GREEN INNOVATIONS IN LAST MILE DELIVERY: A RESEARCH AGENDA

Eric Mogire [1]

A B S T R A C T

The surge in electronic commerce calls for the potential for green innovations in last mile delivery. Existing studies on the topic are fragmented, and have explored diverse green innovations across different regions, reporting conflicting findings. Thus, this review aims to fill this gap by conducting a comprehensive study to identify underlying themes and propose future research agendas on the topic. A word analysis was performed on 628 publications extracted from the Scopus database for the period between 2000 and 2024. Findings reveal an increasing trend in publications, covering five themes: sustainability, optimisation and vehicle routing, consumer behaviour, technological innovations, urban mobility and freight transportation. Sustainability is the most dominant theme. In addition, the underexplored areas include social aspects of sustainability, intangible technological innovations, and consumer behaviour on emerging delivery technologies. Future studies should target under-researched areas, such as regulatory interventions required to increase the uptake of green innovations, real-world application of intangible technologies (e.g. artificial intelligence), demand and willingness to pay for emerging delivery technologies (e.g. electric vehicles), integrating smart city innovations and renewable energy sources into last mile delivery. However, this review is limited to publications extracted from the Scopus database.

1. INTRODUCTION

Globally, electronic commerce (e-commerce) sales are forecasted to reach $8.034 trillion in 2027 from $5.784 trillion sales in 2023 (eMarketer, 2023), a 38.9% increase in four years. China, which is known to be a global leader in e-commerce, contributed $2.931 trillion (more than half) of the total global e-commerce sales in 2023 (eMarketer, 2023). China's success in e-commerce is driven by a developed last mile delivery system, among other factors (Hongfei, 2017; Zandi et al., 2021). Even though last mile delivery (LMD) is considered crucial for e-commerce, research has shown that it faces environmental challenges. These include the negative impacts of high carbon emissions, urban congestion, habitat loss, air, and noise pollution (World Economic Forum, 2020; Mucowska, 2021; Mogire et al., 2022). The negative impacts can be attributed to the increasing number of delivery vehicles expected to grow by 36% until 2030 in the top 100 cities in the world (World Economic Forum, 2020).

Green innovations, as well as other alternatives, are increasingly being explored in the last mile delivery to resolve the environmental challenges for the sustainability of e-commerce. Research has shown a significant and positive relationship between environmental performance and sustainable performance (Demir et al., 2025). Thus, green innovations refer to

---
[1] Corresponding author: Eric Mogire
  Email: emogire@uj.ac.za

those innovations utilised by e-commerce firms to improve competitiveness in the last mile delivery while enhancing environmental performance (Franceschin et al., 2016; Degler et al., 2021). These include but are not limited to cargo bikes, electric vehicles (EVs), autonomous vehicles, smart lockers, drones, micro hubs, big data analytics, and Internet-of-Things (IoT). These green innovations are transforming last mile delivery by enhancing delivery speed, reducing environmental impact, and increasing customer trust in e-commerce. In addition, electric vehicles and drones are powered by clean and renewable energy sources such as hydro, wind, and solar power, contributing to reduced demand for fossil fuels. Industry 4.0 technologies such as IoT, big data analytics, and blockchain technology promote efficient use of resources, and minimise waste and pollution (Kumar et al., 2023). Despite their potential, adopting green innovations in last mile delivery is hindered by various barriers, such as high capital investments and/or operational expenses (Engelhardt, 2023). In addition, prior studies have reported that customers do not favour emerging delivery carriers such as drones, which are reliable, safer, and efficient (Mogire et al., 2024a).

Research in existing studies on green innovations is fragmented and differs across different regions. For instance, existing studies have identified diverse green innovations (Ranieri et al., 2018; Mohammad et al., 2023; Mogire et al., 2024b), underexplored aspects (Mucowska, 2021; Mogire, Kilbourn & Rose, 2025), conflicting findings (Mucowska, 2021; Mogire et al., 2025), and regional differences (Schnieder, 2024; Mogire et al., 2025). A keyword search in the Scopus database (Article title: ("*green innovation**") AND ("*last mile*" OR "*last-mile*")) failed to identify a study directly aligned with the focus of this review. One relevant study was found in Google Scholar: *Green innovations in last mile delivery for electronic commerce: A bibliometric review* (Mogire et al., 2024b). Even though the study was a bibliometric review, it lacked the in-depth word analysis necessary to identify the key themes in the field. Thus, there is a need for a deeper textual analysis to identify underlying themes and emerging trends on the topic. This gap highlights the need to go beyond the bibliometric metrics to offer deeper insights into green innovations in last mile delivery. This is crucial in supporting policy development and accelerating the broad adoption of green innovations in last mile delivery. The objectives of this review are:

i. To identify the key themes that have been used in green innovations and last mile delivery research.
ii. To propose future research agendas on green innovations in last mile delivery.

The subsequent sections of the review are as follows: Section 2 explores a literature review on green innovations in last mile delivery, Section 3 covers methodology, Section 4 displays results, Section 5 discusses the results, and Section 6 provides the conclusion.

2. LITERATURE REVIEW

This section examines the key terms used in the review. It starts by introducing the concept of last mile delivery and then looks at reviews on green innovations in last mile delivery.

2.1 Last mile delivery

Last mile delivery is the final leg of transporting goods to the final destination (Sorooshian et al., 2022; Mohammad et al., 2023). This starts once a package has arrived at a starting point in an urban area (e.g., a central depot after long-haul transportation) and stops once the package has successfully been delivered at the final customer's preferred point (Boysen et al., 2021). Last mile delivery refers to the activities necessary for the physical delivery of goods to the final destination chosen by the receiver (Olsson et al., 2019). These include emerging technologies and innovations (such as innovative delivery vehicles), operational optimisation (e.g., routing and facility location), and supply chain structures (for example, urban freight terminals), among other activities. Last mile delivery is also defined as the service provided by an online retailer to their customers from the point when a product is released from the retailer (e.g., manufacturing site or fulfilment centre) to the point where a product is delivered to the customer (e.g., at the customer's home or a collection point) (Mogire, 2022; Mogire et al., 2023). From the definitions, last mile delivery has a start point (i.e., when goods are released from e-commerce businesses) and an end point (i.e., when the final customer receives goods). In addition, last mile delivery activities comprise physical/ tangible aspects (e.g., innovative delivery vehicles and urban freight terminals) and intangible aspects (e.g., routing).

2.2 Green innovations in last mile delivery

Innovations are crucial for the survival and growth of any business organisation (Tohidi & Jabbari, 2012). Without innovation, a business organisation will fall behind its competitors. While various e-commerce businesses have started to offer green delivery options, customers may be skeptical (Kader et al., 2023). Thus, integrating green innovations into last mile delivery is crucial for the sustainability of the e-commerce industry.

In last mile delivery, innovative services for delivering packages have generated considerable interest in literature, and attempts are underway to find either new solutions or improve existing ones (Mohammad et al., 2023). Over the past few years, various innovations have emerged to reduce negative effects on the environment. Bonilla et al. (2024) noted that various innovations have emerged to enhance efficiency and minimise the environmental impacts of logistics. Innovations that reduce the adverse effect on the environment can be classified as green innovation, eco-innovation, sustainable innovation, and environmental innovation

(Degler et al., 2021). Although the four types of innovations are often used interchangeably, they differ in meaning. Dane et al. (2019) agree that the overlap between the four types of innovation is clear, and the contribution of each concept is less distinctive.

Sustainable innovation focuses on societal impact, while eco-innovation focuses on economic impact (e.g., eco-design) to minimise negative effects on the environment (Degler et al., 2021). Environmental innovation focuses on environmental impact, precisely the regulatory and policy issues, while green innovation focuses on the managerial impact (e.g., competition) (Degler et al., 2021). Green innovation is a type of innovation that aims to reduce or prevent environmental damage while safeguarding the environment and helping companies to fulfil new customer demands, create value, and increase yields (Albort-Morant et al., 2017). Due to various attempts to define green innovations, clarity is necessary to enhance the body of knowledge for academicians and practitioners.

Last mile delivery innovations are categorised differently. Ranieri et al. (2018) review of last mile delivery innovations in an externalities cost reduction identified various innovations. These include proximity points or stations (e.g., parcel machines and lockers) and innovative vehicles (autonomous and electric vehicles). Ha et al. (2023) bibliometric analysis on last mile delivery identified operational optimisation (i.e., routing) and emerging technologies / innovations as the main research areas. The innovations included electric vehicles, smart locker systems, crowdsourcing, and drones. Mohammad et al. (2023) broadly categorised innovative solutions in last mile delivery either as current innovative solutions (such as cargo bikes, human-driven delivery vans, and parcel lockers) or solutions for the near future (e.g., drones and robots). Intelligent technologies for modern last mile delivery were categorised as either tangible technologies (e.g., drones, autonomous vehicles, and robots) or intangible technologies (e.g., operating systems and decision support tools) (Sorooshian et al., 2022). Boysen et al. (2021) addressed alternative last mile delivery concepts such as transport vehicles (such as drones and delivery vans), storage facilities (e.g., postal lockers and central depot), and handover options (for example, self-service by customers and the attended home delivery). In addition, the author indicated that last mile delivery concepts are surveyed as today's concepts (e.g., cargo bikes, human-driven vans, and self-service parcel lockers), near-future concepts (such as autonomous delivery robots, drones, and crowd shipping), and further future concepts (for example autonomous vehicles). Engelhardt (2023) indicated that environmental challenges from freight transportation in e-commerce required radical innovations in environmentally friendly transportation modes (e.g., cargo bikes) and consolidation points (such as micro hubs). Silva et al. (2023) systematic analysis of sustainable urban last mile logistics identified vehicular solutions (such as autonomous and electric vehicles, drones, and cargo

bikes), organisational solutions (e.g., urban consolidation centres, parcel lockers, and crowdsourcing), and operational solutions (for example, technological systems). A systematic literature review on the adoption of green vehicles in last mile logistics identified green vehicles that include electric vehicles, cargo bikes, unmanned vehicles, and drones, among others (Patella et al., 2020). A systematic literature review on sustainability practices for last mile logistics networks in e-retail found that sustainability practices include consolidation centres, shared freight transportation, shared micro-depots, electric vehicles (e.g., tricycles and bicycles), and implementation of collection and delivery points (Bonilla et al., 2024). A bibliometric review on green innovations in last mile delivery for e-commerce identified the innovations as green vehicles (such as electric vehicles and drones), green technologies (such as, blockchain, artificial intelligence (AI), and IoT), and green proximity points (such as parcel lockers) (Mogire et al., 2024b). However, the bibliometric review failed to utilise textual analysis to identify underlying themes and emerging trends on the topic. From the preceding discussion, it is evident that there is a lack of uniformity on how innovations in last mile delivery are classified by prior research.

3. METHODOLOGY

A word analysis was utilised to go beyond citation metrics and gain deeper insights into green innovations in last mile delivery. A search was undertaken in the Scopus database on 2nd January 2025. The Scopus is a trusted source of bibliometric data (Baas et al., 2020). The search in Scopus used a combination of keywords: (ALL FIELDS (“*green*”) AND (“*innovati**” OR “*solution**” OR “*technolog**” OR “*drone**” OR “*robot**” OR “*autonomous vehicle**” OR “*electric**” OR “*bike**” OR “*bicycle**” OR “*tricycle**” OR “*scooter**” OR “*locker**” OR “**centre*” OR “**hub*” OR “*internet-of-things*” OR “*big data*” OR “*blockchain*” OR “*artificial intelligence*” OR “*machine learning*” OR “*augmented reality*” OR “*decision support system*” OR “*routing algorithm*” OR “*optimisation system*” OR “*crowd**”) AND ("*last mile*" OR "*last-mile*") AND (“*delivery*” OR “*logistics*” OR “*distribution*” OR “*transport*”) AND ("*electronic commerce*" OR "*e-commerce*" OR "**retail*"). This resulted in 944 publications (i.e., review papers, journal articles, conference proceedings, and book chapters) in Business Management published in the English language from 2000 to 2024.

The selected keywords specifically targeted various green innovations used in e-commerce for last mile delivery because an earlier search (Article title: ("*green innovation**") AND ("*last mile*" OR "*last-mile*") failed to identify a study directly aligned with the focus of this review. A thorough screening of the abstracts and titles of the publications to assess their relevance ultimately reduced the number to 628 publications. The excluded publications were duplicates, irrelevant to the topic, or

missed abstracts. The 628 publications were exported from the Scopus database as a comma-separated values (CSV) file for in-depth analysis. The RStudio software (specifically the Biblioshiny app) was utilised to undertake a word analysis to reveal current and emerging themes in the study of green innovations in last mile delivery.

Table **1** show publications on green innovations in last mile delivery have a high annual growth rate of 27.45%, indicating a topic attracting more research attention.

Table 1. Main information about the publications (2000 – 2024)

Description	Results
Timespan	2003:2024
Sources (Journals, Books, etc.)	219
Documents	628
Annual Growth Rate %	27.45
Document Average Age	3.32
Average citations per doc	18.35
References	42659
DOCUMENT CONTENTS	
Keywords Plus (ID)	1731
Author's Keywords (DE)	1972
AUTHORS	
Authors	1634
Authors of single-authored docs	50
AUTHORS COLLABORATION	
Single-authored docs	53
Co-Authors per Doc	3.33
International co-authorships %	34.08
DOCUMENT TYPES	
Article	526
book chapter	31
conference paper	40
Review	31

The average age per document is 3.32 (

Table **1**), implying a relatively new topic. Most publications are journal articles (83.8%), with reviews accounting for 4.9% (

Table **1**), justifying a need for more reviews.

4. RESULTS

4.1 Number of publications per year

Results showed that research on green innovations in last mile delivery for e-commerce started in 2003 (Figure 1). There was minimal research in the early years up to 2013, with very few publications per year (i.e., mostly 0 to 3) (Figure 1). Research focused on expansion of e-commerce, rather than green innovations in last mile delivery. The period from 2014 to 2018 experienced slow growth, with 20 publications in 2018 (Figure 1). This indicates a rising interest in green innovations for last

mile delivery, driven by the high carbon emissions from conventional delivery vehicles as researchers sought solutions on cleaner alternatives. The period from 2019 to 2021 recorded high growth, with 67 publications in 2021 (Figure 1). This was due to advancements in electric vehicles, climate change awareness, and the emergence of more innovations in last mile delivery. In particular, electric vehicles became common, highlighting the transition from fossil-powered vehicles to clean energy-powered vehicles. The period from 2022 to 2024 is expected to continue this trend, with projections of significant growth resulting in 163 publications by 2024 (Figure 1). This increase may be linked to technological advancements such as AI and blockchain, greater acceptance of these innovations, and a heightened awareness of sustainability issues.
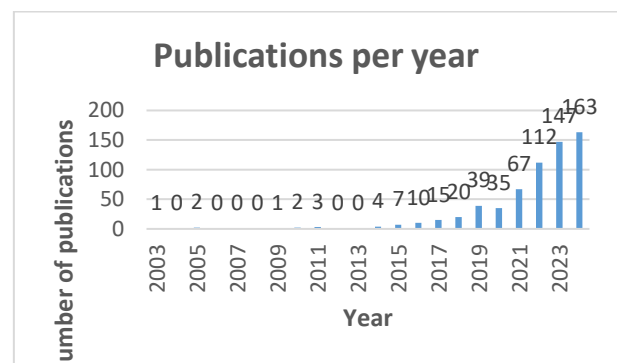
Figure 1. Number of publications on green innovations in LMD research (2000 - 2024)

4.2 Word analysis

Word analysis helps to identify key themes and trends by examining the frequency of keywords. This includes word frequency analysis, word cloud, words' frequency over time, and trend topics.

4.2.1 Word frequency analysis
Word frequency analysis was conducted to identify frequently discussed concepts and keywords on the topic. Table 2 presents the top 50 most frequent words on green innovations in last mile delivery. Five main themes emerge: sustainability, optimisation, technology, consumer behavior, and urban mobility. The sustainability theme includes keywords like *sustainable development, environmental impact, sustainability, environmental technology, economic and social effects* (Table 2). This shows that green innovations leverage on environmental technology to address environmental, social, and economic effects in last mile delivery. The optimisation theme includes keywords like *vehicle routing, decision-making, costs, optimisation, vehicle routing problems, profitability, cost-effectiveness, fleet operations, competition,* and *efficiency* (Table 2). This indicates that green innovations can improve last mile delivery through efficient routing and cost reduction.

The technology theme includes keywords like *transportation system, crowdsourcing, drones, genetic algorithms, technology adoption, autonomous vehicles,*

technological development, algorithm, unmanned vehicle, artificial intelligence, environmental technology, information and communication technology (Table 2).

Table 2. Top 50 most frequent words on green innovations in LMD research (2000 – 2024)

	Word(s)	Occurrences		Word(s)	Occurrences
1	sustainable development	45	26	fleet operations	11
2	consumption behavior	39	27	location	11
3	sales	38	28	transportation planning	11
4	vehicle routing	33	29	autonomous vehicles	10
5	decision making	21	30	freight transport	10
6	vehicles	20	31	consumer behavior	9
7	costs	18	32	customer satisfaction	9
8	optimisation	18	33	technological development	9
9	pickups	17	34	urban area	9
10	transportation system	17	35	algorithm	8
11	COVID-19	15	36	city logistics	8
12	vehicle routing problems	15	37	competition	8
13	crowdsourcing	14	38	perception	8
14	drones	14	39	routings	8
15	environmental impact	14	40	service quality	8
16	genetic algorithms	14	41	service sector	8
17	sustainability	14	42	shopping activity	8
18	urban transportation	14	43	unmanned vehicle	8
19	freight transportation	13	44	artificial intelligence	7
20	profitability	13	45	economic and social effects	7
21	trucks	13	46	economics	7
22	China	12	47	efficiency	7
23	cost effectiveness	12	48	environmental technology	7
24	technology adoption	12	49	food delivery	7
25	urban transport	12	50	information and communication technology	7

This implies that green innovations integrate intelligent systems and automation.

The consumer behaviour theme includes keywords such as *consumption behaviour, sales, COVID-19, consumer behaviour, customer satisfaction, perception, service quality*, and *shopping activity* (Table 2). This means that understanding customer preferences helps in the uptake of green innovations in last mile delivery. The urban mobility theme includes keywords such as *urban transportation, freight transportation, urban transport, freight transport, urban area*, and *city logistics* (Table 2). This implies that green innovations in last mile delivery can enhance urban freight transport. Thus, green innovations leverage on automation to enhance efficiency, while addressing environmental, social, and urban freight challenges.

4.2.2 Word cloud

A word cloud is used to visually represent words in a text according to their frequency in different colours. This is important in research because it helps to identify key themes and trends in a research topic. This review used the word cloud to identify key themes on green innovations in last mile delivery.

Figure 2. Word cloud on green innovations in LMD research (2000 – 2024)

Figure 2 reveals five key themes: consumption behaviour (maroon colour), sales and profitability (lime green), vehicle routing and optimisation (dark green colour), sustainability and environmental impact (dark blue colour), and technological innovations in transportation (light green).

i) Consumption behaviour

Consumption behavior is the most dominant keyword in the word cloud (Figure 2). This indicates that consumer demand and purchasing habits drive green innovations in last mile delivery. Grouping *consumption behaviour, fleet operations, profitability,* and *China* in the same colour (Figure 2) suggests a close connection between the keywords. This implies that the profitability of e-commerce businesses and last mile fleet operations in China are heavily influenced by consumption behaviour. The dominant keyword *consumption behaviour* is also very close to *sales*, revealing that e-commerce sales are directly related to consumer purchasing behavior, thus driving the demand for green innovations in last mile delivery. *Consumption behaviour* is surrounded by transport-related keywords such as *transportation system, urban transport*, and *freight transport* (Figure 2).

Thus, existing research focuses on consumption behaviour in transportation systems, urban transport, and freight transportation in last mile delivery. At the outer left part of the word cloud, close to *transportation system,* is the keyword *COVID-19* (Figure 2). This shows that the emergence of COVID-19 accelerated the shift to green, innovation-driven transport systems in last mile delivery to meet customer demand and sales expectations. *Consumption behaviour* is also close to *cost-effectiveness* and *optimisation* (Figure 2). Thus, research on green innovations in last mile delivery enables e-commerce businesses to improve their transportation efficiency and fleet optimisation. The appearance of the keyword *sensitivity analysis* at the outer edge of the word cloud placed near *consumption behaviour* (Figure 2), implies that e-commerce businesses must assess consumer behavior, such as preferences for *cost-effectiveness* and *profitability* when implementing green innovations in last mile delivery. The appearance of the keywords *vehicles* and *pickups* close to *consumption behaviour* (Figure 2) shows that last mile delivery options in e-commerce should be aligned with consumer expectations such as economic and social effects (sustainability), and cost-effectiveness. The keywords such as *cost-effectiveness, crowdsourcing, genetic algorithms, drones*, and *autonomous vehicles* are close to *consumption behavior* (Figure 2). Thus, increasing customer demand for cost-effective last mile delivery options has resulted in the development of green innovations in last mile delivery, such as crowdsourcing, genetic algorithms, drones, and other autonomous vehicles.

ii) Sales and profitability

The keyword *sales* is at the center of the word cloud (Figure 2). This indicates a close link between e-commerce growth (i.e., sales) and green innovations in the last mile delivery. Green innovations in last mile delivery can enhance sales for e-commerce businesses and strengthen competitive advantage. Grouping keywords *sales, perception, and optimisation* in the same colour (Figure 2), suggests a close connection between the keywords. Thus, optimising last mile delivery enhances e-commerce sales by improving delivery efficiency while shaping consumer perception of green innovations. In addition, artificial intelligence-powered route optimisation algorithms can be used to enhance last mile delivery efficiency in the e-commerce industry. *Sensitivity analysis* and *optimisation* research have helped e-commerce companies understand *cost-effectiveness, profitability*, and delivery *efficiency*. This strengthens their competitive advantage over other companies in last mile delivery. According to Figure 2, the keyword s*ales* appear next to *consumption behavior*, implying a close connection between the two keywords. This shows that consumer purchasing decisions directly drive e-commerce sales, influencing demand for green innovations in last mile delivery. The keyword *sales* is also close to other keywords like *pickups* and *drones* (Figure 2). This means green innovations in last mile

delivery have seen a rise in pickup models that reduce emissions. The pickup models include drone-assisted collection points in urban areas.

iii) Vehicle routing and optimisation

Grouping keywords *vehicle routing, routing algorithms, economics, costs, economic and social effects, and freight transportation* in the same colour (Figure 2), suggests a strong thematic relationship among the keywords. This means optimising vehicle routing and routing algorithms in freight transportation reduces costs, enhances economic and social effects, and improves overall economics in last mile delivery. The keyword *vehicle routing* is located close to *urban transport, urban area, fleet operations, and freight transportation* (Figure 2). Thus, vehicle routing facilitates freight transportation in last mile delivery. The keywords such as *artificial intelligence, drones, environmental technology, technological development, information and communication technology* are positioned around the keyword *vehicle routing* (Figure 2). As the last mile delivery shifts towards cost-effective and sustainable solutions, e-commerce businesses must prioritise research and development on green innovations, such as drones, and artificial intelligence. Artificial intelligence can improve vehicle routing through predictive analytics, dynamic scheduling, and real-time traffic optimisation. Drones can improve delivery route efficiency by enabling fast, low-emission deliveries in urban areas. The keywords *sustainability, environmental technology, economics, and social effects* are located around the keyword *vehicle routing problems* (Figure 2). This suggests a strong connection between green innovations, cost-effectiveness, and social impact in last mile delivery. New green innovations, such as electric vehicles, can assist e-commerce businesses in reducing carbon emissions. In addition, optimising delivery routes can minimise fuel consumption, traffic congestion, and operational costs. The close positioning of the keywords *vehicle routing problem* and *consumer behavior* in the word cloud (Figure 2) suggests a strong relationship between last mile delivery and customer expectations. This may include customer preferences for cost-effective, efficient, and sustainable green innovations in the last mile delivery. Thus, green innovations are used to optimise last mile delivery, reducing costs and enhancing delivery efficiency.

iv) Sustainability and environmental impact

The keyword *sustainability* is located at the bottom of the word cloud (Figure 2). Grouping keywords *sustainability, vehicles, and routing* in the same colour (Figure 2), suggests a strong thematic relationship. Optimising vehicle usage and routing can improve sustainability in last mile delivery. This can help reduce carbon emissions, costs, and negative effects on the environment. The keyword *sustainability* is located close to the keywords *urban transportation* and *freight transport* (Figure 2*).* This highlights the relationship between green innovations and last mile

delivery. Sustainability relies on optimising urban transportation and freight transport to reduce emissions, enhance efficiency, and support green innovations in the last mile delivery. The keyword *sustainability* is also located close to *vehicle routing problems, economic, and social effects* (Figure 2). This highlights the challenge of designing efficient, low-emission last mile delivery routes while balancing with delivery cost. Thus, e-commerce businesses should invest in research and development on vehicle routing solutions to minimise fuel consumption and carbon in last mile delivery. S*ustainability* is also located close to the keyword *consumer behaviour* (Figure 2). This demonstrates that customer preferences influence green innovations e-commerce businesses use for last mile delivery. Online customers increasingly prioritise carbon-free, energy-efficient, and less-polluting last mile green innovations. Adopting alternative fuels for last mile delivery vehicles helps cut carbon emissions and supports the global shift toward cleaner energy systems. The keyword *sustainability* is also located close to the keyword *information and communication technology* (Figure 2). This highlights the role of digital innovations in enabling green last mile delivery solutions. Research and development in information and technology-driven vehicle routing algorithms can help achieve sustainability by minimising fuel consumption, carbon emissions, and pollution. Integrating renewable energy technologies with smart routing systems can create a more sustainable, resilient, and adaptive last mile delivery. Thus, green technologies improve sustainability and reduce environmental impact in last mile delivery. However, it was noted that the social aspect of sustainability is underexplored in the topic.

v) Technological innovations in transportation

The keyword *technology adoption* at the top of the word cloud with similar keywords like *artificial intelligence, algorithm, unmanned vehicle, routing algorithm, electric vehicles, autonomous vehicles, genetic algorithms, drones, technology development, environmental technology, information and communication technology* are located at the edges of the word cloud (Figure 2). Terms at the edges often indicate emerging or niche areas that are relevant but not yet dominant. Thus, green technological innovations like *genetic algorithms, unmanned vehicles,* and *autonomous vehicles* are still in the experimental or early adoption phase in many last mile delivery systems. While green technological innovations are crucial for last mile delivery, their widespread adoption is still evolving and depends on overcoming cost, infrastructure, and market readiness challenges. The keyword *genetic algorithms* is surrounded by keywords such as *consumption behaviour, vehicles, transportation system and autonomous vehicles* (Figure 2). This suggests that genetic algorithms are being applied to predict customer demand, optimise delivery routes based on consumer preferences, and personalise last mile delivery options. In addition, these algorithms help train AI models in autonomous route

planning, obstacle avoidance, and efficient parcel delivery without human intervention. *Environmental technology* is surrounded by keywords like *freight transportation, vehicle routing,* and *technology development* (Figure 2). This suggests that green innovations in last mile delivery are closely linked to operational aspects of last mile delivery.
Artificial intelligence is surrounded by keywords like *algorithm, vehicle routing problems, efficiency, and decision-making* (Figure 2). This shows that artificial intelligence enhances efficiency and decision-making through algorithms, optimising vehicle routing and logistics solutions. The keyword *unmanned vehicle* is surrounded by keywords like *COVID-19, transportation system, and economics* (Figure 2). This suggests that the COVID-19 pandemic accelerated interest in unmanned last mile delivery innovations like autonomous drones, robots, and self-driving vans. *Electric vehicles* are near keywords such as *technology adoption* and *environmental impact* (Figure 2). This implies that technological advancements in electric vehicles contribute to reducing adverse environmental effects in last mile delivery. The focus is to reduce the adverse environmental effects from last mile delivery through cleaner energy sources, fuel-efficient vehicles, and sustainable delivery option. This includes integrating renewable energy sources such as solar, wind, and hydro-electric power to charge electric vehicles. The keyword *drones* is surrounded by keywords like *vehicle routing, fleet operations,* and *optimisation* (Figure 2). This implies that e-commerce businesses are actively exploring how to integrate drones into broader last mile delivery networks for faster, more sustainable, and cost-effective deliveries. *Information and communication technology* is located next to keywords such as *urban transportation, economic and social effects* (Figure 2). Thus, technological advancements enable data-driven sustainability in last mile delivery by optimising urban transportation, reducing costs, and supporting green innovations. However, it was noted that intangible technological innovations are underexplored in the topic.

4.2.3 Words' frequency over time

Figure 3 depicts an increasing trend in the frequency of keywords used in the study of green innovations in last mile delivery. From 2000 to 2015, the frequency of keywords remained relatively low. *Sales* and *vehicles* were the most common keywords during this period (Figure 3). During this period, green innovations were in their infancy, with limited integration into last mile delivery. Thus, research focused on expanding e-commerce using conventional vehicles rather than green innovations in last mile delivery. There is a moderate increase in the frequency of keywords from 2015 to 2019. In addition to the keywords from the previous period, *optimisation, sustainable development, vehicle routing,* and *consumption behaviour* became more common (Figure 3). This period saw the integration of advanced vehicle routing algorithms to optimise delivery routes to reduce operational costs and the environmental impact of

last mile delivery. In addition, there was a focus on understanding consumer preferences to tailor last mile delivery services to green innovations. However, *sales* was the most frequent keyword during this period (Figure 3). This is the same period when there was a rapid rise in e-commerce, which significantly increased the volume of goods ordered by customers.
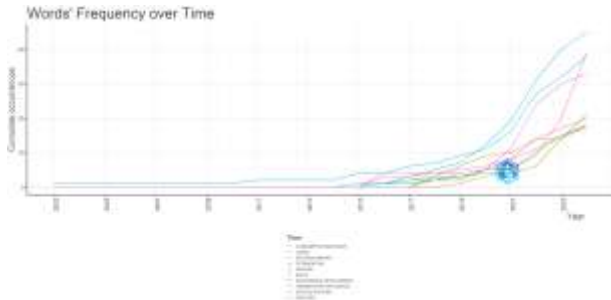

Figure 3. Words' frequency over time on green innovations in LMD research (2000 – 2024)

A significant increase in the frequency of all the keywords from the previous periods was reported from 2019 onwards. During this period, *sustainable development* was the most frequent keyword from the year 2020 (Figure 3). This highlights the e-commerce industry's trend to incorporate sustainable green innovations in last mile delivery.

4.2.4 Trend topics
Environmental sustainability has been well-established and consistently studied since 2017 (Figure 4). The rapid growth in online shopping significantly increased delivery volumes, leading to higher emissions and the need for greener delivery innovations. *Sustainable development, sales*, and *vehicle routing* have experienced the most significant research (larger bubbles) (Figure 4). This highlights the need to balance e-commerce growth (*sales*), last mile operational efficiency (*vehicle routing*), and sustainability (*sustainable development*). Post-2020, emerging topics include *carbon, time windows,* and *urban logistics* (smaller bubbles) (Figure 4). These emerging topics highlight the e-commerce industry's push for decarbonisation, efficiency, and flexibility in last mile delivery.
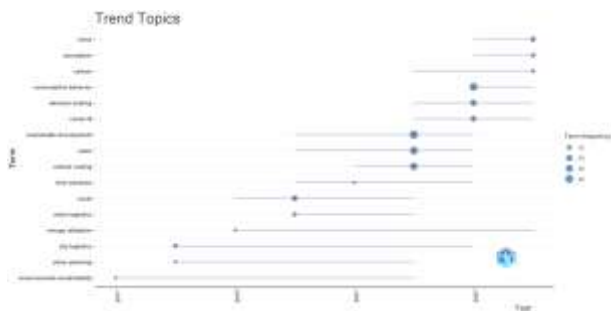
Figure 4. Trend topics on green innovations in LMD research (2000 – 2024)

This includes exploration of how electric vehicles and renewable energy infrastructure, such as solar or wind-powered EV charging stations, can be integrated into last mile delivery. It was also noted that research on the topic has moved from broad themes such as *sustainability* to narrow themes like *carbon* reduction and energy *utilisation*. This shift highlights the need for cleaner energy sources to reduce carbon emissions in last mile delivery.

5. DISCUSSION

Sustainability is the most dominant theme in existing research on green innovations in last mile delivery. Sustainability in last mile delivery covers three elements: environmental, economic, and social aspects (Ha et al., 2023). This is reflected in the use of keywords like *sustainable development, environmental impact, economic and social effects* in the word frequency analysis. A word cloud displays a connection between *sustainability, freight transport*, and *urban transportation*. This illustrates how optimising delivery routes and adopting electric vehicles can improve urban mobility while cutting emissions. Existing studies have identified environmental challenges, including high carbon emissions, urban congestion, habitat loss, air, and noise pollution in last mile delivery (World Economic Forum, 2020; Mucowska, 2021; Mogire et al., 2022). The increasing number of delivery vehicles expected to grow by 36% until 2030 in the top 100 cities in the world (World Economic Forum, 2020), further highlights the need to optimise routing to mitigate urban congestion and carbon emissions. This can be achieved by shifting from fossil fuels to clean and renewable energy sources like wind, solar, and hydro-electric sources to power electric vehicles. Words frequency over time shows that sustainability has gained importance, particularly after 2020. In agreement, Ha et al. (2023) observed a rapid growth in recent years in the number of studies focused on sustainability issues in the last mile delivery.

Optimisation and vehicle routing has become an important research topic on green innovations in last mile delivery. Route optimisation is the process of identifying the most cost-efficient route (Sorooshian et al., 2022). The word frequency analysis revealed keywords like *vehicle routing, genetic algorithms, decision-making,* and *fleet operations.* Recent studies have indicated that artificial intelligence can optimise delivery routes by using real-time traffic and weather data, leading to last mile delivery efficiency (Mogire et al., 2025). Keywords like *optimisation* and *vehicle routing* in the word frequency over time show that since 2015, research has increasingly focused on optimising last mile delivery. In agreement, Ha et al. (2023) noted a growing interest in optimisation in last mile delivery, precisely routing, transport planning, and innovative vehicles. The location of these keywords around *economic and social effects* in the word cloud shows the importance of routing optimisation in reducing operational costs and enhancing

delivery efficiency. Optimising delivery routes reduces costs and supports environmental sustainability (Sorooshian et al., 2022), emphasising the need to integrate AI-driven innovations in last mile delivery. Over time, there has been a growing interest in AI-driven routing solutions to enhance last mile delivery efficiency and sustainability (Sorooshian et al., 2022; Mogire et al., 2025). Such developments highlight the importance of AI-driven innovations as integral for achieving more efficient vehicle routing solutions in last mile delivery. AI routing can significantly reduce overall energy consumption and greenhouse gas emissions when combined with low-emission, renewable energy-powered vehicles.

Green innovations in last mile delivery are heavily influenced by consumer behavior. The word cloud shows *consumption behavior* as a prominent keyword. The word cloud also highlights the strong relationship between *consumption behaviour, fleet operations,* and *profitability*, especially in countries like *China*. The link between *sales* and *perception* suggests that optimising last mile delivery can enhance e-commerce sales by increasing efficiency and customer satisfaction. For instance, China's success in e-commerce can be attributed to a developed last mile delivery system (Hongfei, 2017; Zandi et al., 2021), which has sustained high customer demand. Words' frequency over time showed that prior studies focused on *consumer behavior* and *sales* before sustainability became a priority. Post-COVID-19 pandemic, most research focused on data-driven last mile delivery systems. This emphasises the need to align last mile delivery innovations with customer expectations. In agreement, after the COVID-19 pandemic, there have been changes in delivery processes and e-commerce activities (Toraman et al., 2023).

Technology innovations in transportation is one of the topics researched on green innovations in last mile delivery. The word frequency analysis revealed keywords like *artificial intelligence, autonomous vehicles, drones, genetic algorithms, information and communication technology* appear frequently in existing studies. Existing studies indicate that the role of artificial intelligence, autonomous vehicles, electric vehicles, and drones in last mile delivery is increasingly gaining attention due to their potential to address urban congestion and environmental challenges (Sorooshian et al., 2022; Mogire et al., 2024b). In the word cloud, these keywords are located at the edges, indicating their emerging role and interest among researchers on the topic. Ha et al. (2023) assert that innovations like drones, robots, and autonomous cars reduce labour costs and enhance last mile productivity. Without adopting emerging technologies, an e-commerce business will fall behind its competitors.

Urban mobility and freight transportation is a critical topic on green innovations in last mile delivery. Existing studies have pointed to the growing significance of urban mobility as a factor in shaping future green innovations, with an increasing focus on integrating urban transportation and freight delivery systems (World Economic Forum, 2020; Mucowska, 2021). The word frequency analysis identified keywords like *urban area, urban transportation,* and *freight transportation*. The word cloud displays *urban transport* near *vehicle routing* and *sustainability*, emphasising their interrelated roles in improving last mile delivery in urban areas. Existing studies show that last mile innovations such as electric vehicles and AI-driven routing solutions are essential for achieving more sustainable urban transport systems (Ha et al., 2023; Mohammad et al., 2023; Dhanush & Nanjundeswarswamy, 2025). The increasing number of delivery vehicles expected to grow by 36% until 2030 in the top 100 cities in the world (World Economic Forum, 2020), further highlights the need to optimise routing to mitigate urban congestion and carbon emissions. Integrating emerging technologies (such as IoT and artificial intelligence) into urban mobility systems optimises delivery processes and reduces negative effects on the environment (Sorooshian et al., 2022; Mogire et al., 2025). Such developments highlight the importance of AI-driven innovations as integral to achieving more efficient urban mobility solutions in the last mile delivery. In addition, incorporating renewable energy infrastructure, such as electric vehicle charging stations powered by clean energy, can reinforce sustainability efforts in last mile delivery.

6. CONCLUSION

Notably, existing research on green innovations in last mile delivery is on the rise, signaling a promising future for e-commerce. This growth is attributed to technological advancements, regulatory policies and compliance, consumer demand, and the United Nation SDGs. This review identified key themes on existing research: sustainability, optimisation and vehicle routing, consumer behaviour, technological innovations, urban mobility, and freight transportation. The themes collectively contribute to the competitive advantage of e-commerce businesses by enhancing sales, delivery efficiency, and reduced emissions.

- Despite considerable attention being given to sustainability, current research has not fully examined the social aspect. For instance, regulatory and policy frameworks are necessary for promoting the widespread uptake of green innovations in last mile delivery. Future research should investigate regulatory interventions required to increase the uptake of green innovations, such as autonomous and electric delivery vehicles. It was also noted that renewable energy sources are underexplored in current research. Future research can explore regulatory interventions to enhance the adoption of renewable energy to power autonomous and electric vehicles in last mile delivery.
- Current research has focused on tangible technologies such as electric vehicles, drones,

and unmanned vehicles. Intangible technologies such as algorithmic advancements are not widely researched, e.g., addressing real-world implementation challenges, such as infrastructure limitations, regulatory barriers, and cost feasibility. Future research should focus on the practical application of intangible technologies such as AI-driven routing in real-world logistics networks. Most studies focus on technological innovations like autonomous vehicles and drones and their contribution to environmental effects. These studies fail to address scalability, regulatory challenges, and social acceptance. Future research should focus on regulatory and legal challenges in different regions and investigate cybersecurity threats in AI-powered last mile delivery. In addition, future research can explore the role of AI in optimising energy consumption by delivery vehicles and reducing carbon emissions in last mile delivery.

- While existing research has examined consumer preferences, there is a limited understanding of how behavioural nudges and incentives can drive consumer acceptance of green innovations. Future studies should investigate consumer willingness to pay for sustainable delivery and assess the impact of incentives and regulations on green last mile delivery adoption. In addition, future research should focus on customer demand for emerging technologies like unmanned and electric vehicles.

- Most studies have examined freight transportation in urban areas. There is limited research that combines urban design, transportation engineering, and environmental science to develop comprehensive green innovations for last mile delivery. Future research should focus on integrating urban freight planning, assessing how smart city technologies can improve last mile delivery, and analysing the effects of regulations on their efficiency.

This review provides a comprehensive framework for analysing green innovations in last mile delivery by identifying five key themes: consumer behavior, technological innovations, sustainability, optimisation and vehicle routing, and urban mobility. Unlike current research that treats these elements separately, this review provides an integrated perspective, showing how green innovations can optimise delivery networks, reduce urban congestion, and support environmental goals. The integrated framework helps e-commerce managers and policymakers comprehensively clarify the meaning of green innovations in last mile delivery. Dane et al. (2019) highlight that the overlap between the four types of innovation is clear, and the contribution of each concept is less distinctive. This review indicates that green innovations improve delivery efficiency, reduce emissions, and increase sales, thus contributing to the competitive advantage of e-commerce businesses. Sustainability is a dominant theme in existing research. However, there is a theoretical gap in understanding how regulatory and policy frameworks influence the adoption of green innovations in last mile delivery. This study emphasises the need for interdisciplinary research integrating policy into green innovations in last mile delivery. Logistics firms and policymakers should collaborate to develop standardised policies and provide incentives for adopting green innovations and legal frameworks that facilitate innovation in last mile delivery.

This word analysis has limitations. First, the word analysis was based on specific keywords outlined in Section 3 (i.e., methodology). Even though these keywords are relevant, green innovation is a dynamic topic. Future studies should incorporate emerging terms to ensure a more comprehensive word analysis on the topic. Secondly, this word analysis utilised publications extracted from the Scopus database. Even though the Scopus database is reputable, some niche studies might have been missed. Future studies should consider other databases like Science Direct and Web of Science to have a more comprehensive word analysis on this topic.

References:

Albort-Morant, G., Henseler, J., Leal-Millán, A. & Cepeda-Carrión, G. (2017). Mapping the field: A bibliometric analysis of green innovation. *Sustainability*, 9 (6), 1011. DOI: 10.3390/su9061011

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. DOI: 10.1162/qss_a_00019

Bonilla, M. A. M., Bouzon, M., & Peña-Montoya, C. C. (2024). Taxonomy of key practices for a sustainable last mile logistics network in e-Retail: A comprehensive literature review. *Cleaner Logistics and Supply Chain*, 100149. DOI: 10.1016/j.clscn.2024.100149

Boysen, N., Fedtke, S. & Schwerdfeger, S. (2021). Last mile delivery concepts: A survey from an operational research perspective. *OR Spectrum*, 43(1), 1-58. DOI: 10.1007/s00291-020-00607-8

Dane, A., Wright, D. & Montmasson-Clair, G. (2019). Exploring the policy impacts of a transition to electric vehicles in South Africa. *Pretoria: Trade & Industrial Policy Strategies*.

Degler, T., Agarwal, N., Nylund, P. A. & Brem, A. (2021). Sustainable innovation types: A bibliometric review. *International Journal of Innovation Management*, 25(09), 2150096. DOI: 10.1142/S1363919621500961

Demir, B., Akdemir, M. A., Kara, A. U., Sagbas, M., Sahin, Y., & Topcuoglu, E. (2025). The mediating role of green innovation and environmental performance in the effect of green transformational leadership on sustainable competitive advantage. *Sustainability*, 17(4), 1407. DOI: 10.3390/su17041407

Dhanush, N., V., & Nanjundeswarswamy, T., S. (2025). Dynamics of electric vehicle adoption: A comprehensive analysis of consumer preferences. *Journal of Innovations in Business and Industry.* 3(1). DOI: 10.61552/JIBI.2025.01.008

eMarketer. (2023). *Worldwide ecommerce forecast 2023.* Accessed 02 March 2025, from https://www.emarketer.com/content/worldwide-ecommerce-forecast-2023

Engelhardt, M. (2023). Who is willing-to-pay for sustainable last mile innovations? *Transportation Research Procedia*, 69, 910-917. DOI: 10.1016/j.trpro.2023.02.252

Franceschini, S., Faria, L. G. & Jurowetzki, R. (2016). Unveiling scientific communities about sustainability and innovation. A bibliometric journey around sustainable terms. *Journal of Cleaner Production*, 127, 72-83. DOI: 10.1016/j.jclepro.2016.03.142

Ha, N. T., Akbari, M. & Au, B. (2023). Last mile delivery in logistics and supply chain management: A bibliometric analysis and future directions. *Benchmarking: An International Journal*, 30(4), 1137-1170. DOI: 10.1108/BIJ-07-2021-0409

Hongfei, Y. 2017. *National report on development of e-commerce in China.* Accessed 11 July 2024, from https://www.unido.org/sites/default/files/2017-10/WP_17_2017.pdf

Kader, M. S., Rashaduzzaman, M., Huang, X. & Kim, S. (2023). Influencing factors toward e-shoppers' adoption of green last mile delivery. *International Journal of Retail & Distribution Management*, 51(2), 220-237. DOI: 10.1108/IJRDM-10-2021-0480

Kumar, S., Dubey, M., Mehdi, H., Kalla, S., & Krishanan, R. (2023). A study of industry 4.0 for circular economy and sustainable development goals in the environment of VUCA. *Journal of Innovations in Business and Industry.* 3(1). DOI: 10.61552/JIBI.2024.02.005

Mogire, E., Kilbourn, P.J. & Luke, R. (2022). The last mile delivery problem: A Kenyan retail perspective. *Acta Logistica (AL)*, 9(4). DOI: 10.22306/al.v9i4.329

Mogire, E., Kilbourn, P.J. & Luke, R. (2023). Customer satisfaction with last mile delivery in Kenya: An online customer perspective. *Journal of Transport and Supply Chain Management,* 17(1), e1-e8. DOI: 10.4102/jtscm.v17i0.844

Mogire, E., Kilbourn, P.J. & Luke, R. (2024a). A comparative analysis of last mile delivery in Ken-ya's online retail subsector. *The Retail and Marketing Review*, 20(1), 12-30. DOI: 10.5281/zenodo.11612249

Mogire, E., Kilbourn, P., & Luke, R. (2024b). *Green innovations in last mile delivery for e-commerce: A bibliometric review.* [Conference presentation]. The 17th International Business Conference (IBC), Stellenbosch, South Africa.

Mogire, E., Kilbourn, P., & Luke, R. (2025). Electric vehicles in last-mile delivery: A bibliometric review. *World Electric Vehicle Journal*, 16(1), 52. DOI: 10.3390/wevj16010052

Mohammad, W. A., Nazih Diab, Y., Elomri, A. & Triki, C. (2023). Innovative solutions in last mile delivery: Concepts, practices, challenges, and future directions. *Supply Chain Forum,* 24(2), 151-169. DOI: 10.1080/16258312.2023.2173488

Mucowska, M. (2021). Trends of environmentally sustainable solutions of urban last mile deliveries on the e-commerce market: a literature review. *Sustainability*, 13 (11), 5894. DOI: 10.3390/su13115894

Olsson, J., Hellström, D & Pålsson, H. (2019). Framework of last mile logistics research: A systematic review of the literature. *Sustainability*, 11(24), 7131. DOI: 10.3390/su11247131

Patella, S. M., Grazieschi, G., Gatta, V., Marcucci, E., & Carrese, S. (2020). The adoption of green vehicles in last mile logistics: A systematic review. *Sustainability*, 13(1), 6. DOI: 10.3390/su13010006

Ranieri, L., Digiesi, S., Silvestri, B., & Roccotelli, M. (2018). A review of last mile logistics innovations in an externalities cost reduction vision. *Sustainability*, 10(3), 782. DOI: 10.3390/su10030782

Schnieder, M. (2024). Visualising carrier consolidation and alternative delivery locations: A digital model of last-mile delivery in England and Wales. *Logistics*, 8(3), 77. DOI: 10.3390/logistics8030077

Silva, V., Amaral, A., & Fontes, T. (2023). Sustainable urban last mile logistics: A systematic literature review. *Sustainability*, 15(3), 2285. DOI: 10.3390/su15032285

Sorooshian, S., Khademi Sharifabad, S., Parsaee, M. & Afshari, A. R. (2022). Toward a modern last mile delivery: Consequences and obstacles of intelligent technology. *Applied System Innovation,* 5(4), 82. DOI: 10.3390/asi5040082

Tohidi, H., & Jabbari, M. M. (2012). The important of innovation and its crucial role in growth, survival and success of organizations. *Procedia technology*, 1, 535-538. DOI: 10.1016/j.protcy.2012.02.116

Toraman, Y., Bayirli, M. & Ramadani, V. (2023). New technologies in small business models: Use of electric vehicles in last-mile delivery for fast-moving consumer goods. *Journal of Small Business and Enterprise Development*, 31(3), 515-531. DOI: 10.1108/JSBED-08-2023-0375

World Economic Forum. (2020). *The future of the last mile ecosystem.* Accessed 02 July 2024, from https://www.weforum.org/publications/the-future-of-the-last-mile-ecosystem/

Zandi, G., Torabi, R., Mohammad, M.A. & Dan, X.Y. 2021. Customer's satisfaction via online shopping environment: The case of China. *Journal of Information Technology Management,* 13(3), 16-32. DOI: 10.22059/jitm.2021.83110

Eric Mogire
Department of Transport and
Supply Chain Management,
University of Johannesburg,
South Africa.
emogire@uj.ac.za
ORCID: 0000-0002-1477-2568