



Innovating Last-Mile Delivery Post-Pandemic: A Dual-Continent Framework for Leveraging Robotics and AI

Ogechi Thelma Uzozie ^{1*}, Osazee Onaghinor ², Oluwafunmilayo Janet Esan ³

¹ Independent Researcher, Lagos Nigeria

² Independent Researcher, Alberta, Canada

³ Amazon.com, USA

* Corresponding Author: **Ogechi Thelma Uzozie**

Article Info

ISSN (online): 2582-7138

Volume: 03

Issue: 01

January-February 2022

Received: 22-12-2021

Accepted: 20-01-2022

Page No: 887-892

Abstract

The COVID-19 pandemic significantly disrupted traditional logistics and delivery models, prompting a shift toward more innovative and efficient solutions in the last-mile delivery sector. This paper examines the role of robotics and artificial intelligence (AI) in transforming last-mile delivery systems, focusing on a dual-continent framework that explores their adoption in both developed and emerging economies. The literature review synthesizes key findings regarding the impact of the pandemic on delivery systems, highlighting how robotics, such as drones and autonomous vehicles, alongside AI technologies like route optimization and demand forecasting, have been leveraged to enhance delivery efficiency. The review also delves into regional differences in technology adoption, analyzing challenges and opportunities specific to advanced and developing markets. The paper concludes by discussing the implications for business practices and policymaking, emphasizing the need for clear regulatory frameworks and infrastructure development. It identifies gaps in the current research, particularly concerning the long-term sustainability, employment impact, and potential for further technological innovation in last-mile delivery. This paper contributes valuable insights into the future trajectory of last-mile delivery systems and provides directions for further research to address existing gaps.

DOI: <https://doi.org/10.54660/IJMRGE.2022.3.1.887-892>

Keywords: Last-Mile Delivery, Robotics, Artificial Intelligence, E-Commerce, Post-Pandemic Logistics, Regional Adoption

1. Introduction

1. Introduction

1.1 Background of last-mile delivery

The concept of last-mile delivery refers to the final leg of the supply chain, where goods are transported from a distribution center to the final consumer. This part of the logistics process is crucial as it accounts for a significant portion of the cost and time in delivery systems. Traditionally, last-mile delivery has been characterized by inefficiency due to factors such as traffic congestion, lack of infrastructure, and high operational costs (Adeleke, Igunma, & Nwokediegwu). However, these challenges have become even more pronounced in the wake of the COVID-19 pandemic. The surge in e-commerce during the pandemic has led to an increased demand for faster and more efficient delivery services. As consumers became more reliant on online shopping, traditional delivery models struggled to keep up with the high volumes and speed required, underscoring the need for innovative solutions (Adebisi, Aigbedion, Ayorinde, & Onukwulu, 2021; Sam-Bulya, Omokhoa, Ewim, & Achumie).

With this demand for quicker and more reliable deliveries, companies began to look for ways to improve their last-mile logistics. The pandemic highlighted the critical role that efficient last-mile delivery plays in ensuring customer satisfaction and operational efficiency (Adepoju *et al.*, 2021).

It also revealed the limitations of conventional systems, particularly in urban environments, where traffic congestion and environmental concerns added to the complexity. These challenges have forced businesses to rethink their delivery models, driving the need for automation, better route optimization, and other technologies that can enhance operational efficiency in the final stage of the delivery process (Afolabi & Akinsooto, 2021).

1.2 Role of robotics and AI

The rise of robotics and artificial intelligence (AI) in logistics has presented a transformative solution to the problems facing last-mile delivery systems. Robotics, such as autonomous delivery vehicles, drones, and robots, are increasingly being integrated into the logistics sector to reduce labor costs, improve delivery speed, and enhance the accuracy of deliveries (Sorooshian, Khademi Sharifabad, Parsaee, & Afshari, 2022). AI, on the other hand, plays a critical role in optimizing route planning, managing inventory, forecasting demand, and personalizing customer experiences. By combining these two technologies, last-mile delivery systems can become more efficient and scalable, capable of handling a higher volume of orders at reduced costs (Elujide *et al.*, 2021).

In the post-pandemic world, the urgency for adopting these technologies has increased. The global supply chain disruptions caused by the pandemic have created an environment where businesses need to accelerate the adoption of automation to remain competitive (Balaska *et al.*, 2022). Robotics and AI offer promising solutions to tackle these disruptions, providing faster, more reliable deliveries while minimizing human error and operational inefficiencies. Autonomous delivery vehicles, for example, can operate in crowded urban areas without being hindered by traffic, and drones can quickly transport packages over short distances. Together, these technologies are helping to redefine the future of last-mile delivery by offering faster, safer, and more cost-effective solutions (Alonge *et al.*, 2021; BALOGUN, OGUNSOLA, & SAMUEL, 2021).

1.3 Purpose and scope of the review

This literature review aims to provide a comprehensive analysis of the role of robotics and AI in transforming last-mile delivery systems, with a particular focus on post-pandemic innovations. The review will synthesize existing research to explore how these technologies have been implemented across different regions, with a dual-continent framework that examines both developed and emerging economies. By comparing these regions, the review seeks to highlight the global variations in adoption, challenges, and successes in leveraging robotics and AI for last-mile delivery. The scope of the review will extend beyond mere technological advancements, also considering the operational, economic, and regulatory factors that influence the adoption of these innovations. It will analyze the extent to which robotics and AI can address critical challenges in last-mile logistics, such as reducing costs, improving delivery speed, and enhancing sustainability. Through the dual-continent framework, the review will explore how different regions have approached the integration of these technologies and the resulting impact on delivery systems, providing valuable insights for businesses and policymakers looking to optimize last-mile delivery.

2. Literature on last-mile delivery challenges post-pandemic

2.1 Impact of the pandemic on delivery systems

The COVID-19 pandemic had a profound impact on traditional logistics and delivery systems, highlighting vulnerabilities in last-mile delivery operations. As lockdowns and social distancing measures took effect, e-commerce activity surged, leading to a dramatic increase in demand for delivery services. However, the existing delivery infrastructure, which was designed for lower volumes, struggled to keep pace with this sudden spike. Many delivery companies found themselves overwhelmed by the volume of orders, leading to delays and inefficiencies. Furthermore, the health risks associated with human contact during the pandemic led to a surge in demand for contactless delivery methods, necessitating rapid technological adaptation (Ewim, Omokhoa, Ogundej, & Ibeh, 2021; EZEANOCHIE, AFOLABI, & AKINSOOTO, 2021).

The pandemic revealed how reliant global supply chains had become on just-in-time inventory and human labor, making these systems vulnerable in times of crisis. In response, companies sought innovative solutions, accelerating the adoption of automation technologies such as robotics, AI, and drones to streamline last-mile delivery. These technologies provided a means to address the challenges posed by the pandemic, offering greater flexibility and resilience in delivery operations, which are crucial for long-term sustainability in the post-pandemic world (Hassan, Collins, Babatunde, Alabi, & Mustapha, 2021; Odunaiya, Soyombo, & Ogunsola, 2021).

2.2 Consumer behavior and delivery expectations

The pandemic significantly altered consumer expectations, leading to a shift in the demands placed on last-mile delivery systems. Prior to the pandemic, consumers were accustomed to standard delivery timelines, but the surge in online shopping during the crisis has led to a heightened expectation for faster, more flexible delivery options. Consumers now prioritize speed, with many expecting same-day or next-day delivery as the new standard. This shift has prompted businesses to reimagine their delivery strategies, pushing the need for more efficient operations and faster turnaround times (Ogbeta, Mbata, & Katas, 2021; Otokiti, Igwe, Ewim, & Ibeh, 2021).

In addition to speed, consumers are also placing greater importance on delivery safety and transparency. The desire for contactless delivery methods increased during the pandemic, and this trend has continued as customers seek to minimize physical interaction with delivery personnel. Moreover, consumers now expect greater visibility into the status of their deliveries, pushing for real-time tracking and updates. This shift in consumer behavior has led to greater pressure on last-mile delivery providers to adopt innovative technologies that can meet these evolving expectations, including autonomous vehicles and AI-driven systems capable of delivering faster and more efficiently (Abisoye & Akerele, 2022; Paul, Abbey, Onukwulu, Agho, & Louis, 2021).

2.3 Logistical and operational bottlenecks

The post-pandemic literature highlights several operational bottlenecks that continue to plague last-mile delivery systems, particularly in urban environments. One major

challenge is congestion, which remains a significant impediment to timely and cost-effective deliveries. Traffic congestion, especially in metropolitan areas, results in longer delivery times, higher fuel consumption, and increased costs. These inefficiencies are compounded by the need to navigate complex urban infrastructures, where road access and parking restrictions can further delay deliveries (Adekola, Kassem, & Mbata, 2022; BALOGUN, OGUNSOLA, & SAMUEL, 2022).

Another bottleneck identified in the literature is inefficiency in route planning and scheduling. Traditional delivery methods rely on manual route optimization, which can be suboptimal in real-time. Poorly planned routes extend delivery times, increase fuel costs, and contribute to environmental pollution. The literature suggests that incorporating AI-driven algorithms can significantly improve route planning, enabling real-time adjustments based on traffic conditions, weather, and customer preferences (Charles *et al.*, 2022).

Finally, operational costs remain a major issue for last-mile delivery providers. The cost of labor, vehicle maintenance, and infrastructure investments is rising, particularly as customer expectations for faster delivery intensify. These costs make it increasingly difficult for companies to maintain profitability while offering competitive delivery times. To address these operational bottlenecks, many companies are turning to automation and technology solutions, such as robotic delivery systems and AI-based logistics platforms, which can help reduce costs and improve the overall efficiency of last-mile delivery (Elumilade, Ogundej, Achumie, Omokhoa, & Omowole, 2022; EZEANOCHIE, AFOLABI, & AKINSOOTO, 2022).

3. Technological advancements in last-mile delivery

3.1 Robotics in last-mile delivery

The use of robotics in last-mile delivery has gained significant attention due to its potential to revolutionize logistics operations. Delivery drones and autonomous vehicles, in particular, have emerged as promising solutions to overcome the challenges associated with traditional delivery methods (Engesser, Rombaut, Vanhaverbeke, & Lebeau, 2023). Drones offer the ability to bypass road traffic, delivering packages directly to customers over short distances, thus reducing delivery times and operational costs. Autonomous vehicles, including self-driving cars and robots, are being deployed in urban areas to provide on-demand deliveries without human drivers, further increasing efficiency. These robotics technologies offer the advantage of 24/7 operation, enabling deliveries outside of peak traffic hours and potentially reducing congestion in urban areas (Govender *et al.*, 2022; Isibor, Ibeh, Ewim, Sam-Bulya, & Martha, 2022).

Studies have shown that robotic delivery systems can improve efficiency by optimizing routes and reducing the human labor involved in deliveries. Drones, for example, can be dispatched to remote or hard-to-reach areas that would otherwise be costly or time-consuming to serve through traditional methods. Moreover, the introduction of robots into last-mile delivery is expected to lower costs by reducing the need for human drivers and increasing the scalability of delivery networks. These innovations are still in the pilot stages in many regions, but the potential benefits are clear, with improvements in speed, reliability, and cost-effectiveness (Jessa, 2022; Mustapha & Ibitoye, 2022a).

3.2 AI and machine learning applications

AI and machine learning have played a transformative role in optimizing last-mile delivery systems. AI-driven solutions are increasingly used for route optimization, predictive analytics, and demand forecasting, all of which contribute to making the delivery process faster, more reliable, and more cost-effective. Machine learning algorithms analyze large datasets to predict delivery times, adjust routes in real-time based on traffic conditions, and even forecast customer demand. By predicting the optimal routes and delivery schedules, these technologies help reduce fuel consumption and improve the accuracy of estimated delivery times (Ogbuagu *et al.*, 2022b).

Research has shown that AI applications in last-mile delivery can also improve the customer experience by providing more accurate delivery windows, enabling real-time tracking, and allowing for personalized delivery options. Additionally, predictive analytics is being used to forecast demand more accurately, helping delivery companies better manage their inventory and avoid overstocking or understocking. These capabilities are especially valuable during peak seasons or unforeseen disruptions, such as the COVID-19 pandemic, where demand for deliveries can fluctuate dramatically. Overall, AI and machine learning have the potential to streamline last-mile delivery operations, reducing costs while improving both efficiency and customer satisfaction (Mustapha & Ibitoye, 2022b; Odunaiya, Soyombo, & Ogunsola, 2022).

3.3 Integration of robotics and AI

The integration of robotics and AI represents a significant step forward in enhancing the efficiency and cost-effectiveness of last-mile delivery systems. While robotics technologies, such as drones and autonomous vehicles, provide the physical infrastructure for delivery, AI powers the decision-making processes behind these systems, enabling them to operate autonomously and efficiently. By combining these two technologies, last-mile delivery systems can optimize routes, avoid traffic congestion, and ensure timely deliveries, all while reducing operational costs (Ogunsola, Balogun, & Ogunmokin, 2022).

AI algorithms can be integrated with robotic systems to analyze real-time data, such as traffic conditions, weather patterns, and package locations, to adjust delivery routes dynamically. For example, AI can guide autonomous vehicles through the most efficient routes based on real-time traffic analysis, while drones can autonomously avoid obstacles and adjust their flight paths to ensure timely delivery (Otokiti, Igwe, Ewim, Ibeh, & Sikhakhane-Nwokediegwu, 2022). The synergy between robotics and AI improves operational efficiency and increases scalability, allowing delivery networks to handle a higher volume of deliveries without a corresponding increase in costs. Research has demonstrated that the combined application of these technologies can lead to faster delivery times, reduced costs, and a more seamless customer experience, positioning them as key drivers in the future of last-mile logistics (Ogbuagu *et al.*, 2022a; Ogunmokin, Balogun, & Ogunsola, 2022).

4. Regional perspectives on robotics and AI adoption

4.1 Adoption in developed economies

Developed economies, particularly in regions such as North America and Europe, have been at the forefront of adopting

robotics and AI technologies in last-mile delivery systems. These regions benefit from advanced technological infrastructures, higher levels of investment, and a more mature market for e-commerce, all of which have facilitated the integration of autonomous delivery systems. Studies in these regions have highlighted that robotics, such as autonomous delivery vehicles and drones, are increasingly being deployed to address the growing demand for faster and more efficient delivery services. In the United States and Europe, major e-commerce companies, such as Amazon and DHL, have been conducting trials with delivery drones and robots, leveraging AI to optimize delivery routes and reduce operational costs (Elujide *et al.*, 2021; Ewim *et al.*, 2021). However, the adoption of robotics and AI in these economies is not without challenges. One key issue is regulatory frameworks, which often lag behind technological advancements. The integration of autonomous vehicles and drones into public spaces requires navigating complex legal and safety regulations, which can slow down implementation. Additionally, the high cost of technology deployment, along with consumer acceptance of autonomous delivery methods, presents hurdles to widespread adoption. Despite these challenges, the technological maturity in these markets means that many of these barriers are likely to be overcome with time, as infrastructure continues to develop and regulations are adapted to accommodate new technologies (Ogunsola *et al.*, 2022; Sikirat, 2022).

4.2 Adoption in emerging economies

In emerging economies, such as parts of Asia and Africa, the integration of robotics and AI into last-mile delivery presents a unique set of challenges and opportunities. While these regions are generally not as technologically advanced as developed economies, they offer fertile ground for innovation due to the rapid growth of e-commerce and a young, tech-savvy population. In countries like China and India, for example, robotics and AI are being increasingly tested in urban environments, particularly in cities with high population densities and traffic congestion. These technologies promise to address challenges such as inefficient delivery routes, overcrowded roads, and limited access to remote areas.

However, emerging economies face several hurdles in adopting these technologies. One of the primary challenges is the lack of infrastructure, including reliable internet access, transportation networks, and regulatory frameworks to support the deployment of autonomous systems (Ejiaku, 2014). In some African countries, limited investment in digital infrastructure and concerns about the affordability of technology also impede the widespread adoption of AI and robotics. Despite these challenges, there are significant opportunities in these regions, particularly in improving the efficiency of deliveries to remote or underserved areas, where traditional delivery methods are often inefficient or costly. The integration of robotics and AI in last-mile delivery has the potential to transform logistics in these regions, particularly as technology becomes more accessible and affordable (Elujide *et al.*, 2021).

4.3 Cross-continental comparisons

A comparative analysis of robotics and AI adoption in developed and emerging economies reveals significant differences in the pace and nature of implementation. In developed economies, the adoption is largely driven by the

need for efficiency and cost reduction in highly competitive markets, where technological infrastructure is already robust. In contrast, emerging economies are often more focused on overcoming logistical inefficiencies and expanding access to underserved areas, such as rural or remote communities. While developed economies focus on enhancing the speed and reliability of delivery systems, emerging economies are more focused on expanding the reach of delivery services, using technology to overcome infrastructure challenges (Afolabi & Akinsooto, 2021).

Furthermore, the regulatory environment plays a crucial role in determining the pace of adoption across regions. In developed markets, clear regulations are being established to govern the use of autonomous vehicles and drones, although these regulations often lag behind technological innovation. In emerging markets, regulatory frameworks are often less defined, and government support for the integration of these technologies can vary significantly (Shen *et al.*, 2014). Additionally, differences in infrastructure—such as internet connectivity and urban planning—also influence how these technologies are deployed. Developed economies are better positioned to integrate advanced technologies into their existing infrastructure, while emerging economies must address basic infrastructure issues before fully realizing the potential of robotics and AI in last-mile delivery (Abisoye & Akerele, 2022; Paul *et al.*, 2021).

In conclusion, while robotics and AI are revolutionizing last-mile delivery systems worldwide, the extent and manner of their adoption vary significantly across regions. Developed economies are more likely to lead in technological sophistication and regulatory frameworks, whereas emerging economies face unique challenges but also have the opportunity to leapfrog traditional delivery methods and address critical logistical inefficiencies. The adoption of these technologies will continue to evolve based on regional needs, infrastructure development, and regulatory support.

5. Conclusions

The study reveals several important insights into the evolving landscape of last-mile delivery, especially in the context of the post-pandemic era. One of the primary findings is the accelerated shift toward automation and technology-driven solutions as a response to the challenges posed by the pandemic. The surge in e-commerce demand, coupled with the need for contactless, efficient, and safe delivery methods, has made robotics and AI central to transforming last-mile delivery operations. Robotics, including drones and autonomous vehicles, are showing significant potential in overcoming traffic congestion and reducing delivery costs, while AI plays a critical role in optimizing routes, forecasting demand, and personalizing customer experiences.

Another key finding is the differential adoption of these technologies across regions. In developed economies, the adoption of robotics and AI is driven by the maturity of technological infrastructure and a focus on efficiency and cost reduction. Meanwhile, in emerging economies, the emphasis is often on overcoming logistical inefficiencies and reaching underserved areas. This dichotomy in regional adoption highlights the diverse approaches to leveraging technology in last-mile delivery. Despite the advances, challenges such as regulatory hurdles, infrastructure limitations, and consumer acceptance remain key barriers that need to be addressed for widespread adoption.

The practical implications for businesses and policymakers

are profound. For businesses, adopting robotics and AI technologies can lead to improved delivery efficiency, reduced operational costs, and enhanced customer satisfaction. By leveraging autonomous vehicles and drones, companies can reduce delivery times, optimize routes in real-time, and provide more flexible delivery options. However, businesses must also navigate the challenges of implementing these technologies, including initial capital investment, regulatory compliance, and consumer acceptance of autonomous delivery methods. In practice, businesses should focus on scaling these technologies gradually, integrating them into existing delivery networks while ensuring the technology's reliability and safety.

For policymakers, the adoption of robotics and AI in last-mile delivery presents opportunities for regulatory innovation. Governments should develop clear and adaptive frameworks that facilitate the safe and efficient integration of autonomous technologies into public spaces. This includes setting standards for safety, data privacy, and ethical considerations. Policymakers should also support infrastructure development, particularly in emerging economies, to enable the widespread deployment of these technologies. Additionally, public-private partnerships could play a critical role in facilitating research and development in last-mile delivery, helping to reduce the technological and financial barriers for smaller players in the logistics industry.

Despite the progress in robotics and AI adoption in last-mile delivery, several gaps in current research warrant further exploration. One significant area that needs more attention is the long-term sustainability of these technologies. While current studies focus on the efficiency and cost-effectiveness of robotics and AI, fewer studies examine the environmental impact of widespread deployment, particularly regarding energy consumption and the carbon footprint of autonomous vehicles and drones. Understanding the ecological implications of these technologies is crucial as businesses and policymakers strive for sustainability in the logistics sector.

Another gap in the literature pertains to the social and economic impact of these technologies, particularly in terms of employment. The automation of last-mile delivery raises concerns about job displacement, especially in sectors that rely on human labor for delivery services. Research is needed to explore how the workforce can adapt to these changes, including the development of new roles in the technology and maintenance sectors. Furthermore, the potential impact of robotics and AI on local economies and smaller businesses, especially in emerging markets, should be investigated.

Finally, there is a need for continued innovation in last-mile delivery technologies. While robotics and AI have demonstrated significant potential, many opportunities exist to improve their integration. Research could focus on enhancing autonomous vehicles' and drones' reliability and safety, reducing operational costs, and increasing their scalability in different regional contexts. Additionally, exploring the potential of hybrid delivery systems that combine traditional delivery methods with robotics and AI could provide a more flexible solution that addresses the diverse needs of global markets. Future research in these areas will be essential for advancing the next generation of last-mile delivery systems and ensuring their successful and sustainable integration into logistics networks.

6. References

1. Abisoye A, Akerele JI. A practical framework for advancing cybersecurity, artificial intelligence and technological ecosystems to support regional economic development and innovation. *International Journal of Multidisciplinary Research and Growth Evaluation*. 2022;3(1):700–13.
2. Adebisi B, Aigbedion E, Ayorinde OB, Onukwulu EC. A conceptual model for predictive asset integrity management using data analytics to enhance maintenance and reliability in oil & gas operations. Unpublished manuscript; 2021.
3. Adekola AD, Kassem RG, Mbata AO. Convergence of AI, blockchain and pharmacoeconomics in building adaptive pharmaceutical supply chains: A novel paradigm shift for equitable global drug access. Unpublished manuscript; 2022.
4. Adeleke AK, Igunma TO, Nwokediegwu ZS. Modeling advanced numerical control systems to enhance precision in next-generation coordinate measuring machine. Unpublished manuscript.
5. Adepoju P, Austin-Gabriel B, Hussain Y, Ige B, Amoo O, Adeoye N. Advancing zero trust architecture with AI and data science. Unpublished manuscript; 2021.
6. Afolabi SO, Akinsooto O. Theoretical framework for dynamic mechanical analysis in material selection for high-performance engineering applications. *Noûs*. 2021;3.
7. Alonge EO, Eyo-Udo NL, Ubanadu BC, Daraojimba AI, Balogun ED, Ogunsola KO. Enhancing data security with machine learning: A study on fraud detection algorithms. Unpublished manuscript; 2021.
8. Balaska V, Tsiakas K, Giakoumis D, Kostavelis I, Folinas D, Gasteratos A, Tzovaras D. A viewpoint on the challenges and solutions for driverless last-mile delivery. *Machines*. 2022;10(11):1059.
9. Balogun ED, Ogunsola KO, Samuel A. A cloud-based data warehousing framework for real-time business intelligence and decision-making optimization. Unpublished manuscript; 2021.
10. Balogun ED, Ogunsola KO, Samuel A. Developing an advanced predictive model for financial planning and analysis using machine learning. Unpublished manuscript; 2022.
11. Charles OI, Hamza O, Eweje A, Collins A, Babatunde GO, Ubamadu BC. *International Journal of Social Science Exceptional Research*. 2022.
12. Ejiaku SA. Technology adoption: Issues and challenges in information technology adoption in emerging economies. *Journal of International Technology and Information Management*. 2014;23(2):5.
13. Elujide I, Fashoto SG, Fashoto B, Mbunge E, Folorunso SO, Olamijuwon JO. Application of deep and machine learning techniques for multi-label classification performance on psychotic disorder diseases. *Informatics in Medicine Unlocked*. 2021;23:100545.
14. Elumilade OO, Ogundejì IA, Achumie GO, Omokhoa HE, Omowole BM. Optimizing corporate tax strategies and transfer pricing policies to improve financial efficiency and compliance. *Journal of Advance Multidisciplinary Research*. 2022;1(2):28–38.

15. Engesser V, Rombaut E, Vanhaverbeke L, Lebeau P. Autonomous delivery solutions for last-mile logistics operations: A literature review and research agenda. *Sustainability*. 2023;15(3):2774.
16. Ewim CP-M, Omokhoa HE, Ogundejia IA, Ibeh AI. Future of work in banking: Adapting workforce skills to digital transformation challenges. *Future*. 2021;2(1).
17. Ezeanochie CC, Afolabi SO, Akinsooto O. A conceptual model for Industry 4.0 integration to drive digital transformation in renewable energy manufacturing. Unpublished manuscript; 2021.
18. Ezeanochie CC, Afolabi SO, Akinsooto O. Advancing automation frameworks for safety and compliance in offshore operations and manufacturing environments. Unpublished manuscript; 2022.
19. Govender P, Fashoto SG, Maharaj L, Adeleke MA, Mbunge E, Olamijuwon J, *et al.* The application of machine learning to predict genetic relatedness using human mtDNA hypervariable region I sequences. *PLOS ONE*. 2022;17(2):e0263790.
20. Hassan YG, Collins A, Babatunde GO, Alabi AA, Mustapha SD. AI-driven intrusion detection and threat modeling to prevent unauthorized access in smart manufacturing networks. *Artificial Intelligence (AI)*. 2021;16.
21. Isibor NJ, Ibeh AI, Ewim CP-M, Sam-Bulya NJ, Martha E. A financial control and performance management framework for SMEs: Strengthening budgeting, risk mitigation, and profitability. Unpublished manuscript; 2022.
22. Jessa EK. Evolution of masonry techniques. *Communication in Physical Sciences*. 2022;8(4).
23. Mustapha SD, Ibitoye B. Comprehension analysis of traffic signs by drivers on urban roads in Ilorin, Kwara State. *Journal of Engineering Research and Reports*. 2022a;23(6):53–63.
24. Mustapha SD, Ibitoye B. Understanding of traffic signs by drivers on urban roads—A case study of Ilorin, Kwara State. *Journal of Engineering Research and Reports*. 2022b;23(12):39–47.
25. Odunaiya OG, Soyombo OT, Ogunsola OY. Economic incentives for EV adoption: A comparative study between the United States and Nigeria. *Journal of Advanced Education and Sciences*. 2021;1(2):64–74.
26. Odunaiya OG, Soyombo OT, Ogunsola OY. Sustainable energy solutions through AI and software engineering: Optimizing resource management in renewable energy systems. *Journal of Advanced Education and Sciences*. 2022;2(1):26–37.
27. Ogbeta C, Mbata A, Katas K. Innovative strategies in community and clinical pharmacy leadership: Advances in healthcare accessibility, patient-centered care, and environmental stewardship. *Open Access Research Journal of Science and Technology*. 2021;2(2):16–22.
28. Ogbuagu OO, Mbata AO, Balogun OD, Oladapo O, Ojo OO, Muonde M. Enhancing biopharmaceutical supply chains: Strategies for efficient drug formulary development in emerging markets. Unpublished manuscript; 2022a.
29. Ogbuagu OO, Mbata AO, Balogun OD, Oladapo O, Ojo OO, Muonde M. Novel phytochemicals in traditional medicine: Isolation and pharmacological profiling of bioactive compounds. Unpublished manuscript; 2022b.
30. Ogunmokun AS, Balogun ED, Ogunsola KO. A strategic fraud risk mitigation framework for corporate finance cost optimization and loss prevention. Unpublished manuscript; 2022.
31. Ogunsola KO, Balogun ED, Ogunmokun AS. Developing an automated ETL pipeline model for enhanced data quality and governance in analytics. Unpublished manuscript; 2022.
32. Otokiti BO, Igwe AN, Ewim C, Ibeh AI, Sikhakhane-Nwokediegwu Z. A framework for developing resilient business models for Nigerian SMEs in response to economic disruptions. *International Journal of Multidisciplinary Research and Growth Evaluation*. 2022;3(1):647–59.
33. Otokiti BO, Igwe AN, Ewim CP-M, Ibeh AI. Developing a framework for leveraging social media as a strategic tool for growth in Nigerian women entrepreneurs. *International Journal of Multidisciplinary Research and Growth Evaluation*. 2021;2(1):597–607.
34. Paul PO, Abbey ABN, Onukwulu EC, Agho MO, Louis N. Integrating procurement strategies for infectious disease control: Best practices from global programs. *Prevention*. 2021;7:9.
35. Sam-Bulya NJ, Omokhoa HE, Ewim CP-M, Achumie GO. Developing a framework for artificial intelligence-driven financial inclusion in emerging markets. Unpublished manuscript.
36. Shen B, Ghatikar G, Lei Z, Li J, Wikler G, Martin P. The role of regulatory reforms, market changes, and technology development to make demand response a viable resource in meeting energy challenges. *Applied Energy*. 2014;130:814–23.
37. Sikirat MD. Comprehension analysis of traffic signs by drivers on urban roads in Ilorin, Kwara State. Kwara State University (Nigeria); 2022.
38. Sorooshian S, Khademi Sharifabad S, Parsaee M, Afshari AR. Toward a modern last-mile delivery: Consequences and obstacles of intelligent technology. *Applied System Innovation*. 2022;5(4):82.