Proceedings of the International Conference on Industrial Engineering and Operations Management

Publisher: IEOM Society International, USA DOI: 10.46254/AF07.20260301
Published: May 13, 2026

Supply Chain as a Driver of Cost and Sustainability in the Automotive Industry in South Africa

Tharelelo Mokgokong
Industrial Engineering
Faculty of Engineering and the Built Environment
Tshwane University of Technology
Pretoria, South Africa
tharelelo@gmail.com

T Kunene, and F Chiromo
Department of Mechanical, Robotics and Industrial Engineering
University of Johannesburg
Johannesburg, South Africa
kunenet@uj.ac.za, chiromof@uj.ac.za

V Hashe
Department of Mechanical Engineering
Walter Sisulu University
Johannesburg, South Africa
vhashe@gmail.com

Abstract

This study demonstrated the effectiveness of decarbonising automotive products through sustainable dynamic supply chain decentralisation. A case study was used to examine a dynamic decentralised supply chain as a tool to decouple the large supply chain, and system dynamics was used to simulate the impact of reducing kilometres travelled on transportation costs, illustrating how sustainable supply chains can drive profitability. Reduced kilometres travelled per fuel tank has resulted in a significant reduction in Greenhouse Gas Emissions (GHG). The simulation demonstrates a 73% reduction in logistics costs and 75% reduction in carbon emissions. This study suggests that the automotive industry can explore a decentralised supply chain to reduce its carbon footprint and improve cost-effectiveness. The novelty is demonstrating that pursuing sustainable development goals reduces carbon emissions and transportation costs. The research demonstrates progress toward the Sustainable Development Goals (SDGs). SDG 13: Climate action, by actively reducing and striving to reduce greenhouse gas emissions within the supply chain and SDG 12: Responsible consumption and production, by actively looking for ways to reduce the distance travelled of each component of the product.

Keywords
Sustainability, Supply chain, Automotive industry, Fuel tank

1. Introduction
The automotive component manufacturing industry is growing rapidly, and as the value chain expands, sustainability issues become increasingly relevant, (Mathivanthanan, Agarwal, Mathiyazhangan, Saikouk, & Appolloni, 2022).

Sustainability is a daunting task when it comes to driving manufacturing toward more sustainable processes and products. (Ferreira, Lopes, Gomes, & Rammal, 2023). However, companies that use sustainable practices have significant competitive and economic advantages over those that neglect them (Shekarian, Ijadi, Zare, & Majava, 2022). Automotive Original Equipment Manufacturers (OEMs) need to adopt sustainable practices to reduce Carbon dioxide (CO2) emissions and the carbon footprint of the automotive product (Da Silva, Lohmer, Rohla, & Angelis, 2023). A sustainable supply chain incorporates sustainability as a principle for business decision-making (Ahmed, et al., 2025) . The industry must realise the importance of sustainability and its application in its Supply Chain (SC) design (Shekarian, Ijadi, Zare, & Majava, 2022). To integrate more sustainable practices in the industry, new ways of operating need to be developed to drive manufacturers towards sustainable solutions (Ahmed, et al., 2025).

The automotive supply chain must deliver more than 10,000 parts and components to produce one automobile, sourced from different locations and companies. The failure thereof highlights the challenges OEMs face in attaining sustainable operations (Yu, Fan, Ye, & Xia, 2024). The vast globalised supply chain plays a critical role in the drive for sustainable operations (Da Silva, Lohmer, Rohla, & Angelis, 2023). The production and use of these parts and components significantly impact the vehicle's carbon footprint (Yu, Fan, Ye, & Xia, 2024). The industry is struggling with sustainability in its supply chain. It is responsible for 10% of global emissions (Da Silva, Lohmer, Rohla, & Angelis, 2023).

The objectives of this research work are to reduce the carbon footprint of the automotive products in South Africa. There are many ways to look at the problem of sustainability in the automotive sector. One can look at it from replacing plastics with bioinspired materials. Others view the electrification of mobility as a key aspect of creating a more sustainable, low-carbon automotive product (Da Silva, Lohmer, Rohla, & Angelis, 2023). However, Yu et al. (2024) concluded that, to effectively control the carbon footprint of automotive products, every link in the supply chain must be managed to reduce emissions at the source. The automotive industry is facing ongoing challenges in improving the sustainability of its manufacturing processes and vehicle emissions due to economic, environmental, marketability, and policy concerns (Lukin, Krajnovic, & Bosna, 2022).

1.1 Objectives

Lunkin et al. (2022) investigate conceptual frameworks for applying sustainability in the automotive industry and find that, upon examination, a research gap emerges. There is no solid research agenda on sustainability in the automotive industry that provides a clear platform for attaining sustainable operations. The literature on environmental innovations primarily focuses on regulation as a driver of the adoption of sustainable processes. This research aims to demonstrate the practical implications of decarbonising industry supply chains and to provide pathways to achieve sustainable operations.

2. Literature Review

Sustainable supply chain management (SSCM) "*is the management of supply chain operations, resources, information, and funds to maximise social welfare and supply chain profitability while minimising environmental impacts"* (Kazacoglu, Pala, Mangla, Kumar, & Kazancoglu, 2023). The sustainability trend is also evident in the automotive industry, which has enabled greater human mobility and the ability to cover long distances in a relatively short time (Lukin, Krajnovic, & Bosna, 2022). Since 2021, global Battery Electric Vehicle (BEV) sales have increased by 109% year-on-year, demonstrating a paradigm shift towards electric propulsion to reduce carbon emissions. (Ashraf, et al., 2025). Yu et al (2024) found that pure Electric Vehicles (EVs) have 18% lower life-cycle carbon emissions than fuel-powered vehicles because the sourcing of the parts is still within the same supply chain as conventional vehicles, leading to a similar carbon footprint (Malik, Hussain, Haider, Alkhabit, & Lehtonen, 2025).

The SDGs have emerged as a key framework for balancing economic, environmental, and social dimensions, with an emphasis on decoupling growth from resource overuse (Salimi, Shahriari, & Khosroshahi, 2026). Sustainable business strategies are based on evaluating the needs of all key stakeholders of a particular company, where the company is oriented towards achieving sustainable goals, namely the principles of sustainable development and environmental protection (Lukin, Krajnovic, & Bosna, 2022). The industry has explored innovative bio-based materials to improve the product's carbon footprint and gain advantages, including their potential to reduce weight and, by implication, fuel consumption (Carvahlo, et al., 2024). That does not address the supply chain for the new bio-inspired material, which will end up in the normal supply chain and offset any carbon-emission benefits it offers.

The relationship between the automotive industry and the raw material supply chain poses significant challenges and obstacles to sustainable operations, even for new energy vehicles, thereby pressuring the industry to meet both economic and environmental demands. The automotive sector continues to face ongoing challenges in enhancing the sustainability of its supply chain processes (Lukin et al., 2022). The recovery of raw materials is being utilised to reduce reliance on the supply chain; however, a comprehensive business model has yet to be established to ensure scalability and alignment among supply chain participants, thereby maximising the process's full potential. Recent research has examined the prospects and implications of EVB in a circular economy. Applications of EVB in a circular economy (Da Silva, Lohmer, Rohla, & Angelis, 2023).

2.1 Automotive industry in South Africa

Globally, passenger vehicles are the largest contributors of carbon emissions, responsible for 45% of overall CO2 emissions from the transportation sector (Koroma, et al., 2022). In South Africa, 90% of automobiles sold are passenger vehicles and light commercial vehicles, leading to an industry contribution of 12% to the national carbon emissions (Editor, 2025). Ikome et al. (2022) noted that South Africa's automotive industry supply chain compares favourably with those of other developing countries in similar sectors. However, this also means the supply chain is heavily reliant on carbon emissions, as its structure resembles that of other countries. The industry has over 450 component manufacturers supporting OEMs based in the country, as illustrated in Figure 1, which support 66% of overall industry employment (Editor, 2025).

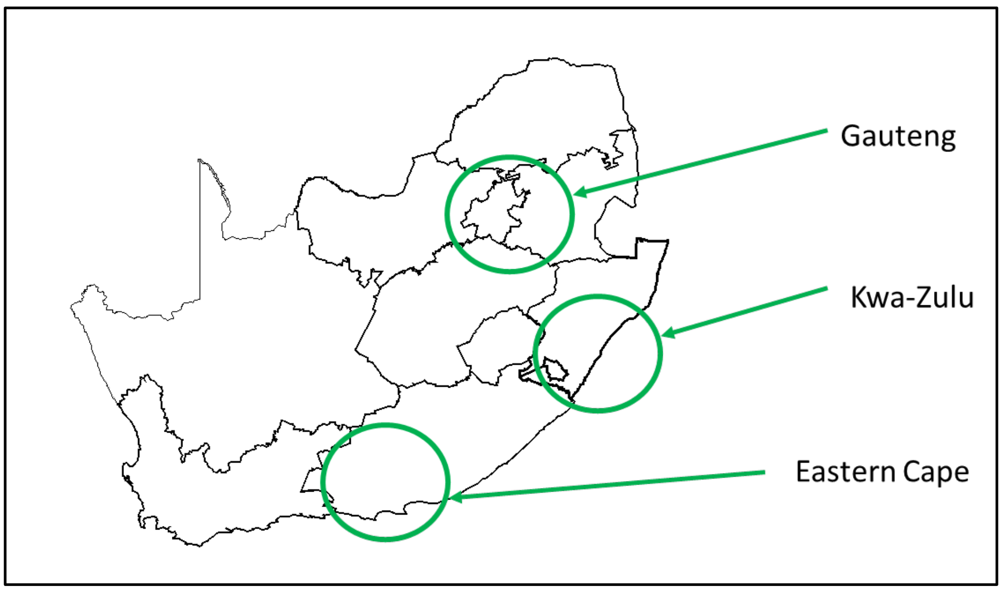


Figure 1. Location of automotive suppliers

The industry is facing sustainability challenges related to manufacturing, supply chain, and policy frameworks. The carbon footprint of both individual components and the entire system remains a significant challenge (Kristen, Mthethwa, Sitsha, & Niemaan, 2025).

The automotive sector in South Africa is of strategic importance; in 2025, it contributed 20.6% of the overall manufacturing output and 5.2% of the country's gross domestic product (Kirsten, Mthethwa, Sitsha, & Niemann, 2025). The automotive industry in South Africa contributes significantly to a sustainable economy through numerous categories of businesses, both upstream and downstream, resulting in strong multiplier effects that drive sustainability (Mothibi, Kleyhans, Meyer, & Adelowo, 2025).

3. Methods

A case study is a powerful tool for analysing sustainability in the automotive industry, providing an empirical foundation. The researcher gained significant value from a variety of techniques for exploring the subject across different dimensions. This approach enabled an understanding of sustainability from multiple perspectives, which were utilised in this research to present a comprehensive view of the phenomenon in the automotive sector. The supply chain is crucial in the automotive industry and will remain a key driver of economic growth. Finding sustainable solutions for the supply chain is essential to meeting the SDGs. The search criteria used are shown in Figure 2 to identify key sustainability-related outputs in the supply chain thoroughly.

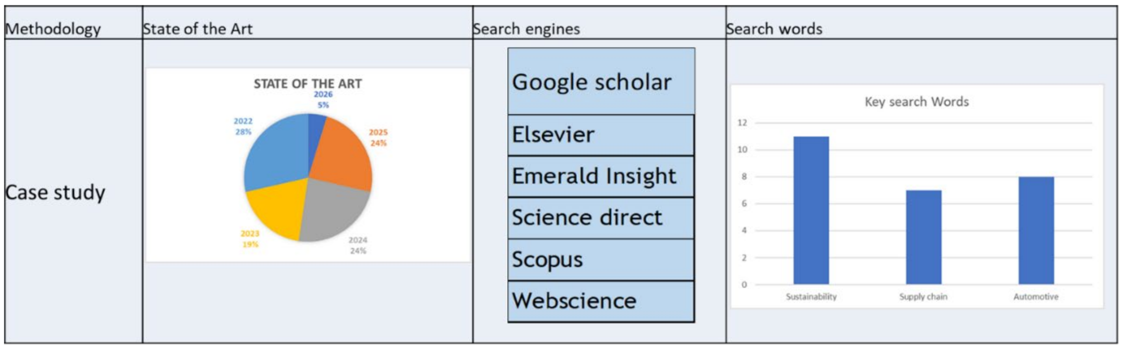


Figure 2. Research methodology

Secondary data was collected from the management database and public records. A system dynamics model was employed to analyse the impact of sustainability on transportation costs. The model was run for 120 months, which is twice the product's life cycle, to illustrate how reducing kilometres travelled affects transportation costs. The researcher utilised Vensim 10.4.0 software to develop stock-and-flow diagrams for the simulation. Secondary data available in the public domain was used, and Google Maps was employed to calculate distances travelled for both scenarios, using a standard emission factor for an 18-wheeler truck. Sensitivity analysis measures the extent to which outcome indicators change in response to changes in specific factors by identifying the factors that have the greatest impact on the results. In this study, a one-factor sensitivity analysis was conducted (Yu, Fan, Ye, & Xia, 2024). The model ran multiple times as the order size decreased; the results were comparable, demonstrating consistency and stability. running the model multiple times with varying parameters, validating the results, and assessing the model's reliability.

4. Case study: Fuel Tank

In 2025, 92% of cars produced in South Africa will be internal combustion engine vehicles, meaning the fuel tank remains a key component of the product and value chain. The fuel tank manufacturer will deliver at least 552,000 fuel tanks in that year. The automotive supply chain in South Africa functions through a centralised sourcing strategy, which is the dominant approach in many industries for managing the supplier base. This centralised method effectively enables an organisation to control and manage the flow of goods, information, and funds, as shown in Figure 3. The manufacturer operates a plant in the Northwest Province, near Gauteng (OEM), and another in the Eastern Cape (OEM1), and one in the Eastern Cape (OEM1).

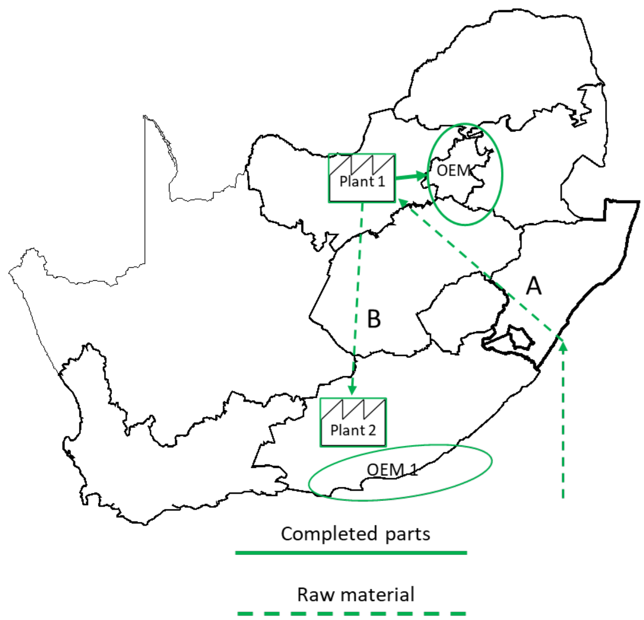


Figure 3. Centralized Supply chain in the automotive industry

Raw material comes from overseas and travels to plant 1 and then to plant 2, both of which satisfy demand in their immediate areas, as illustrated in Figure 4. The distance to deliver raw material to manufacturing plants and to finished products to the OEM production line.

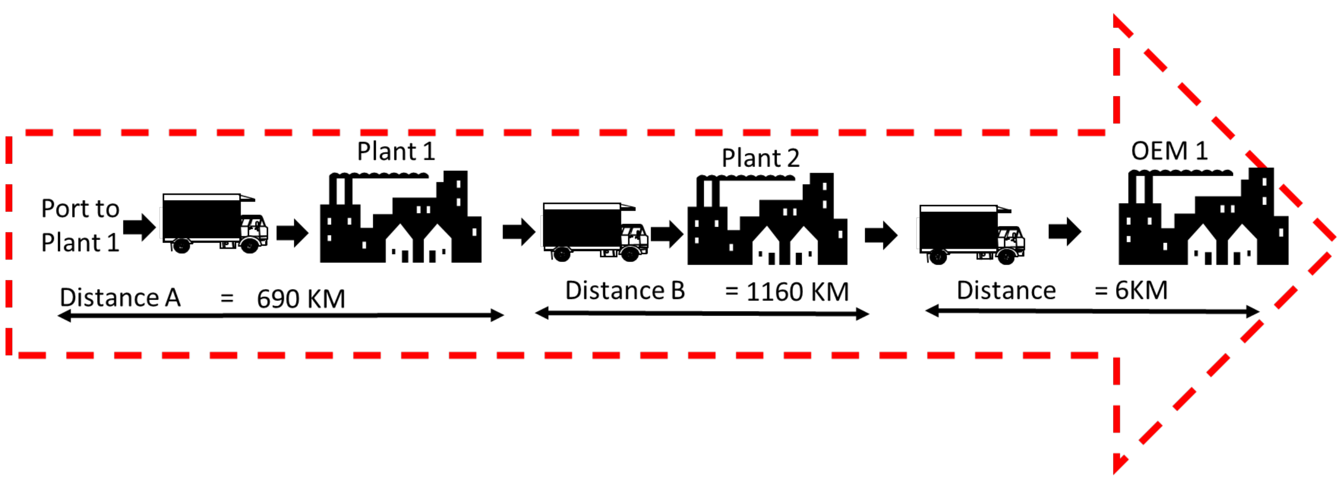


Figure 4. Actual kilometres travelled from raw material to OEM production line.

Original equipment manufacturer (OEM 1) in the Eastern Cape region manufactured 115,000 units, with 115,000 fuel tanks delivered at a rate of 9,500 units per month. Figure 5 shows the production data and transportation required to meet the fuel tank demand for OEM 1.

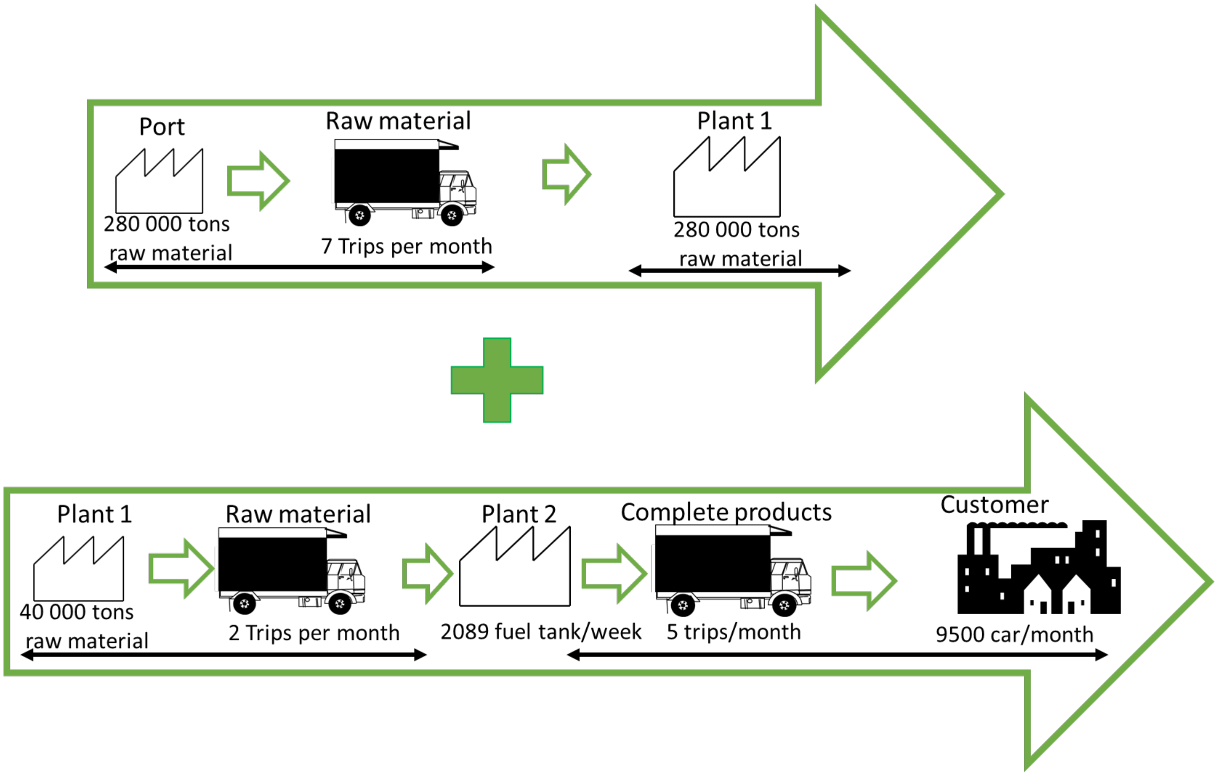


Figure 5. Production data of the fuel tank

Decentralisation of the automotive supply chain offers opportunities to decarbonise components by altering the structural flow of materials within the supply chain (Adana et al., 2024) and through adopting dynamic decentralisation of supply chain activities. Decentralising the supply chain boosts its flexibility and agility in addressing challenges, including sustainability concerns (Urra-Calfunir et al., 2024). Figure 6 demonstrates how dynamic decentralisation can enhance flexibility and reduce carbon emissions in the fuel tank's supply chain.

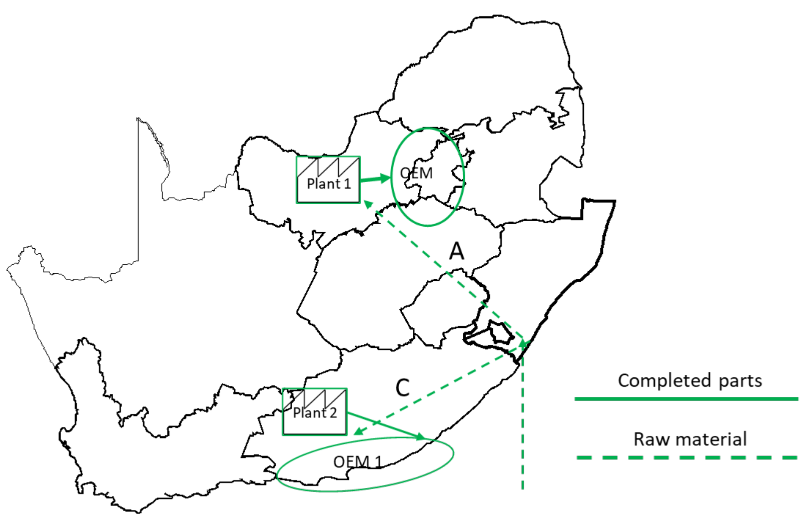


Figure 6. Decentralised fuel tank supply chain.

A decentralised inventory design contributes to risk diversification and promotes agility in leveraging available opportunities (Adana, Manuj, Herbeger, Cevikparmak, & Celik, 2024), as illustrated in Figure 7, demonstrates what can be achieved through dynamic decentralisation to reduce the distance the raw material travels.

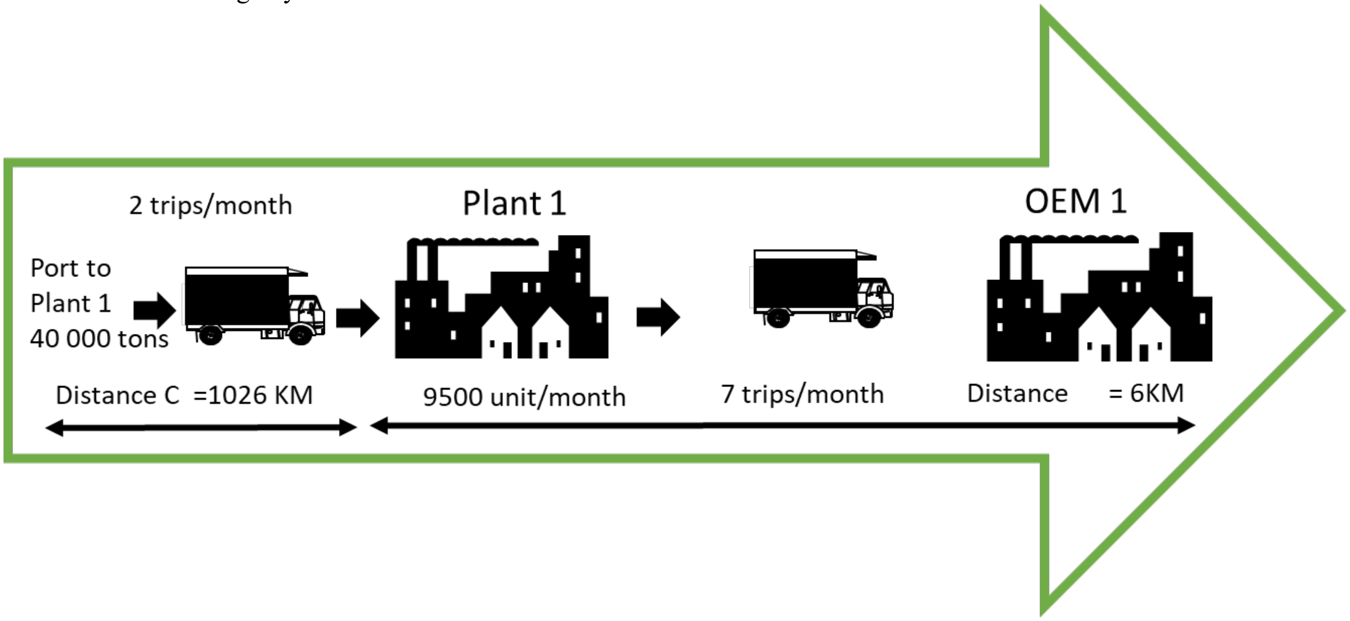


Figure 7. Decentralised supply chain production data.

5. Results and Discussion

The development of a simple Vensim system dynamics model for both the centralised and decentralised supply chains, as illustrated in Figures 5 and 7, is represented by the stock-and-flow diagram in Figure 8.

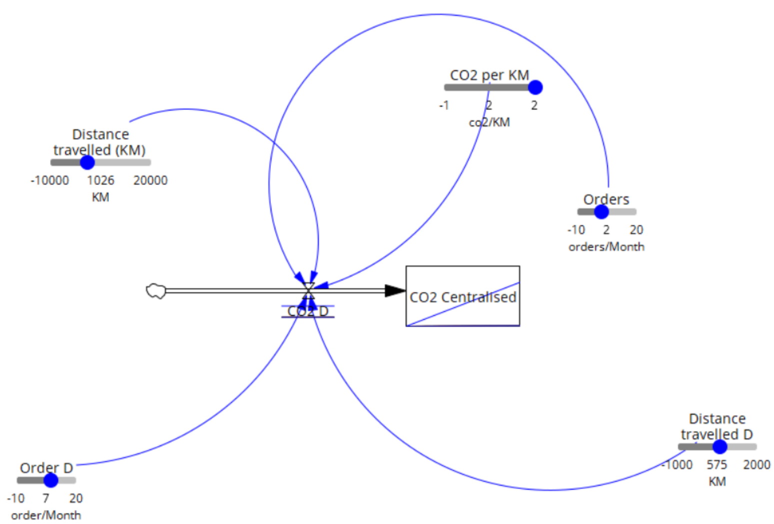
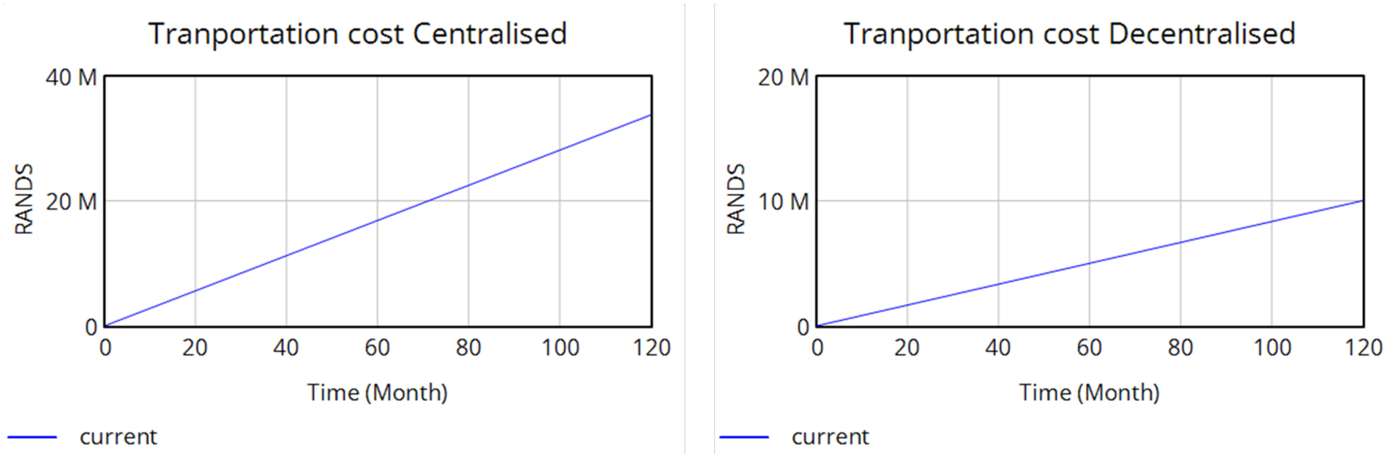


Figure 8. Stock and flow diagram for the supply chains

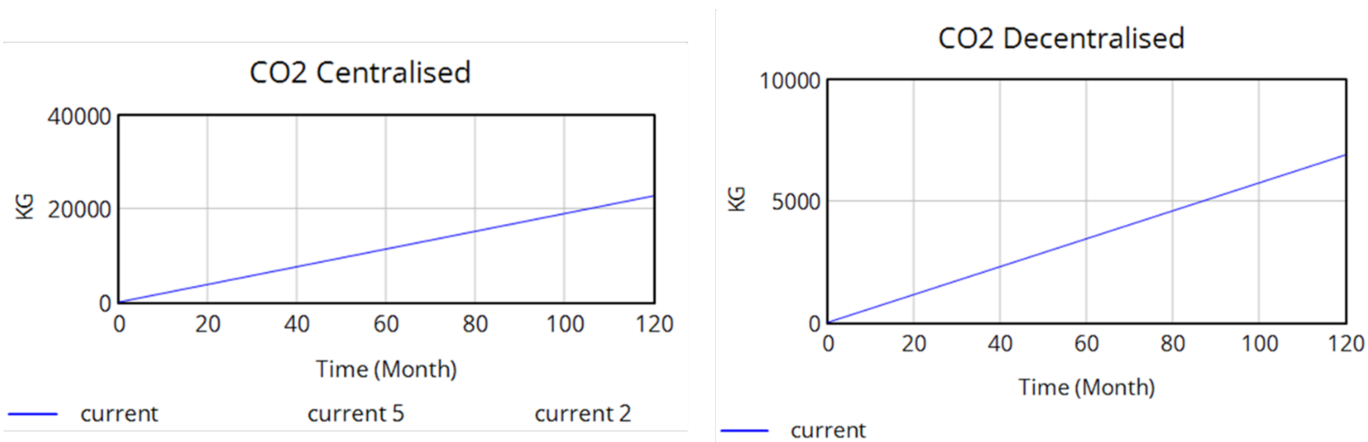
By modelling both the transportation cost and carbon emissions for centralised and decentralised supply chains, as shown in Figure 9.



The centralized supply chain shows a cost of R34 million over 120 months, while decentralized shows a cost of only R10 million

Figure 9. Simulation results

While the CO2 of the two supply chains is illustrated in Figure 10.



The centralised supply chain shows a CO2 emissions of 22 000 tons over 120 months, while decentralised CO2 emissions of only 7 tons over the same period

Figure 10. Simulation results for supply chains' CO2 emissions

5.1 Validation

One-way sensitivity analysis was performed, and the model was run multiple times; the results were consistent, demonstrating its stability. This involved running the model repeatedly with different parameters, validating the results, and assessing the model's reliability, as shown in Figure 11.

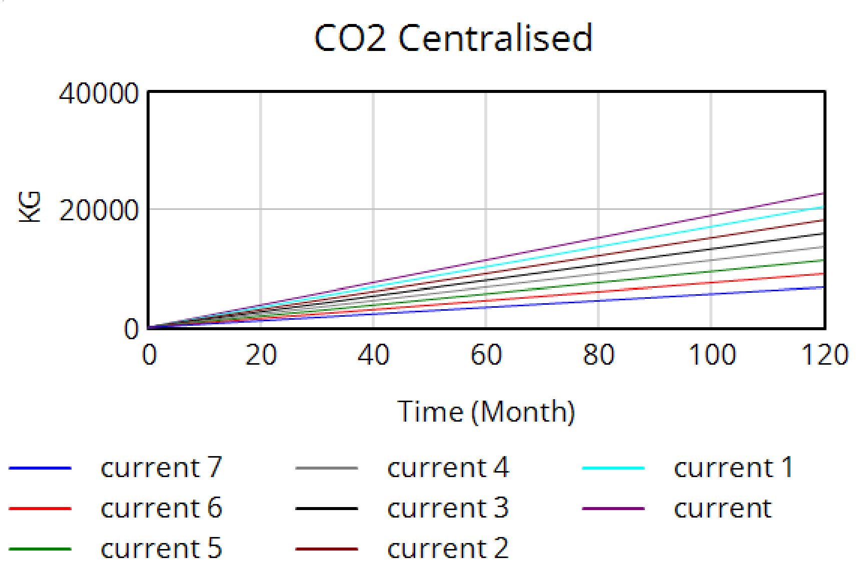


Figure 11. One at a time sensitivity analysis

Furthermore, Figure 12 illustrates a two-way sensitivity analysis by varying CO2 per kilometer and the distance travelled, clearly indicating an increase in CO2 as expected, practically demonstrating the rigidity and stability of the model.

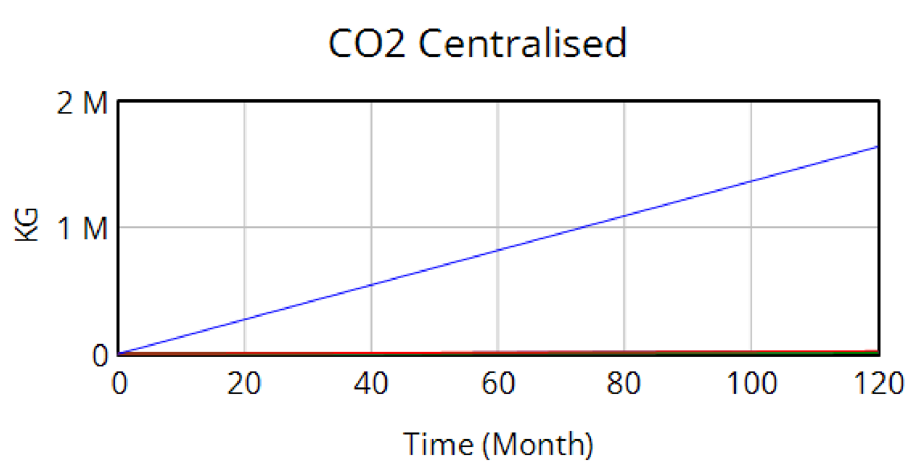


Figure 12. Two-way sensitivity

6. Conclusion

The research aimed to demonstrate that the automotive supply chain can enhance both cost efficiency and sustainability by decarbonising automotive components. It has been shown that costs can be reduced through the dynamic decentralisation of the supply chain, moving away from a traditional rigid structure by actively managing opportunities for improvement and sustainability. The findings indicate a reduction of R24 million over 120 months and a significant decrease of 18,000 tonnes in the same period. This demonstrates that the traditional structure is no longer suitable in this era of sustainable operations.

Decentralisation of the supply chain offers significant benefits, representing a subtle paradigm shift that improves the industry's bottom line and advances sustainability goals. The pursuit of sustainability in the industry is possible; SDG 12 and SDG 13 are attained in this research by reducing carbon emissions. The research demonstrates climate action and responsible production and consumption. The industry needs solutions to pursue sustainability and cost-effectiveness. This research work illustrates the possibility of attaining both. The result of this research highlights the practical implications of viewing the traditional supply chain differently and being willing to adapt it dynamically when necessary to seize immediate opportunities.

Even though Decentralisation leads to short, localised supply chains that can satisfy demand in their local area. However, it creates a complex distribution system with multiple sites, which leads to high holding costs and operating costs (Cantini, Leoni, Ferraro, & F, 2025) Decentralisation creates inconsistencies in customer experience due to a lack of specific skills, capacity, and specialised services at decentralised locations. (Boadway & Dougherty, 2018), since the locations need to guarantee high service levels while operating on the same inventory policy as the main operations (Cantini, Leoni, Ferraro, & F, 2025).

Improvement is a never-ending process. By always looking at the industry from the inside, one can achieve great results for sustainability, as this research has shown. In conclusion, the contributions of this research work are highlighted through the results and the methodology applied to the fuel tank. There will be challenges in the decoupling of the supply chain. Future researchers can explore those challenges and develop frameworks that guide the industry in decoupling the supply chain in an orderly manner, without creating instability. The advancement of technology will also assist with future applications.

References

Adana, S., Manuj, I., Herbeger, M., Cevikparmak, S. and Celik, H., Linking decentralisation in decision making to resilience outcomes: a supply chain perspective. The International Journal of Logistics Management, 35(1), pp. 256–280, 2024.

Ahmed, R., Manik, K., Nath, A., Shoag, R., Mim, J. and Hossain, N., Recent advances in sustainable natural fibre composite: Environmental benefits, application and future prospects. Materials Today Sustainability, 32, 101220, 2025.

Andersen, B. and Kreye, M., Implementing a centralised procurement for global supplier base management. Production Planning & Control, 35(15), pp. 2021–2033, 2024.

Ashraf, F., Equbal, A., Khan, O., Yahya, Z., Alhodaib, A. and Parvez, A., Assessment and ranking of different vehicle carbon footprint: A comparative study utilising entropy and TOPSIS methodologies. Green Technologies and Sustainability, 3, 100128, 2025.

Boadway, R. and Dougherty, S., Decentralisation in a Globalised World: Consequences and Opportunities. OECD Publishing, 2018.

Cantini, A., Leoni, L., Ferraro, S. and De Carlo, F., Centralised and decentralised supply chain: Performance maps for comparing the cost effectiveness of distribution network configurations. Transportation Research Part E: Logistics and Transportation Review, 204, 104435, 2025.

Carvalho, D., Ferreira, N., Franco, B., Marques, R., Silva, M., Silva, S. and Oliveira, C., Advancing sustainability in the automotive industry: Bioprepregs and fully bio-based composites. Composites Part C: Open Access, 100549, 2024.

Da Silva, E., Lohmer, J., Rohla, M. and Angelis, J., Unleashing the circular economy in the electric vehicle battery supply chain: A case study on data sharing and blockchain potential. Resources, Conservation and Recycling, 193, 106969, 2023.

Del Solar, G., Velarde, K., Díaz-Garay, K. and Pollard, V., A methodology for embedding building information modelling (BIM) in an undergraduate engineering program. Applied Sciences, 12, 12203, 2022.

Editor, Sustainability in South Africa's Automotive Industry. Pretoria: Trade and Industrial Policy Strategies (TIPS), 2025.

Ferreira, J., Lopes, L., Gomes, S. and Rammal, G., Industry 4.0 implementation: Environmental and social sustainability in manufacturing multinational enterprises. Journal of Cleaner Production, 404, 136841, 2023.

Ikome, J., Laisende, T. and Kanakana-Katumba, G., The future of the automotive manufacturing industry in developing nations: A case of South Africa's paradigm. Procedia Computer Science, 200, pp. 1165–1173, 2022.

Kazancoglu, I., Pala, M., Mangla, S. K., Kumar, A. and Kazancoglu, Y., Using emerging technologies to improve the sustainability and resilience of the supply chain in a fuzzy environment in the context of COVID-19. Annals of Operations Research, 322, pp. 217–240, 2023.

Kirsten, M., Mthethwa, S., Sitsha, S. and Niemann, W., Advancing sustainable supply chain management through digitisation: Insights from the South African automotive industry. Journal of Transport and Supply Chain Management, 19, 1221, 2025.

Koroma, M., Gösta, D., Philippot, M., Cardellini, G., Hosen, S., Coosemans, T. and Messagie, M., Life cycle assessment of battery electric vehicles: Implications of future electricity mix and different battery end-of-life management. Science of the Total Environment, 831, 154859, 2022.

Lukin, E., Krajnović, A. and Bosna, J., Sustainability strategies and achieving SDGs: A comparative analysis of companies in the automotive industry. Sustainability, 14(12), 4000, 2022.

Malik, F., Hussain, W., Haider, G., Alkhabit, Z. and Lehtonen, F., Evaluating carbon emissions: A lifecycle comparison between electric and conventional vehicles. World Electric Vehicle Journal, 16, 287, 2025.

Mathiyazhagan, K., Agarwal, V., Mathivathanan, D., Saikouk, T. and Appolloni, A., Modelling the pressures for sustainability adoption in the Indian automotive industry. Journal of Cleaner Production, 342, 130972, 2022.

Mincha, A. and Kruszewska, J., Industry 4.0 solutions and company performance: Empirical evidence from multiple case studies of the automotive industry. Scientific Papers of Silesian University of Technology: Organization and Management Series, 190, pp. 79–94, 2023.

Mothibi, L., Kleynhans, E., Meyer, D. and Adelowo, C., An assessment of the South African automotive industry towards economic growth: A pre-COVID-19 analysis. African Journal of Business and Economic Research, 20(4), pp. 213–239, 2025.

Salimi, S., Shahriari, M. and Khosroshahi, H., Strategic decision-making in the sharing economy: Balancing profitability and sustainability in retail, rental and second-hand markets using a game-theoretic approach. Journal of Retailing and Consumer Services, 88, 104445, 2026.

Shekarian, E., Ijadi, N., Zare, B. and Majava, J., Sustainable supply chain management: A comprehensive systematic review of industrial practices. Sustainability, 14, 7892, 2022.

Urra-Calfunir, B., Monardes-Concha, C. and Miranda-González, M., Agri-food supply chain optimisation through decentralised production processes in the olive industry. Computers and Industrial Engineering, 192, 110818, 2024.

Yu, N., Fan, H., Ye, J. and Xia, L., Carbon footprint accounting of automotive parts based on life cycle assessment. Polish Journal of Environmental Studies, 34(5), pp. 5383–5399, 2024.

Biographies

Tharelelo Mokgokong is a South African industrial engineering practitioner, academic, and researcher with work associated with universities such as the University of Johannesburg (UJ) and Tshwane University of Technology (TUT). His main research areas are: Biomimicry in engineering (using nature-inspired systems), Sustainable supply chain design, and Industrial & logistics engineering.

Thokozani Justin Kunene holds a PhD and is a Senior lecturer in the Department of Mechanical and Industrial Engineering Technology at the University of Johannesburg in South Africa. He worked as a chief industrial technician in the South African Navy (Naval Engineering Services) for two years. His primary research areas are Atomic Layer Deposition (ALD), Fluid Mechanics, Computational Fluid Dynamics (CFD), Magnetohydrodynamic (MHD) flows, Microfluidics, Molecular Dynamics (MD), Multiphase flow and energy efficiency/optimisation.

Vuyo T. Hashe holds a PhD in Mechanical Engineering and is an academic and researcher with extensive experience working with institutions such as the University of Johannesburg and Walter Sisulu University. His published work shows a strong focus on: Hydrogen energy & fuel generation, Renewable energy systems, Materials engineering, Mechanical design & manufacturing systems.

Forbes Chiromo is a graduate of DPhil in Engineering (Supply Chain Management) from the University of Johannesburg (2018) and Supervision from the University of Johannesburg (2020). Forbes joined the University of Johannesburg in 2008 as a Senior Lecturer in the Department of Mechanical and Industrial Engineering Technology. Before joining the University of Johannesburg, Forbes worked in Zimbabwe at Zimbabwe Iron and Steel Company, the Scientific and Industrial Research and Development Centre, UNIDO, National Printing and Packaging and at Harare Institute of Technology.