufacturing (AM) also known as 3D printing technology, which is described as a manufacturing method that enables the layer-by-layer addition of three-dimensional design models through direct production. Additive manufacturing offers an opportunity to lower material usage and associated inventories because it is intrinsically less wasteful and only uses raw materials where necessary (Kunovjanek & Reiner 2020). In addition, cloud computing, on one end, is a concept that combines computing, storage and network infrastructure as one platform that offers faster innovation, economies of scale, flexible resources and computer services (Bashar 2019), while cyber security, on the other end, is described as a technique for keeping data safe against theft, hacking and other threats (Bai et al. 2020). Radio frequency identification (RFID) technology and the Internet of things (IoT) are described as a technology using wireless communication between two objects (one as a tag and the other as a reader) to automatically track and identify these objects (Bai et al. 2020) and a technology that can embed a network of physical items with sensors or both sensors and software to connect and allow them to exchange data and systems over the Internet (Garg et al. 2022).

Methodology

This study used a systematic literature review (SLR) technique. An SLR is a research approach that collects, classifies and assesses different existing research studies using a logical procedure (Mohamed Shaffril, Samsuddin & Abu Samah 2021). This method is adopted to ensure and provide comprehensive evidence and a bias-free approach (Al-Zubidy & Carver 2019) towards the examination of applicable 4IR technologies to optimise the sourcing phase in a manufacturing organisation. An SLR methodology developed by Carrera-Rivera et al. (2022) was adapted to complete the systematic review and accomplish the primary goal of the study.



Source: Adapted from Carrera-Rivera, A., Ochoa, W., Larrinaga, F. & Lasa, G., 2022, 'How-to conduct a systematic literature review: A quick guide for computer science research', *MethodsX* 9, 101895. https://doi.org/10.1016/j.mex.2022.101895

FIGURE 1: Methodology for systematic literature review.

The methodology consists of five steps that follow each other in chronological order. Figure 1 shows the modified step-by-step procedure, which includes: database selection, keywords generation, filters (inclusion and exclusion criteria), where to search (in the database) and lastly, the review.

An SLR encourages researchers to find studies outside of their own subject areas and networks by introducing comprehensive searching techniques, specified search strings, and established inclusion and exclusion criteria (Paul et al. 2021).

Database selection

Selecting an appropriate database is a critical step in ensuring the validity of literature review studies, as the quality of sources directly impacts the reliability and depth of the research findings (Carrera-Rivera et al. 2022). For this study, the Scopus database was chosen because of its extensive indexing of high-quality, peer-reviewed literature across diverse disciplines. As noted by Abalkina (2024:395), Scopus is recognised internationally as a premier bibliographic database that prioritises indexing reputable and influential journals. This makes it particularly valuable for academic and scientific research, offering a reliable platform for accessing credible and comprehensive sources. Scopus's rigorous verification process ensures that researchers can access in-depth and reliable research materials, which strengthens the foundation and integrity of scholarly work (Baas et al. 2020). Additionally, Scopus' advanced search capabilities and broad coverage enable researchers to conduct thorough literature reviews,

track citation trends, and identify key studies and emerging topics within their fields, making it a powerful tool for supporting high-quality research.

Database search keywords

This step used keywords in the form of search string to source documents on related topics. Boolean operators like 'AND' were used to search for documents that contain all of the identified keywords, while the boolean operator 'OR' was used to search for documents that contain either of the identified keywords. 'Parentheses ( )' on the other hand was used to group multiple keywords and search for documents that contain the grouped keywords in a specific order, and 'asterisks*' on the search string were used to search for documents that contain variations of the root word. Lastly, quotation marks "" were employed to search for the exact phrase in the quotation marks. The Boolean search string of keywords used in this study is ('Sourcing' OR 'Procur*' OR 'Buying' OR 'supplier selection' OR 'Purchas*' OR 'reliable supplier lead*' OR 'on-time delivery' OR 'on time delivery' OR 'shorter purchase order cycle time' OR ' supplier availability' OR 'vendor availability' OR 'supplier defect rate' OR 'supplier compliance rate' OR 'purchase order accuracy' OR 'procurement return on investment' OR 'price competitiveness' OR 'cost per purchase order' OR 'Sustainable sourcing' OR 'Sustainable buying' OR 'Sustainable purchasing' OR 'Sustainable procurement' OR 'Sustainable supplier selection' OR 'Green sourcing' OR 'Green buying' OR 'Green purchasing' OR 'Green procurement' OR 'Green supplier selection' OR 'Ethical sourcing' OR 'Ethical buying' OR 'Ethical purchasing' OR 'Ethical procurement' OR 'Ethical supplier selection') AND ('4.0 technology' or '4IR technology' OR 'industry 4.0' OR 'fourth industrial revolution technology' OR '4.0 technologies' OR 'industry 4.0 technology' OR 'artificial intelligence' OR 'machine learning' OR 'big data' OR 'data mining' OR 'augmented reality' OR 'simulation' OR 'system integration' OR 'additive manufacturing' OR '3D printing' OR 'cloud computing' OR 'cyber security' OR 'RFID technology' or 'internet of things' or 'IoT' or 'digital tw*') AND ('Manufacturing' OR 'Production'). The first part of the string was focussed on sourcing activities and key performance indicators, the second part separated by the 'AND' operator focussed on the 4IR technologies, while the last part focussed on the sector, that is, manufacturing sector.

Filters: Inclusion and exclusion criteria

This step centred on establishing inclusion and exclusion criteria for the document search. The first criterion was the publication period, limiting the review to documents published between 2019 and October 2024 to ensure the incorporation of recent and relevant literature. The second and third criteria addressed document and source types, restricting the review to journal articles and conference papers. Additionally, only documents presented in English were included in the literature review.

Database search area (where to search)

Databases like Scopus provide options for specifying the location of keyword searches, allowing searches within the study title, abstract, keywords or a combination of these fields, among other configurations. In this study, the constructed Boolean search strings were applied across the title, abstract and keywords to maximise the inclusion of relevant documents. This approach was chosen to ensure a comprehensive coverage of pertinent literature. The documents retrieved from this step were exported and analysed using VOSviewer to determine co-occurrences of keywords and also, the Scopus 'analyse results' feature was used to summarise the number of documents contributed annually within the period range, countries and sources.

Review of keywords

The last step was focussed on the review of the document keywords; only documents that focussed on the application of 4IR technologies in the sourcing phase of supply chain within manufacturing companies were further analysed. The title of the study, year of publication, authors, the objective and the applied 4IR technology were summarised.

Section 'Discussion of results' summarises results obtained from the described methodology.

Ethical considerations

Ethical clearance to conduct this study was obtained from the Ethics and Plagiarism Committee (FEPC) of the Faculty of Engineering and the Built Environment at the University of Johannesburg (reference no.: UJ_FEBE_FEPC_01196).

Discussion of results

Following the initial four steps of the methodology, 1,530 documents were retrieved from the Scopus database, comprising 930 journal articles and 600 conference papers. The distribution of documents by publication year was as follows: 173 in 2019, 215 in 2020, 257 in 2021, 299 in 2022, 304 in 2023 and 282 in 2024 to date. This output from 2019 to 2022 indicates a linear growth trend in publications on the topic, as illustrated in Figure 2.

A total of 133 sources, including conferences and journals, contributed to these publications, with contributions per source ranging from 2 to 31 documents. The top 10 contributing sources are as follows: AIP Conference Proceedings (31 documents), Sustainability (Switzerland) (28 documents), Energies (24 documents), ACM International Conference Proceedings Series (19 documents), and Applied Sciences (Switzerland), Computers and Industrial Engineering, International Journal of Production Research, and Journal of Physics Conference Series each contributing 16 documents. Additionally, IFAC PapersOnLine and the International Journal of Production Economics each contributed 15 documents. The analysis also identified China as the leading contributor, with 271 publications on the topic.

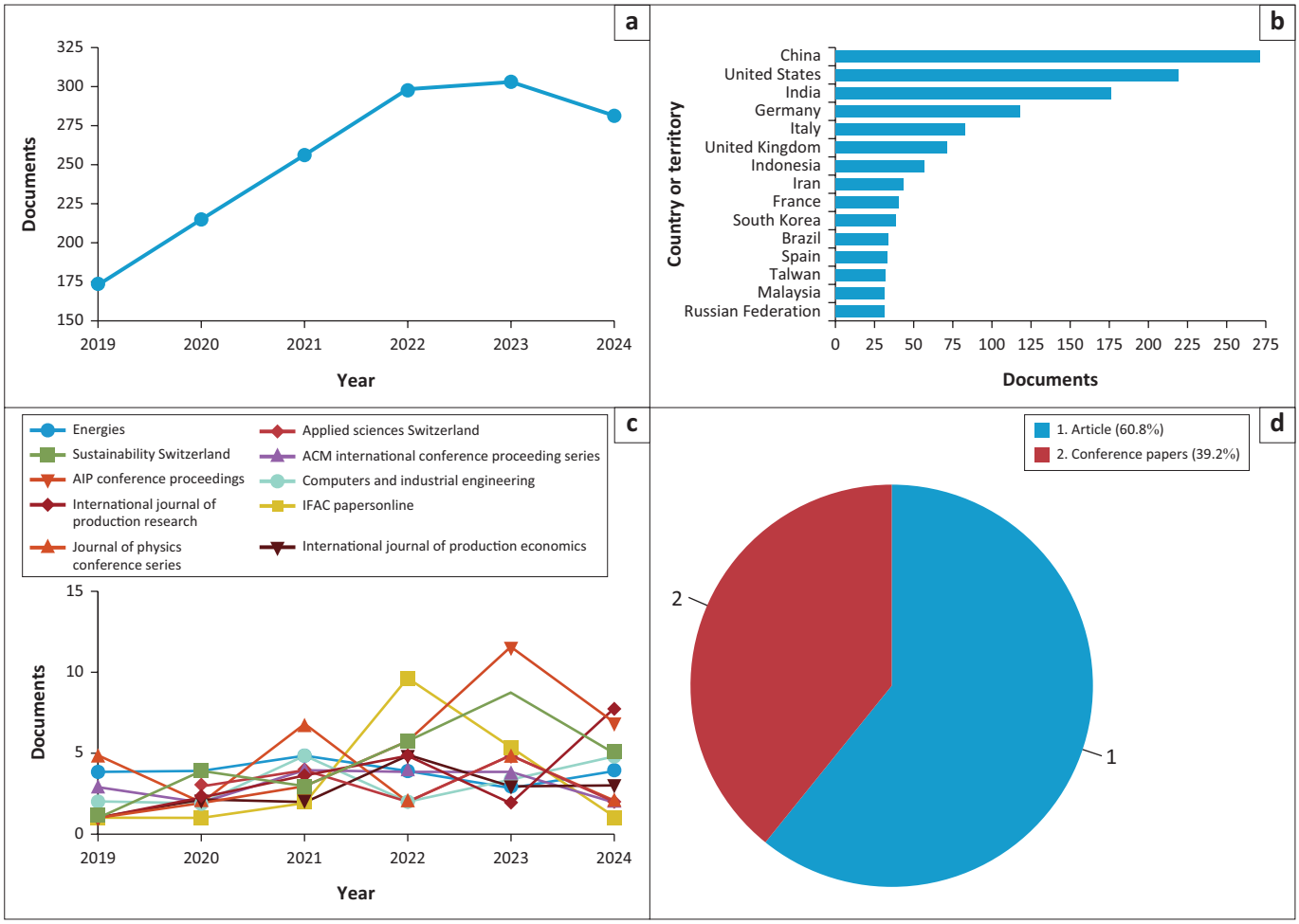


FIGURE 2: Summary of published documents from 2019 to date that is, October 2024: (a) documents by year, (b) documents by country or territory, (c) documents by year, and (d) documents by type.

The top 10 contributing countries are China (271), the United States of America (219), India (175), Germany (118), Italy (83), the United Kingdom (71), Indonesia (56), Iran (43), France (40) and South Korea (38). A summary of these findings is provided in Figure 2.

Using VOSviewer, a co-occurrence map was generated, as shown in Figure 3. The map visualises frequently co-occurring keywords: the shorter the distance between two keywords, the more often they co-occur; larger nodes indicate a higher frequency of keyword appearance; and lines between nodes represent the links between keywords (Irawan, Rosjanuardi & Prabawanto 2024; Yu et al. 2020).

In creating the map with VOSviewer, data from the 1530 documents retrieved from the Scopus database yielded a total of 12 539 unique keywords, each appearing at least once across the documents. VOSviewer allows for setting a minimum occurrence threshold for keywords to be included in the visualisation. For instance, setting the threshold at 5, 10 and 15 occurrences resulted in 699, 265 and 157 keywords, respectively. For this study, a threshold of at least 15 occurrences was selected, resulting in keywords grouped into five clusters. Each cluster represents keywords that frequently co-occur, suggesting thematic relationships. A summary of these clusters is provided in Table 1.

The keywords with the biggest visible nodes include the terms: sales, costs, decision making, supply chain, supply chain management, AI, ML, industry 4.0, simulation, IoT and 3D printing, which indicate that these keywords frequently occur in this topic. The map further illustrates that key activities and KPIs in the sourcing phase of the supply chain co-occur with some of the 4IR technologies, for example, looking at supplier selection which is closely related to IoT, ML and AI, while purchasing is closely positioned next to simulation, ML, AI, 3D printing, data mining and IoT. On-time delivery is closely linked to AI, IoT, discrete event simulation, and sustainability, and sustainability development is close to simulation and 3D printing, and lastly, cost reduction is not close to, or linked to any 4IR technology which indicates a gap in the literature.

Based on Table 1, there are clusters 1, 2, 3, 4 and 5 represented by the colours red, green, blue, yellow and purple, respectively, on the network map. The red cluster is dominating with 61 keywords, while the purple cluster consists of only 9 keywords. Following the findings on the network map, cost reduction is found in the green cluster, which dominates and is focussed on renewable energy. There are no common 4IR technologies found in this

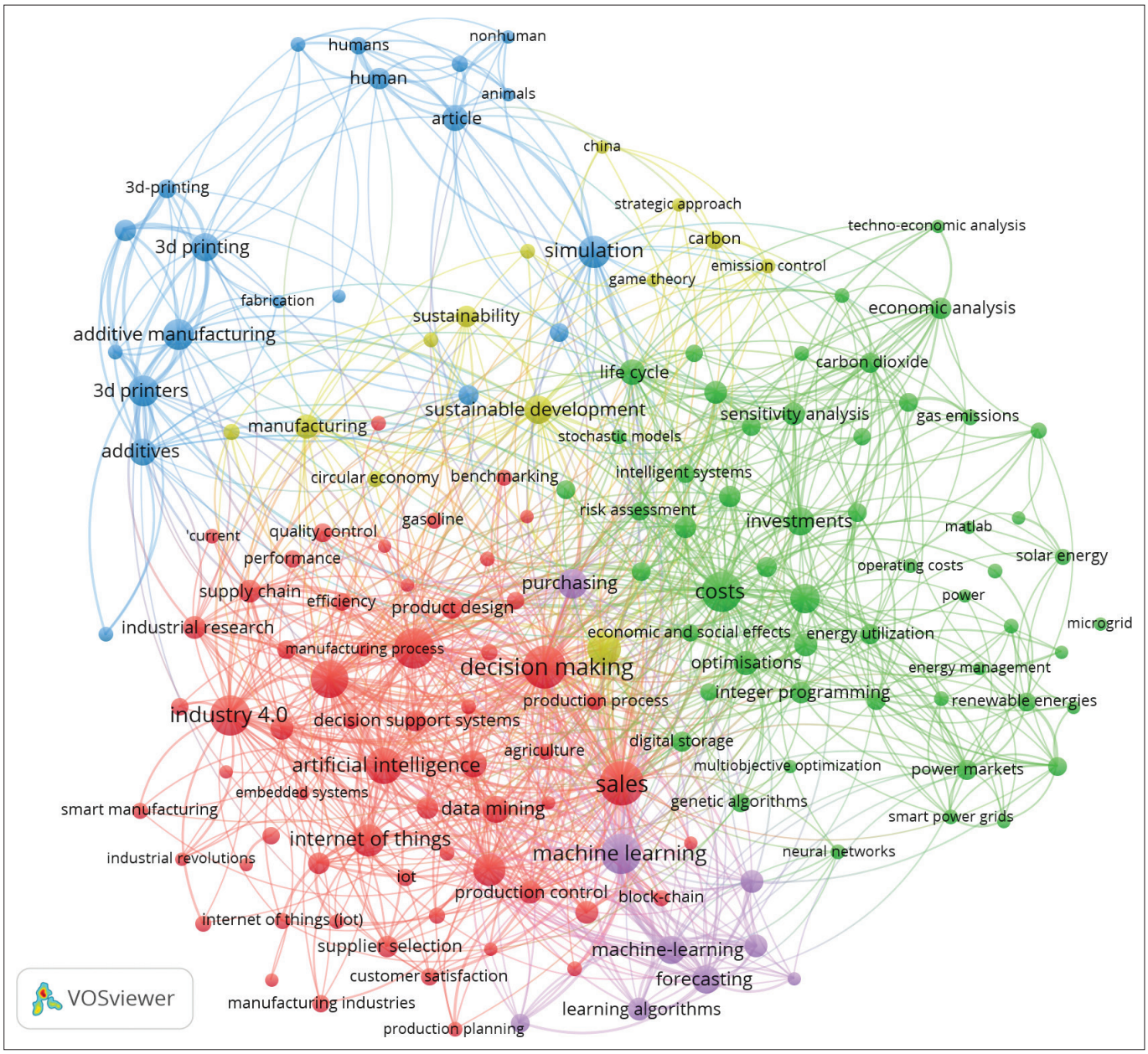


FIGURE 3: Co-occurrence of keywords.

cluster, which collaborate with the observation in Figure 3. It is also noted that within the clusters, all keywords with cost variants are in the green cluster, except for cost-effectiveness which is in the blue cluster sharing a theme with 4IR technologies such as 3D printing also known as Additive Manufacturing (AM).

Application of Fourth Industrial Revolution technologies in the sourcing phase of manufacturing supply chains

This section presents the results of the final step (step 5) of the SLR methodology. The search resulted in 118 documents. These documents were browsed to identify only studies that focussed on applying 4IR technologies for sourcing activities and their corresponding KPIs within the manufacturing sector. As summarised in Table 2, only 16 documents were applicable. The review highlighted that nine of the 4IR technologies were applied in the sourcing phase of the manufacturing supply chain. The review also revealed that some studies used more than one 4IR technology to improve sourcing activities. It was also noted that research studies published in 2020 did not meet this criterion.

Based on the 16 documents, blockchain, cloud computing and big data were each used one time, RFID 'radio frequency identification', and digital twin were each used two times, while AM and ML were each used three times, and lastly, simulation and IoT were each used four times. This information was used to develop a Pareto analysis, as depicted in Figure 4; this was carried out to prioritise the key 4IR technologies applicable to the sourcing phase of the manufacturing supply chain.

TABLE 1: Clusters of keywords that co-occur.

Cluster	Number of keywords	Colour	Keywords
1	61	Red	Current, agriculture, artificial intelligence, automation, automotive industry, behavioural research, benchmarking, big data, block-chain, blockchain, budget control, case-studies, cloud computing, cloud-computing, competition, construction industry, customer satisfaction, data analytics, data driven, data handling, data mining, decision making, decision support system, decisions makings, digital transformation, digital twin, discrete event simulation, efficiency, electronic commerce, embedded systems, enterprise resource plan, gasoline, industrial research, industrial revolutions, industry, information management, internet of things, internet of things (IoT), inventory control, inventory management, IoT, manufacture, manufacturing company, manufacturing industry, manufacturing process, on time delivery, performance, process control, product design, production control, production planning, project management, quality control, risk management, sales , smart manufacturing, supplier selection, supply chain, supply chain management and supply chains
2	54	Green	Carbon dioxide, climate change, computer software, cost benefit analysis, cost reduction, costs, digital storage, economic analysis, economic and social effects, electric energy storage, electric power transmission, energy, energy efficiency, energy management, energy utilisation, environmental impact, gas emissions, genetic algorithms, global warming, greenhouse gases, hydrogen production, integer programming, intelligent systems, investments, life cycle, MATLAB, microgrid, Monte Carlo methods, multi objective optimisation, neural networks, offshore oil well production, operating costs, optimisations, optimization, power, power markets, profitability, renewable energies, renewable energy, renewable energy resource, renewable energy source, risk assessment, scheduling, sensitivity analysis, smart grid, solar power grids, solar energy, solar power generations, stochastic models, techno-economic analysis, uncertainty, uncertainty analysis and wind power
3	20	Blue	3-d printing, 3d printing, 3d printers, 3d-printing, additive manufacturing, additives, animals, article, computer aided design, controlled study, cost effectiveness, economics, fabrication, human, humans, nonhuman, printing presses, simulation, spare parts and three-dimensional printing
4	13	Yellow	Carbon, China, circular economy, commerce, COVID-19, emission control, game theory, innovation, manufacturing, numerical models, strategic approach, sustainability and sustainable development
5	9	Purple	Decision trees, deep learning, forecasting, learning algorithms, learning systems, long-term, short-term, memory, machine learning, machine-learning and purchasing

COVID-19, coronavirus disease 2019.

TABLE 2: Summary of documents that applied Fourth Industrial Revolution technologies within manufacturing organisations' supply chain sourcing phase.

Year	Author(s)	Study title	The purpose and findings of the study	4IR technology applied	Recommended future studies
2024	Elammari, A., Arif, J., and Jawab, F.	'Procurement Improvement Process Based on Industry 4.0 and Lean Manufacturing: A Case Study'	The goal of the study was to investigate how organisations can ensure raw material availability in the event of supply constraints. A Japanese automotive manufacturer was used as a case study. The application of RFID resulted in an improved Just-In-Time raw material sourcing process and minimised excess stock	Radio Frequency Identification (RFID)	Investigation of cost-effective ways of implementing RFID in businesses to optimise investments
2024	Wang, H., Chen, L., Zhu, J., and Wu, Y.	'Simulation of Manufacturing Procurement Cost Control Model Based on Hybrid Genetic Algorithm'	The study adopted simulation to test the application of Hybrid GA (Genetic Algorithm) for manufacturing procurement cost control. By making use of simulation, the organisation was able to conclude and decide that the Hybrid GA is effective and can solve the optimisation problem for manufacturing procurement cost control with multiple cycles and raw materials	Simulation	N/A
2024	Keckeis, S., Karner, C., and Riester, M.	'Assessing the potential for additive manufacturable spare parts in the railway industry by a data-driven framework'	With a view to avoiding downtime and an increase in procurement cost and shortages, the study presented a model for identifying and classifying spare parts with potential for additive manufacturing (AM)	Additive manufacturing, Big data	The application of deep learning to further improve the data quality and identification of AM spare parts
2023	Bhattacharyya, S.S., Kulkarni, O., and Mishra, A.	'Study of emerging avenues in supply chain resilience; the case of integration of additive manufacturing with spare parts procurement'	To investigate the impact of using additive manufacturing (AM) for the procurement of spare parts. The findings suggested that AM might be a useful instrument to lessen reliance on original equipment manufacturers (OEMs) for the acquisition of spare parts	Additive manufacturing	Exploring solutions to the potential barriers of implementing AM for sourcing spare parts The development of a positive approach framework that assesses the impact of AM on supply chain resilience
2023	Maheshwari, P., Kamble, S., Belhadi, A., Venkatesh, M., and Abedin, M.Z.	'Digital twin-driven real-time planning, monitoring, and controlling in food supply chains'	The study aimed to solve the multifaceted problem of procurement, production and distribution (PPD) strategies using digital twin. By using the digital twin approach, the findings show that the integration of PPD optimises production flexibility; also managers make use of the real-time simulation results to accurately estimate replenishment points with minimal lead time	Digital twin Simulation	The application of multiple sources of real-time data that feeds to achieve a more up-to-date view of the market conditions The development of advanced algorithms which are fit to analyse large datasets and predict trends in the market
2023	Liu, Y., Yang, C., Huang, K., Gui, W., and Hu, S.	'A Systematic Procurement Supply Chain Optimization Technique Based on Industrial Internet of Things and Application'	The study proposes a systematic intelligent technique for procurement supply chain (PSC) optimisation. Experiments of the technique were applied in a zinc production company, and the results obtained established that the proposed technique reduces labour and procurement costs while improving the overall efficiency of the procurement supply chain	Internet of things	Exploring low-risk solutions that take into consideration uncertain lead-time, arrival quality and other factors To expand on this study, variations in raw material procurement issues can be explored in detail to develop a more universality approach
2022	Chen, H.	'Study of Protection Mechanism of On Time Delivery with Smart Production Control System in Industry 4.0'	The objective of this study was to achieve on-time delivery and gain a competitive advantage. The protection mechanism of on-time delivery through smart production control system was adopted. This resulted in 33% of days saved for on-time raw material delivery	Internet of things	Application of customised smart production control system for different industrial organisations
2022	Ni, J., Hu, Y., and Zhong, R.Y.	'A hybrid machine learning method for procurement risk assessment of non-ferrous metals for manufacturing firms'	The purpose of the study was to evaluate and predict the procurement risks of non-ferrous metals connected to intricate industrial processes. This study suggests a data-driven strategy utilising cutting-edge machine learning techniques. The hybrid machine learning model assisted in effectively managing the forecasting risk. It was concluded that the model can be used as an assessment and control tool for procurement risk management firms	Machine learning	The integration of multimedia data into the deep learning model, given that financial news, often presents useful data regarding commodity supply and demand Additionally, the development of a procurement risk assessment model using machine learning for seasonality products

Table 2 continues on the next page →

TABLE 2 (Continues ...): Summary of documents that applied Fourth Industrial Revolution technologies within manufacturing organisations' supply chain sourcing phase.

Year	Author(s)	Study title	The purpose and findings of the study	4IR technology applied	Recommended future studies
2022	Bodendorf, F., Lutz, M., Michelberger, S., and Franke, J.	'An empirical investigation into intelligent cost analysis in purchasing'	The article's goal was to add to the cost analysis tool that facilitates the relationship between suppliers and buyers. While the theoretical findings revealed the complexity of machine learning (ML) application, the empirical study revealed that ML adds value to the cost analysis in purchasing	Machine learning	For ML solutions, a study that will consider the integration of ML technical feasibility, factors of acceptance and organisational conditions should be explored
2022	Fang, X. and Chen, H.-C.	'Using vendor management inventory system for goods inventory management in IoT manufacturing'	In this study, the manufacturing supplier is facing challenges in integrating pertinent inventory data with the Internet of things and acquiring inventory information at the manufacturing hub. The outcome of applying these 4IR technologies resulted in enhanced inventory management processes, reduction in cost, swift response to customers and overall improvement in system performance efficiency	Internet of things Radio frequency identification (RFID) system	Developing a cloud-based operating system to shift from ERP to a business innovation platform
2021	Niu, X. and Qin, S.	'Integrating crowd-/service-sourcing into digital twin for advanced manufacturing service innovation'	The study was centred on connecting the data in the servitisation process and applying it to the development of advanced manufacturing services. The finding revealed that the use of these technologies enables the manufacturer to have continuous information on its product for future developments and upgrades	Digital twin (DT) Internet of beings	The application of data intelligence, data-driven product/service design and innovation methods and processes within an ecosystem The future research work was motivated on the basis that data on human, product and service DTs will quickly amass as the number of services conducted on the platform increases
2021	Xia, T., Zhang, W., Chiu, W.S., and Jing, C.	'Using cloud computing integrated architecture to improve delivery committed rate in smart manufacturing'	In this study, cloud computing was applied, and an electronic purchase order web-based system was created through the application. The study indicated that, this application can reduce processing time and costs while improving accuracy and efficiency	Cloud computing	The development of an integrated cloud computing system that is efficient and cost-efficient, and also reusable
2021	Knofius, N., van der Heijden, M.C., Sleptchenko, A., and Zijm, W.H.M.	'Improving effectiveness of spare parts supply by additive manufacturing as dual sourcing option'	The study investigated possibilities for overcoming high cost and low part reliability associated with additive manufacturing (AM), through the combination of conventional manufacturing and AM sourcing principles. The study indicated that AM individually results in a high cost of purchasing and buying while conventional manufacturing methods are individually prone to increased backordering and holding costs. The study therefore indicated that dual sourcing which is a combination of the two methods has the potential to save organisations up to 30% of sourcing cost	Additive manufacturing	Case studies on the application of AM techniques in the low-volume and critical spare parts business
2019	Cavalcante, I.M., Frazzon, E.M., Forcellini, F.A., and Ivanov, D.	'A supervised machine learning approach to data-driven simulation of resilient supplier selection in digital manufacturing'	The study adopted a simulation and machine learning-based technique to develop data-driven decision-making support for resilient supplier selection. The results revealed that the combination of the two technologies improves delivery reliability. Furthermore, the technique can be used for the identification of critical suppliers. Lastly, the proposed model can also be used to design supply chain risk mitigation strategies	Machine learning Simulation	Extend this study by considering a larger data set to solidify the advantages of using ML
2019	Sutrisno, Wicaksono, and P.A., Solikhin	'Probabilistic multi-objective optimization approach to solve production planning and raw material supplier selection problem under probabilistic demand value'	In this study, a probabilistic multi-objective optimisation model for the optimisation of production planning and procurement of raw materials when demand is uncertain was investigated. The objective was to use simulation and conduct numerical analysis to make optimal decisions. The organisation ran a simulation from generated data resulting in optimal decision-making when it comes to quantities of raw material to purchase from suppliers and quantities to produce	Simulation	The development of a multi-period case model to convert the problem into a dynamic problem
2019	Xu, Z., Liu, Y., Zhang, J., Song, Z., Li, J., and Zhou, J.	'Manufacturing industry supply chain management based on the Ethereum Blockchain'	In this study, it was deduced that a lack of reliable information storage, difficulty to trace and a lack of accountability are the key contributions towards the supply chain management bottleneck. The study proposed the adoption of Ethereum Blockchain. This resulted in a smart contract among stakeholders, which led to an improved supplier selection process	Blockchain	Expand this work through: The development of optimised consensus mechanisms compatible with Ethereum to improve the performance of the system at the consensus level of blockchain Strengthen links by adopting the Internet of things Develop and propose feasible and applicable algorithms or methods of evaluating different suppliers

Note: Please see the full reference list of the article, Selepe, R.L., Makinde, O. & Munyai, T., 2025, 'Application of Fourth Industrial Revolution technologies to enhance supply chain sourcing within manufacturing sector: A systematic literature review', *Journal of Transport and Supply Chain Management* 19(0), a1111. https://doi.org/10.4102/jtscm.v19i0.1111, for more information.

4IR, Fourth Industrial Revolution; RFID, radio frequency identification; ML, machine learning.

In addition to the above findings, the term Internet of beings is categorised into 'Internet of things' for this study and crowdsourcing emerged from the review. While the sourcing phase is traditionally linked to activities that aim to obtain raw materials for production purposes, in this digital era, sourcing information is equally important for manufacturers to make operational and strategic decisions. These studies, in addition, proposed future research work, which ranges from the integration of more data and data sources to optimise decision-making to studies that will develop cost-effective adoption of the technologies; these proposed future studies are summarised in Table 2.

Based on an 80/20 Pareto analysis (Figure 4), simulation, IoT, ML, AM and RFID emerged as the critical few 4IR technologies. However, through observation, RFID appears to have been included arbitrarily, as it holds equal weight with digital twin, which did not meet the 80% threshold. Therefore, digital twin will also be included as one of the critical technologies to ensure effective sourcing operations.

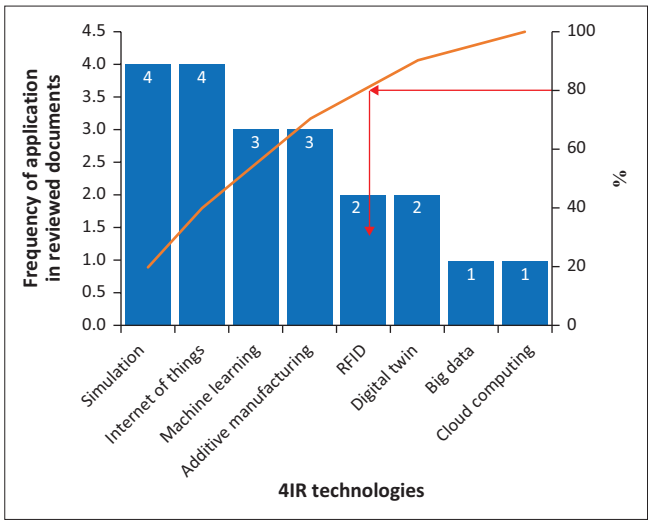


FIGURE 4: Pareto analysis of Fourth Industrial Revolution technologies applied in the sourcing phase of manufacturing supply chains.

Discussion of key results

Multiple keywords forming a string were used to identify relevant literature with a view of achieving the main objective of the study; with that, activities and KPIs within the sourcing phase were predetermined and thus all keywords were covered by literature whether verbatim or by inference, except for ethical sourcing and similar keywords. The reviewed literature provides no insight into ethical sourcing and the application of 4IR technologies thereof. In addition, the 4IR technologies were also predetermined. However, the results of the review clearly demonstrated a lack of coverage regarding the application of AR, data mining, AI, system integration and cyber security in the sourcing phase of manufacturing supply chains. While these predetermined 4IR technologies were not covered, the application of blockchain, which was not part of the initially predetermined keywords emerged, which indicates that the scope of the literature search was not fully dependent on the predetermined keywords.

The study searched for literature from 2019 to 2024 to date. While it was revealed through the results of the first four steps that 215 documents were published in 2020, none of these documents included the application of 4IR technologies in the sourcing phase. The year 2020 was full of uncertainties; while other businesses strongly invested in technology, others paused on investments so as to be financially safe should they be forced to close doors. In addition, academics may have focussed their research lens on the impact of coronavirus disease 2019 (COVID-19) and other topics related to the pandemic in that period.

The study also revealed the application trend of crowdsourcing in sourcing services for a manufacturing organisation. Attention has always been given to sourcing raw materials, especially in manufacturing organisations; however, this study brings forth the importance of sourcing data and information for sourcing decisions in manufacturing organisations for both services and materials. The question, therefore, arises: should crowd-sourcing become a norm for procurement or sourcing teams in manufacturing organisations? Another concept that emerged was the Internet of beings which focusses on the connection of people and machines on the Internet, and this is for the purposes of collecting and analysing data. As it stands, organisational data are vulnerable and prone to cyber-attacks. Thus, another research issue that needs to be investigated is whether the increase in scope for connections between people and machines will increase the volatility and risk of cyber-attacks.

The conclusion section draw inferences based on the study's findings and offering relevant recommendations for stakeholders involved in raw material sourcing within the global supply chain community.

Conclusion and recommendations

This review concludes that 4IR technologies significantly enhance sourcing processes in manufacturing, improving efficiency, cost reduction and supplier collaboration. Internet of things, simulation, ML and AM are especially effective in addressing sourcing KPIs, such as supplier selection, on-time delivery and inventory management. Blockchain technology contributes to data security and transparency in supplier relationships. Notably, while 4IR technologies address many sourcing KPIs, gaps remain in ethical sourcing and cyber security applications. The absence of ethical sourcing applications and minimal application of certain 4IR technologies, such as AR and system integration, indicate areas for further research.

Manufacturing firms should integrate multiple 4IR technologies such as IoT, blockchain and ML to achieve optimised sourcing processes, cost control, sustainability practices and real-time decision-making within the supply chain. Manufacturing organisations should consider using crowdsourcing platforms to gather data insights for sourcing decisions, allowing for real-time adjustments to supplier and production needs in response to market changes.

While the existing literature primarily concentrates on the broad benefits of adopting 4IR technologies to optimise supply chains holistically, this study takes a more focussed approach by identifying specific 4IR technologies that can significantly optimise sourcing processes in manufacturing organisations. It delves into the various applications of these technologies, examining their potential impact on sourcing efficiency, cost reduction and overall operational performance. Furthermore, this study highlights a range of 4IR technologies successfully integrated into manufacturing organisations to improve their sourcing activities. The study illustrates how these technologies have addressed unique sourcing challenges by providing detailed case studies and examples from different manufacturing sectors. Although there may be variations in the specific needs of organisations, the insights provided in this study serve as a comprehensive benchmark for manufacturing entities seeking to choose and implement the most suitable 4IR technologies for optimising

their sourcing processes. These findings can therefore guide decision-makers in making informed decisions given the wide range of 4IR technology alternatives.

Future research should focus on crowdsourcing as a means of data sourcing in procurement, potentially reducing information asymmetry and enabling more informed decision-making in supplier selection and sourcing. Augmented reality, system integration and cyber-security-oriented 4IR technologies should be studied further for their potential roles in the sourcing phase of supply chain systems used in a manufacturing organisation.

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Competing interests

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Authors' contributions

R.L.S. initiated the conception of the research study and collected and analysed the data used in the project. O.A.M. and T.M. contributed to finalising the research study concept and enhancing the quality of the data analysis and discussion of the results presented in the manuscript. R.L.S. prepared the first draft of the manuscript, while O.A.M. and T.M. conducted the critical review and revision. All authors, R.L.S., O.A.M. and T.M., read and approved the final manuscript.

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Data availability

All data that support the findings of this study are available from the corresponding author R.L.S., upon request with full anonymity of participants.

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References

Abalkina, A., 2024, 'Challenges posed by hijacked journals in Scopus', *Journal of the Association for Information Science and Technology* 75(4), 395–422. https://doi.org/10.1002/asi.24855

Ali, S.B., 2022, 'Industrial Revolution 4.0 and supply chain digitization: Future of supply chain management', *South Asian Journal of Social Review* 1(1), 21–41. https://doi.org/10.57044/SAJSR.2022.1.1.2205

AlMulhim, A.F., 2021, 'Smart supply chain and firm performance: The role of digital technologies', *Business Process Management Journal* 27(5), 1353–1372. https://doi.org/10.1108/BPMJ-12-2020-0573

Al-Zubidy, A. & Carver, J.C., 2019, 'Identification and prioritization of SLR search tool requirements: An SLR and a survey', *Empirical Software Engineering* 24,139–169. https://doi.org/10.1007/s10664-018-9626-5

Baas, J., Schotten, M., Plume, A., Côté, G. & Karimi, R., 2020, 'Scopus as a curated, high-quality bibliometric data source for academic research in quantitative science studies', *Quantitative Science Studies* 1(1), 377–386. https://doi.org/10.1162/qss_a_00019

Bai, C., Dallasega, P., Orzes, G. & Sarkis, J., 2020, 'Industry 4.0 technologies assessment: A sustainability perspective', *International Journal of Prodction Economics* 229, 107776. https://doi.org/10.1016/j.ijpe.2020.107776

Bashar, A., 2019, 'Intelligent development of big data analytics for manufacturing industry in cloud computing', *Journal of Ubiquitous Computing and Communication Technologies, (UCCT)* 1(01), 13–22. https://doi.org/10.36548/jucct.2019.1.002

Belhadi, A., Zkik, K., Cherrafi, A. & Sha'ri, M.Y., 2019, 'Understanding big data analytics for manufacturing processes: Insights from literature review and multiple case studies', *Computers & Industrial Engineering* 137, 106099. https://doi.org/10.1016/j.cie.2019.106099

Bhattacharyya, S.S., Kulkarni, O. & Mishra, A., 2023, 'Study of emerging avenues in supply chain resilience; the case of integration of additive manufacturing with spare parts procurement', *Benchmarking: An International Journal* 30(10), 4100–4118. https://doi.org/10.1108/BIJ-03-2022-0163

Bodendorf, F., Lutz, M., Michelberger, S. & Franke, J., 2022, 'An empirical investigation into intelligent cost analysis in purchasing', *Supply Chain Management: An International Journal* 27(6), 785–808. https://doi.org/10.1108/SCM-11-2020-0563

Carrera-Rivera, A., Ochoa, W., Larrinaga, F. & Lasa, G., 2022, 'How-to conduct a systematic literature review: A quick guide for computer science research', *MethodsX* 9, 101895. https://doi.org/10.1016/j.mex.2022.101895

Cavalcante, I.M., Frazzon, E.M., Forcellini, F.A. & Ivanov, D., 2019, 'A supervised machine learning approach to data-driven simulation of resilient supplier selection in digital manufacturing', *International Journal of Information Management* 49, 86–97. https://doi.org/10.1016/j.ijinfomgt.2019.03.004

Charles, M. & Ochieng, S.B., 2023, 'Strategic outsourcing and firm performance: A review of literature', *International Journal of Social Science and Humanities Research (IJSSHR) ISSN* 1(1), 20–29.

Chen, H., 2022, 'Study of protection mechanism of on time delivery with smart production control system in industry 4.0', *IFAC-PapersOnLine* 55(10), 2611–2616. https://doi.org/10.1016/j.ifacol.2022.10.103

Ekechukwu, D.E., 2021, 'Overview of sustainable sourcing strategies in global value chains: A pathway to responsible business practices', *International Journal of Multidisciplinary Research in Science* 3(1), 1–12.

ElAmmari, A., Arif, J. & Jawab, F., 2024, 'Procurement improvement process based on Industry 4.0 & lean manufacturing: A case study', in *2024 IEEE 15th International Colloquium on Logistics and Supply Chain Management (LOGISTIQUA)*, Sousse, Tunisia, May 2-4, 2024, pp. 1–6.

Fang, X. & Chen, H.C., 2022, 'Using vendor management inventory system for goods inventory management in IoT manufacturing', *Enterprise Information Systems* 16(7), 1885743. https://doi.org/10.1080/17517575.2021.1885743

Garg, K., Goswami, C., Chhatrawat, R.S., Dhakar, S.K. & Kumar, G., 2022, 'Internet of things in manufacturing: A review', *Materials Today: Proceedings* 51(part 1), 286–288. https://doi.org/10.1016/j.matpr.2021.05.321

Irawan, E., Rosjanuardi, R. & Prabawanto, S., 2024, 'Research trends of computational thinking in mathematics learning: A bibliometric analysis from 2009 to 2023', *Eurasia Journal of Mathematics, Science and Technology Education* 20(3), em2417. https://doi.org/10.29333/ejmste/14343

Jermsittiparsert, K. & Rungsrisawat, S., 2019, 'Impact strategic sourcing, supplier innovativeness, and information sharing on supply chain agility', *International Journal of Innovation, Creativity and Change* 5(2), 397–415.

Jindal, H. & Kaur, S., 2021, 'Robotics and automation in textile industry', *International Journal of Scientific Research in Science, Engineering and Technology* 8(3), 40–45. https://doi.org/10.32628/IJSRSET21839

Keckeis, S., Karner, C. & Riester, M., 2024, 'Assessing the potential for additive manufacturable spare parts in the railway industry by a data-driven framework', *Procedia CIRP* 122, 575–580. https://doi.org/10.1016/j.procir.2024.02.016

Knofius, N., Van der Heijden, M.C., Sleptchenko, A. & Zijm, W.H., 2021, 'Improving effectiveness of spare parts supply by additive manufacturing as dual sourcing option', *OR Spectrum* 43, 189–221. https://doi.org/10.1007/s00291-020-00608-7

Kunovjanek, M. & Reiner, G., 2020, 'How will the diffusion of additive manufacturing impact the raw material supply chain process?' *International Journal of Production Research* 58(5), 1540–1554. https://doi.org/10.1080/00207543.2019.1661537

Liu, J., Chen, Y. & Zhu, Q., 2023, 'Green supplier governance and firm performance: A comprehensive understanding of three governance approaches', *International Journal of Physical Distribution & Logistics Management* 53(9), 1073–1100. https://doi.org/10.1108/IJPDLM-07-2022-0232

Liu, Y., Yang, C., Huang, K., Gui, W. & Hu, S., 2022, 'A systematic procurement supply chain optimization technique based on industrial internet of things and application', *IEEE Internet of Things Journal* 10(8), 7272–7292. https://doi.org/10.1108/IJPDLM-07-2022-0232

Maheshwari, P., Kamble, S., Belhadi, A., Venkatesh, M. & Abedin, M.Z., 2023, 'Digital twin-driven real-time planning, monitoring, and controlling in food supply chains', *Technological Forecasting and Social Change* 195, 1227999. https://doi.org/10.1016/j.techfore.2023.122799

Mohamed Shaffril, H.A., Samsuddin, S.F. & Abu Samah, A., 2021, 'The ABC of systematic literature review: The basic methodological guidance for beginners', *Quality & Quantity* 55, 1319–1346. https://doi.org/10.1007/s11135-020-01059-6

Mourtzis, D., 2020, 'Simulation in the design and operation of manufacturing systems: State of the art and new trends', *International Journal of Production Research* 58(7), 1927–1949. https://doi.org/10.1080/00207543.2019.1636321

Mubarik, M.S., Kazmi, S.H.A. & Zaman, S.I., 2021, 'Application of Gray DEMATEL-ANP in green-strategic sourcing', *Technology in Society* 64, 101524. https://doi.org/10.1016/j.techsoc.2020.101524

Nasiri, M., Ukko, J., Saunila, M. & Rantala, T., 2022, 'Managing the digital supply chain: The role of smart technologies', *Technovation* 96, 102121. https://doi.org/10.1016/j.technovation.2020.102121

Ni, J., Hu, Y. & Zhong, R.Y., 2022, 'A hybrid machine learning method for procurement risk assessment of non-ferrous metals for manufacturing firms', *International Journal of Computer Integrated Manufacturing* 35(10–11), 1028–1042. https://doi.org/10.1080/0951192X.2021.1901315

Niu, X. & Qin, S., 2021, 'Integrating crowd-/service-sourcing into digital twin for advanced manufacturing service innovation', *Advanced Engineering Informatics* 50, 101422. https://doi.org/10.1016/j.aei.2021.101422

Paul, J., Lim, W.M., O'Cass, A., Hao, A.W. & Bresciani, S., 2021, 'Scientific procedures and rationales for systematic literature reviews (SPAR-4-SLR)', *International Journal of Consumer Studies* 45(4), 1–16. https://doi.org/10.1111/ijcs.12695

Rai, R., Tiwari, M.K., Ivanov, D. & Dolgui, A., 2021, 'Machine learning in manufacturing and industry 4.0 applications', *International Journal of Production Research* 59(16), 4773–4778. https://doi.org/10.1080/00207543.2021.1956675

Sutrisno, P.A., Wicaksono, & Solikhin., 2019, 'Probabilistic multi-objective optimization approach to solve production planning and raw material supplier selection problem under probabilistic demand value', *Journal of Physics: Conference Series* 1397, 012075. https://doi.org/10.1088/1742-6596/1397/1/012075

Van Hoek, R. & Thomas, R., 2021, 'Notes and debate paper: Should merchandising and sourcing be worlds apart? The opportunity for more integrated strategic sourcing research', *Journal of Purchasing and Supply Management* 27(1), 100659. https://doi.org/10.1016/j.pursup.2020.100659

Wang, B., Kostarelos, K., Nelson, B.J. & Zhang, L., 2021, 'Trends in micro-/nanorobotics: Materials development, actuation, localization, and system integration for biomedical applications', *Advanced Materials* 33(4), 2002047. https://doi.org/10.1002/adma.202002047

Wang, H., Chen, L., Zhu, J. & Wu, Y., 2024, 'Simulation of manufacturing procurement cost control model based on hybrid genetic algorithm', in *2024 International Conference on Electrical Drives, Power Electronics & Engineering (EDPEE)*, Athens, February 27-29, 2024, pp. 733–737.

Wu, L., Yue, X., Jin, A. & Yen, D.C., 2016, 'Smart supply chain management: A review and implications for future research', *The International Journal of Logistics Management* 27(2), 395–417. https://doi.org/10.1108/IJLM-02-2014-0035

Xia, T., Zhang, W., Chiu, W.S. & Jing, C., 2021, 'Using cloud computing integrated architecture to improve delivery committed rate in smart manufacturing', *Enterprise Information Systems* 15(9), 1260–1279. https://doi.org/10.1080/17517575.2019.1701715

Xu, Z., Liu, Y., Zhang, J., Song, Z., Li, J. & Zhou, J., 2019, 'Manufacturing industry supply chain management based on the Ethereum blockchain', in *2019 IEEE International Conferences on Ubiquitous Computing & Communications (IUCC) and Data Science and Computational Intelligence (DSCI) and Smart Computing, Networking and Services (SmartCNS)*, Shenyang, Oct 21–23, pp. 592–596.

Yu, Y., Li, Y., Zhang, Z., Gu, Z., Zhong, H., Zha, Q. et al., 2020, 'A bibliometric analysis using VOSviewer of publications on COVID-19', *Annals of translational medicine*, 8(13). http://dx.doi.org/10.21037/atm-20-4235.

Zhao, N., Hong, J. & Lau, K.H., 2023, 'Impact of supply chain digitalization on supply chain resilience and performance: A multi-mediation model', *International Journal of Production Economics* 259, 108817. https://doi.org/10.1016/j.ijpe.2023.108817