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Bibliometric Insights into AI and ML Applications in Last-Mile Delivery Optimisation

Dr. Rubel Amin[1*], Md. Abdul Hannan[2]
[1]School of Business, Woxsen University, Kamkole, Sadasivpet, Sangareddy District, Hyderabad, India.
[2]Bangladesh Commerce Bank LTD., Dhaka, Bangladesh

Abstract

The integration of artificial intelligence (AI) and machine learning (ML) technologies has transformed last-mile delivery optimization, driven by the exponential growth of the global e-commerce market. This study employs a Systematic Literature Review (SLR) combined with a Bibliometric Analysis Approach to explore existing research on AI and ML applications in last-mile delivery. Using targeted keywords such as "last mile," "machine learning," and "artificial intelligence," 81 research articles were screened and analyzed with bibliometric techniques, including co-occurrence and co-citation author analysis, to identify key themes, trends, and collaborative networks among researchers. Findings highlight significant thematic clusters, including advancements in last-mile delivery strategies, digital transformation, and the impact of external factors like the COVID-19 pandemic on logistics operations. The study reveals the chronological evolution of publication trends and identifies critical research gaps, such as comparative studies on vehicle capacity optimization, machine learning for dynamic routing, and AI-based systems to improve first-time delivery success rates. Additionally, it provides solutions for last-mile delivery challenges through AI/ML-driven quantitative techniques, offering practical implications for enhancing delivery efficiency and environmental sustainability. By presenting a comprehensive framework through bibliometric and thematic analyses, this research contributes to the understanding of AI and ML's role in addressing last-mile logistics complexities. It underscores the importance of these technologies for operational efficiency, emphasizing their potential to meet consumer demands, optimize transportation systems, and advance sustainability goals within the evolving logistics and transportation landscape.

Keywords: Artificial intelligence, logistics operations, COVID-19 pandemic, sustainability

1. Introduction

Delivering products from the nearest hub to the customer or the concerned delivery location is called last-mile delivery or the final leg of the delivery process. Efficient last-mile logistics saves time and money by optimizing routes and rates and allows businesses to expand their reach more aggressively. @https://porter.in/blog. In recent years, the tools for improving decision making have diversified statistical instruments and data science are used (Vicario & Coleman, 2020). Another Methodology for problem solving and decision making is formulating through Optimization. This work applies tools for the Road transport industry to improve logistics last mile management (Gutierrez-Franco et al., 2021). In the fast-paced world of e-commerce and supply chain management, the optimization of last-mile delivery has emerged as a critical area of focus (Sorooshian et al., 2022). As online shopping continues to surge, businesses are increasingly challenged to fulfill customer orders efficiently while minimizing costs and environmental impact (Duman et al., 2023). In this context, the integration of artificial intelligence (AI) has shown promising potential to revolutionize last-mile delivery operations. The last-mile delivery phase represents the final leg of the supply chain, wherein goods are transported from distribution centers to the end consumer's doorstep (Singh et al., 2023). Despite its short geographical distance, last-mile delivery accounts for a significant portion of the total logistics costs, often exceeding 50% (Silva et al., 2023). According to industry reports, inefficient last-mile logistics contribute to congestion, pollution, and increased carbon emissions, posing sustainability challenges for urban environments. Moreover, with the rising expectations of consumers for fast and reliable delivery services, businesses are under immense pressure to optimize their last-mile operations (Abdollahi et al., 2023).

The Transport industry changed and grown recently, evolution of E-Commerce and growth in a last 5 years. This paper proposes a solution for the problem of deliveries for a Distribution center by using quantitative technique using AI/ML tools to deal with last mile operations. For Industries, Last Mile directly impacts customer satisfaction, competition, cost efficiency, inventory management, and sustainability (Abouelrous et al., 2023). The global last mile delivery market size was valued at USD 132.71 billion in 2022 and is expected to grow at a compound annual growth rate (CAGR) of 8.8https://www.grandviewresearch.com industry-analysis The global last-mile delivery market should grow at a CAGR of 20.6 percent between 2022 and 2030, reaching a value of 121.1billionby2030.Predictive analytics and AI– powered routing, blockchain and smart contracts, and robotics and automation should drive growth in the last–mile delivery market in the coming years.

Numerous research endeavors have explored various facets of last-mile delivery optimization, employing a range of methodologies including mathematical modeling, simulation, and heuristic algorithms (AlNuaimi, et al., 2023). Traditional approaches have focused on route optimization, vehicle scheduling, and delivery assignment strategies to streamline operations and reduce delivery times and costs. Historically, research in this field has predominantly relied on deterministic models and heuristic algorithms to address the complexities of last-mile logistics. These approaches, while effective to a certain extent, often fail to adapt to dynamic real-world conditions, leading to suboptimal solutions and inefficiencies (Aurambout et al., 2019). Recent advancements in AI technologies, particularly machine learning and optimization algorithms, have spurred a paradigm shift in last-mile delivery research. By harnessing the power of AI, researchers have begun to explore more adaptive and data-driven approaches to optimize delivery routes, predict demand patterns, and enhance resource allocation (Bastarianto et al., 2023). Furthermore, the integration of real-time data sources, such as GPS tracking, weather forecasts, and traffic updates, has enabled researchers to develop dynamic decision-making frameworks that can adapt to unforeseen disruptions and optimize delivery operations in real-time (Bechtsis, et al., 2022).

Last mile is important for industries to reach their Product to End user/Customers. Where enormous efforts taken by supply chain team and Operations. Transportation of goods to customer location with support of Rail, Road and Airways for quick delivery for generating income (Belvedere et al., 2021). To generate profitable income industry, take help of Operations with technology & new techniques where employment is increased. Experience team molding with new technology to give Impact (Bernal et al., 2018). The global last mile delivery market size was valued at USD 132.71 billion in 2022 and is expected to grow at a compound annual growth rate (CAGR) of 8.8. @https://www.grandviewresearch.com industry-analysis. Last mile accounts for more than 45-50% of overall shipping costs and in entire supply chain cost. Benefits – For businesses to optimize costs with excellent delivery to customer.https://www.dispatchtrack.com/blog/last-mile-delivery-costs-breakdown.

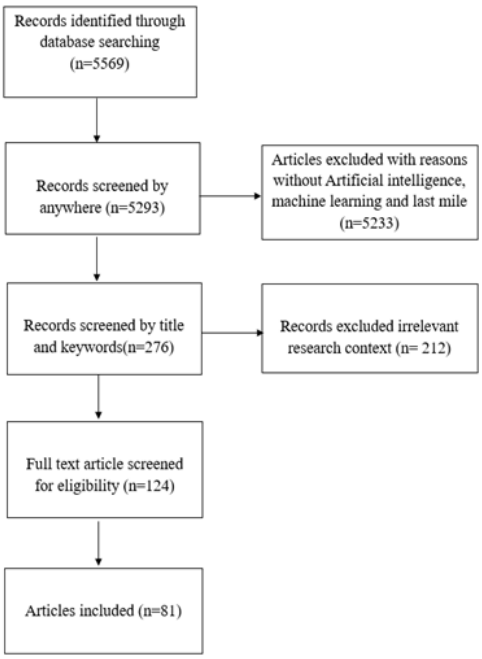
Despite the progress made in last-mile delivery optimization, several gaps and limitations persist, underscoring the need for further research. One of the primary challenges lies in the dynamic nature of urban environments, characterized by fluctuating traffic conditions, varying customer preferences, and evolving delivery demands (Boysen et al., 2021). Traditional optimization techniques often struggle to accommodate such uncertainties, leading to suboptimal solutions and increased operational costs. Moreover, existing research predominantly focuses on operational efficiency metrics such as cost minimization and delivery time optimization, overlooking other important considerations such as environmental sustainability and customer experience (Bray & Cebon, 2022). As sustainability becomes an increasingly prominent concern for businesses and

policymakers alike, there is a growing need to develop holistic delivery optimization frameworks that balance economic efficiency with environmental responsibility (Broekhuizen, et al., 2021). This research aims to address these gaps by leveraging AI-driven optimization techniques to enhance the sustainability and efficiency of last-mile delivery operations through a bibliometric analysis. Bibliometrics, a methodology utilizing statistical and mathematical techniques to analyze patterns and trends in written works, provides a robust framework for exploring the dissemination and reception of scholarly information. By employing bibliometric techniques, this study seeks to uncover the main themes, influential authors, seminal works, and evolving trends related to AI and ML driven last mile delivery.By utilizing bibliometric tools like citation analysis, co-citation analysis, and keyword analysis, this research offers valuable insights into the structure and dynamics of scholarly discussions about AI and ML driven last mile delivery (Bui & Binh, 2016). Furthermore, it aims to delineate emerging research trajectories and highlight areas for further exploration within AI driven last mile delivery. Essentially, this study thoroughly examines the quantitative aspects of the impact AI and ML have in last mile delivery research. By identifying patterns and trends in existing literature, this study enhances our comprehension of how AI and ML services are evolving, performance and influencing in last mile delivery.

2. Literature Review

We identified relevant literature through searched and selected academic articles/ review papers and published with keyword "last mile" "machine learning" "artificial intelligence" 'machine learning in last mile in ecommerce', artificial intelligence in last mile and machine learning in last mile. From the searched articles, extracted eligible and brought out findings also future scope. Presented in Fig 1 – is the number of papers screened and excluded at each stage & selection process - SLR - Systematic Literature Review. Identification of Literature with keywords and brought out the literature selection from previous studies of researchers such as Literature reviews and research articles. Our search strings are keyword "last mile" "machine learning" "artificial intelligence" ‘machine learning in last mile in ecommerce', artificial intelligence in last mile and machine learning in last mile.

To ensure comprehensiveness academic data bases were used – Scopes, IEEE, ScienceDirect, Taylor and Francis and Business source from web. Articles were obtained using above keywords - published papers. A total of 5569 articles were screened in Springer (n = 5135), IEEE (n= 46), ScienceDirect(n=66), Taylor & Francis (n=322). After eliminating duplicates and non-full text, record articles in aligned with the research context but belonged to other disciplines without Artificial intelligence, last mile and ecommerce were discarded due those were outside the scope of this study. The screened process yields 276 research articles. The foregoing eligibility process led 81 articles. work that cited in 81 papers was also examined Systematic.



Descriptive Analysis Presented in Figure 1 is the number of journal articles published annually on Last Mile with AI/ML. The first publication on this topic was published in 2016. Subsequently, the relevant literature has grown rapidly since 2019. In year 2021 -2023 there were high (72%) number of articles were published. Our descriptive analysis thus revealed that research on Last mile delivery using AI/ML apparently is at a nascent stage but demonstrates a growing trend.

3. Research Methodology

This study explores advancements in the domain of AI and ML, mainly focusing on their role in last mile delivery. To achieve this goal, the researchers performed a bibliometric analysis, a frequently employed technique for visually representing the conceptual terrain of a particular research field (Caunhye & Alem, 2023). The study began by conducting a Systematic Literature Review (SLR) to gather pertinent literature, pinpoint keywords, and search terms, and choose relevant articles according to predetermined standards (Butarbutar et al., 2023). Furthermore, the study employed bibliometric techniques to examine the literature, revealing crucial findings about the temporal trends of noteworthy publications, renowned writers, articles, and important research (Cheng & Zhang, 2023; Sallan & Lordan, 2023; Salam& Senin, 2022). And using these approaches, the study seeks to illuminate the changing terrain of AI and ML and their importance in administration, offering a thorough grasp of the topic.

4. Findings

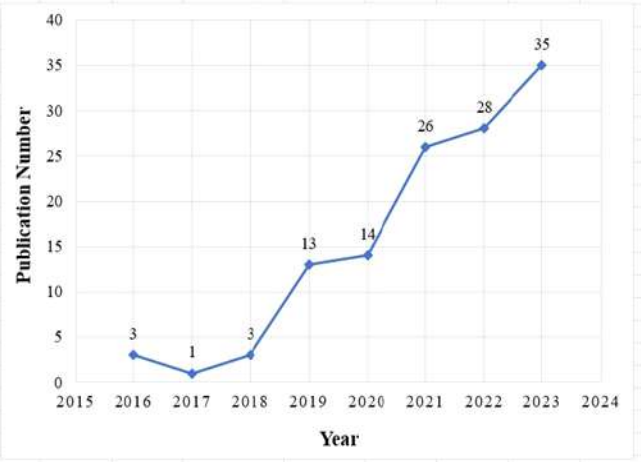


Figure 2 Articles Published per year. (Author own depiction)

The VOS viewer software is able to use as inputs a list of papers, its algorithm performs word mining of the keywords included by the authors and automatically assigned by the indexing database with a procedure called "co-occurrence" (Klarin, 2024). For first analysis a unit only with the authors keyword and set the minimum number of occurrences of a keyword to four. From the 153 keywords, only 9 met the minimum threshold. The Resulting words were last-mile delivery, last mile delivery, vehicle routing, city logistics, digital transformation, logistics, optimization, Routing, and Transportation with Machine learning. To create a keyword network, the software computes for each keyword the total link strength, i.e., the no. of publications in which two keywords occur together. The result of the co-occurrence analysis is reported in table 1.

Table 1: Keywords Occurrences and Link Strength (Author own depiction)

ID	Keyword	Occurrences	Total Link strength
151	last-mile delivery	11	51
148	last mile delivery	6	29
290	vehicle routing	5	17
51	city logistics	4	17
88	digital transformation	4	19
164	Logistics	4	18
190	Optimization	4	26
229	Routing	4	24
270	Transportation	4	25
61	covid-19	3	16
98	drone delivery	3	13
102	Drones	3	22
112	electronic commerce	3	22

The result of the co-occurrence analysis allows the performance of some considerations. The item last-mile delivery and last mile delivery, which is just added with hyphen symbol. These two keywords, a total link strength equal to 51 and 29, this is probably due to be presence of the most articles and review are worked on these keywords.

Thematic Framework of AI and ML research in last mile delivery.

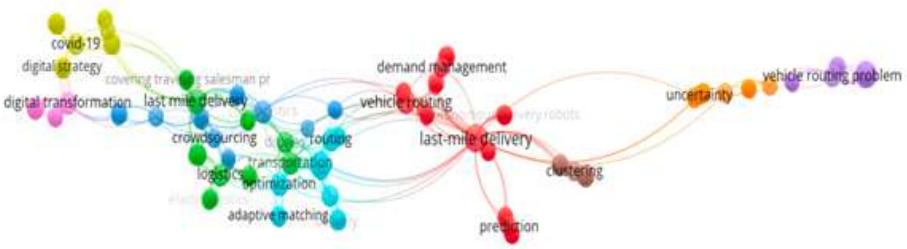


Figure 3 Co-occurrence of 153 keywords (Author own depiction)

Figure 3 illustrates various clusters that display instances of each keyword used by the authors regarding the specified subject.

Cluster 1- Advancing Last Mile Delivery, demand management, vehicle routing and prediction

The initial cluster comprised 12 elements depicted in red, all on Last Mile Delivery, demand management, vehicle routing and prediction. This cluster delves into the robust correlation between AI and ML and its pivotal function in Last Mile Delivery, demand management, vehicle routing and prediction.

Cluster 2-Revolutionizing Last mile delivery, Transportation and Logistics.

This set consists of nine components marked in green, emphasizing the importance of Last mile delivery, Transportation and Logistics in both AI, machine learning with a particular emphasis on last mile delivery.

Cluster 3- last mile delivery, crowdsourcing and logistics

This cluster encompasses nine blue-colored elements associated with last mile delivery, including crowdsourcing and logistics.

Cluster 4-Routing, Transportation, Optimization and Adaptive Matching

This cluster involves six elements related to Routing, Transportation, Optimization and Adaptive Matching, highlighted in light blue. These innovative leadership strategies have a significant impact on AI, ML research in last mile delivery.

Cluster 5- Digital Strategy and Covid19

This group consists of six items marked in yellow. It covers areas such as Digital Strategy and Covid19. The main emphasis of this cluster is on Digital Strategy for last mile delivery.

Cluster 6- Vehicle, Routing and Problem

This cluster involves five items highlighted in purple, all associated with last mile delivery. It includes Vehicle, Routing and Problem. This cluster's primary focus is vehicle and finding the best rout and identifying the problems.

Cluster 7- Vehicle, Routing and Problem

This cluster involves five items highlighted in orange, all associated with last mile delivery. This cluster has focused on uncertainty.

Cluster 8- Digital Transformation

This cluster involves three items highlighted in rose, all associated with last mile delivery. This cluster has focused on digital transformation.

Cluster 9- Digital Transformation

This cluster involves three items highlighted in brown, all associated with last mile delivery. This cluster has focused on clustering.

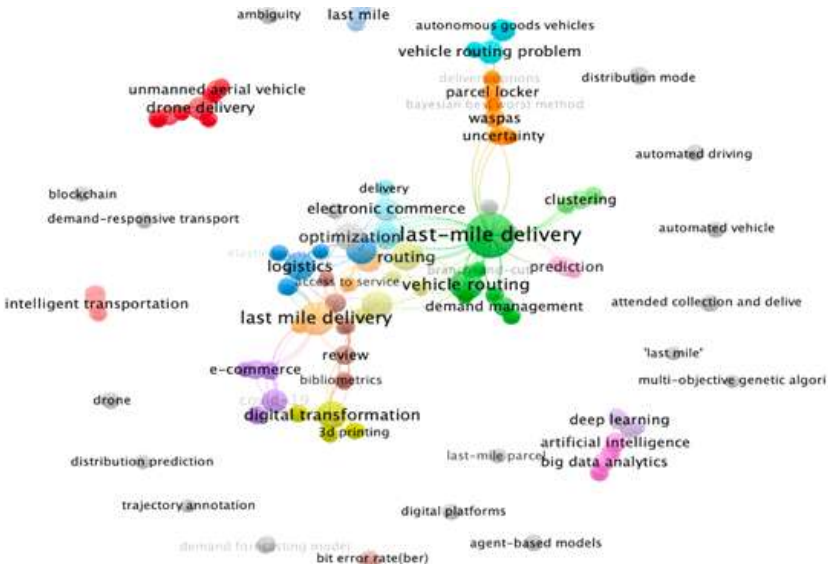


Figure 4: Co-occurrence of 297 keywords (Author own depiction)

The software also allows the performance of a co-authorship analysis. For this analysis, we included the authors who wrote at least two of the documents in the network and were cited at least twice; of the 385 authors, 6 met the threshold. Only three authors have Link strength and documents above two within the network. Figure 5. Co authorship network (VOS viewer).

Bibliometric Analysis Approach. We undergo bibliometric analysis in several steps. Descriptive analysis was conducted to determine the status of publications over time. Relational techniques were used to investigate connections between study disciplines, the formation of new research subjects and methods and patterns of co -citation (Kpsepglu et al., 2016). Analyses were performed using the VOS viewer software. Thematic Analysis Approach. A thematic analysis was conducted based on the summary of bibliometric analysis findings. We searched to obtain structured insights gaps and research directions.

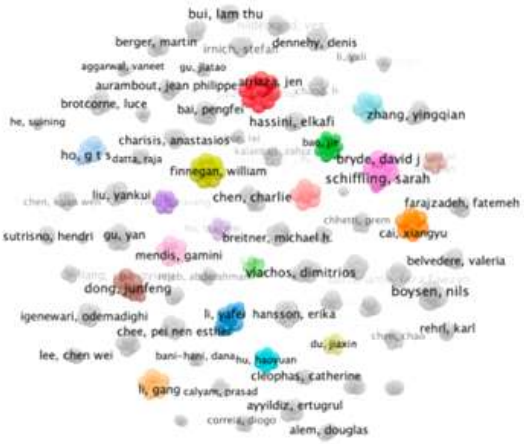


Figure 5: Co-citation Authors (Author own depiction)

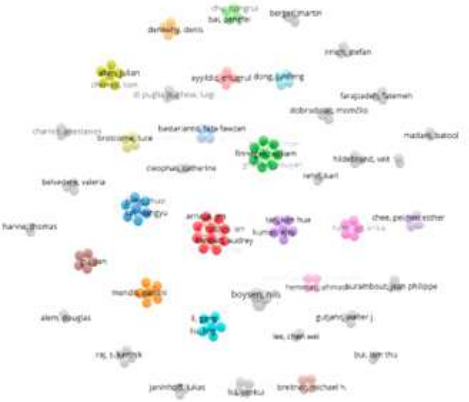


Figure 6 Co-citation Authors Zoom (Author own depiction)

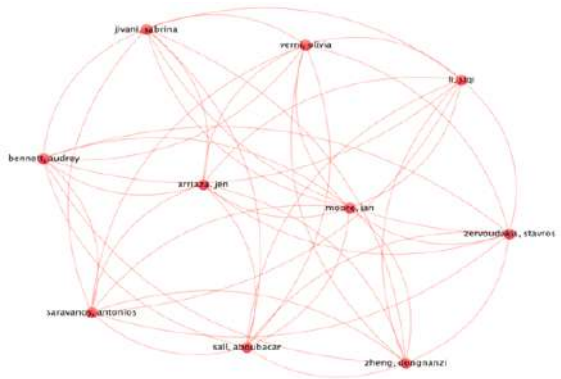


Figure 7 Co-citation of 10 connected Authors Pattern. (Author own depiction)

Two selected Publications cite the set of same authors, these authors were viewed as co-cited. If a greater number of articles to which a set of authors is jointly referred, the stronger is the co-citation relationship between them. Consequently, the closer view displayed in network -Figure 5 and Figure 6 with zoom view of Authors co-citation. The authors chosen for analysis were cited at least 6 times. As a result, 10 authors were identified and classified into group shown in Figure 7 is the co-citation network map that reveals top 10 authors networks. Authors in red cluster establish the last mile theory and developed last-mile delivery research frameworks.

5. Discussion

The integration of artificial intelligence (AI) and machine learning (ML) techniques in optimizing last-mile delivery represents a significant leap in logistics and transportation. This paper presents a comprehensive analysis facilitated by the VOS viewer software, combining bibliometric and thematic

Utilizing the VOS viewer software, our analysis delves into bibliometric trends and thematic patterns, unveiling the pivotal role of AI and ML in last-mile delivery optimization. Co-occurrence analysis identifies dominant themes such as last-mile delivery, vehicle routing, and digital transformation, underscoring their scholarly significance. Furthermore, clustering of keywords reveals distinct thematic clusters, encompassing areas from demand management to digital strategies and the impact of external factors like COVID-19.

Co-authorship analysis exposes collaborative networks among researchers, highlighting influential authors shaping discourse and theory development. Visualization of co-authorship networks aids in understanding collaborative dynamics and expertise distribution within the research community, emphasizing the importance of interdisciplinary collaboration in advancing last-mile delivery optimization.

Bibliometric analysis offers a chronological overview of publication trends, tracing the evolution of research topics and methodologies over time. This historical perspective is crucial for identifying emerging trends and gaps in the literature, providing a solid foundation for future research agendas.

Thematic analysis synthesizes findings from bibliometric insights, enabling the identification of research gaps and future directions. By structuring insights gleaned from bibliometric data, researchers can develop informed strategies to address critical challenges in last-mile delivery optimization, paving the way for innovative solutions in the field.

The combination of bibliometric and thematic analysis provides a comprehensive framework for understanding the current state of research, identifying key stakeholders, and delineating future research agendas in AI and ML-driven optimization of last-mile delivery. This holistic approach contributes to advancing knowledge and innovation in the field, ultimately enhancing the efficiency and sustainability of last-mile logistics operations.

6. Academic Implications

The evolving landscape of last-mile delivery operations demands a new generation equipped with built-in technological solutions. Analytics tools are essential for understanding day-to-day operations, enhancing productivity, and streamlining processes. Qualitative techniques and strategic methodologies play a crucial role in addressing the complexities of last-mile operations. Given the increasing importance of efficient and sustainable delivery systems, there is ample scope for academic exploration. The integration of AI and ML in optimizing last-mile delivery is a focal point of research, as highlighted by bibliometric and thematic analyses. Utilizing tools like the VOS viewer software enables a comprehensive examination of research trends and author relationships. Insights from co-occurrence analysis underscore the significance of key themes in current literature. Co-authorship analysis reveals collaborative networks, while bibliometric analysis provides a chronological overview of publication trends. Thematic analysis aids in identifying research gaps and future directions. This framework empowers academia to harness technology and qualitative techniques, fostering advancements in last-mile logistics and addressing emerging challenges effectively.

7. Practical Implications

The fusion of AI and ML into last-mile delivery presents tangible opportunities for improving operational efficiency and environmental sustainability. Implementation of AI/ML technologies, including drones, delivery robots, and zero-emission vehicles, can significantly reduce carbon footprint while optimizing delivery routes amidst economic pressures from high fuel rates. This

integration offers a dual benefit of financial and environmental sustainability through integrated transportation solutions. Collaborative efforts between public and private sectors are vital for the successful deployment of sustainable transportation initiatives. New strategies must be devised to facilitate the adoption of these technologies. The accelerated growth of online shopping, particularly in response to pandemic-related challenges, underscores the urgency for innovative delivery solutions to meet evolving consumer demands. Comprehensive understanding of cost dynamics, encompassing delivery modalities, geographic considerations, and fleet expenses, is essential for refining last-mile delivery services and ensuring their long-term economic viability.

8. Conclusion

The research conducted through a Systematic Literature Review (SLR) with a Bibliometric Analysis Approach has been instrumental in identifying and analyzing relevant literature using keywords from previous studies, including literature reviews and research articles. By employing relational techniques, connections between study disciplines, the emergence of new research subjects, and patterns of co-citation were investigated, drawing insights from the work of Kpsepglu et al. (2016). Utilizing the VOS viewer software, comprehensive analyses were conducted, encompassing co-citation authors and the co-occurrence of 153 keywords.

The integration of AI and ML techniques in optimizing last-mile delivery marks a significant leap forward in the fields of logistics and transportation. Through thorough bibliometric and thematic approaches, critical insights and research directions have been illuminated. Key themes such as last-mile delivery, vehicle routing, and optimization were identified through co-occurrence analysis, highlighting their significance in scholarly discourse. Moreover, clustering of keywords unveiled distinct thematic clusters, elucidating various facets of last-mile logistics, ranging from demand management to digital transformation.

Co-authorship analysis provided valuable insights into collaborative networks among researchers, spotlighting pivotal contributors to the field. Bibliometric analysis offered a chronological overview of publication trends, essential for discerning emerging trends and literature gaps. Thematic analysis synthesized findings, facilitating the identification of research gaps and future directions. This comprehensive framework enhances understanding of the current research landscape, identifies key stakeholders, and delineates future research agendas in AI and ML-driven last-mile delivery optimization. Through rigorous analysis and strategic insights, this research paves the way for advancements in logistics and transportation, ultimately improving last-mile delivery efficiency and effectiveness.

9. Limitations

The effectiveness of bibliometric and thematic analyses heavily relies on the quality and availability of data. Incomplete or inaccurate datasets may lead to biased results and hinder the identification of comprehensive insights.

While the analyses provide valuable insights into the current state of research, they may not encompass all relevant literature due to scope limitations. Certain niche areas or recent developments may not be adequately represented, potentially overlooking emerging trends or critical research gaps.

The use of AI and ML algorithms in bibliometric analysis may be subject to certain constraints or biases inherent in the algorithms themselves. Misinterpretation of data or oversimplification of complex relationships could impact the accuracy of findings.

Despite rigorous analysis, the interpretation of results remains subjective and prone to individual biases. Different researchers may interpret findings differently, leading to discrepancies in conclusions drawn from the same dataset.

Findings derived from bibliometric and thematic analyses may not be universally applicable across all contexts or industries. Factors such as regional variations, industry-specific nuances, and evolving technological landscapes could limit the generalizability of results.

The dynamic nature of research fields like last-mile delivery means that findings may become outdated over time. Rapid advancements in technology and evolving research trends may render certain insights obsolete or necessitate continuous updates to maintain relevance.

Addressing these limitations requires ongoing refinement of methodologies, improved data quality assurance measures, and careful consideration of contextual factors to ensure the robustness and applicability of findings in advancing last-mile delivery optimization research.

10. Future Research Directions

Future research in the optimization of last-mile delivery should focus on several key areas to advance the field. Firstly, exploring innovative AI and ML algorithms tailored specifically for last-mile logistics could enhance efficiency and address unique challenges. Additionally, investigating the integration of emerging technologies like drones, delivery robots, and zero-emission vehicles into last-mile operations holds promise for enhancing sustainability and reducing environmental impact.

Furthermore, there is a need for in-depth studies on the implications of public-private partnerships in sustainable transportation, particularly concerning policy frameworks and

implementation strategies. Understanding the cost characteristics of last-mile delivery services, including factors such as delivery type and geographical considerations, is crucial for devising cost-effective strategies and optimizing fleet management.

Academically, there is an opportunity to delve deeper into the qualitative techniques and strategic methodologies required to address the complexities of last-mile operations. Exploring interdisciplinary approaches that integrate technology seamlessly into daily operations can lead to improved productivity and streamlined logistics processes.

Overall, future research endeavors should aim to bridge the gap between academic insights and practical applications, driving innovation and sustainability in last-mile delivery optimization. By addressing these research directions, scholars can contribute significantly to the advancement of logistics and transportation systems, ultimately benefiting both academia and industry stakeholders.

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