ADVANCEMENTS IN URBAN FREIGHT TRANSPORT: A COMPREHENSIVE LITERATURE REVIEW ON ELECTRIC VEHICLES

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ABSTRACT

This paper aims to analyze the behavior of electric vehicles in urban last-mile freight transportation and identify the main trends for the upcoming years. The methodology employed in this study is a systematic review with a bibliometric approach, using the Web of Science database. The main finding reveals that the topic of electric vehicles is of great interest and significance in Europe, the United States, and the BRICS countries (Brazil, Russia, India and China - except South Africa), which have been promoting the use of vehicles with low or zero CO2 emissions. This finding emphasizes the need to explore these concepts further in order to pursue sustainable actions.

Keywords: Freight transport, Last mile, Vehicle electric.

RESUMEN

Este trabajo tiene como objetivo analizar el comportamiento de los vehículos eléctricos en el transporte urbano de mercancías de última milla e identificar las principales tendencias para los próximos años. La metodología empleada en este estudio es una revisión sistemática con un enfoque bibliométrico, utilizando la base de datos Web of Science. El principal hallazgo revela que el tema de los vehículos eléctricos es de gran interés y relevancia en Europa, Estados Unidos y los países BRICS (Brasil, Rusia, India y China - excepto Sudáfrica), que han estado promoviendo el uso de vehículos con bajas o nulas emisiones de CO2. Esta constatación subraya la necesidad de profundizar en estos conceptos para llevar a cabo acciones sostenibles.

Palabras clave: Transporte de mercancías, Última milla, Vehículo eléctrico.

1. INTRODUCTION

Environmental changes and accelerated technological progress are central aspects of the contemporary global economic scenario (De Assis et al., 2022c). New technologies can increase production efficiency and reduce resource consumption, and this dynamic is particularly relevant for the automotive sector, as it is one of the sectors that invests the most in research and development, but also contributes a significant portion to greenhouse gas emissions - GHG (Santos et al., 2021; De Assis et al., 2022b; De Abreu et al., 2022).

Companies from various sectors are trying to find environmentally sustainable solutions to minimize environmental impacts caused by their activities, therefore, currently, diesel commercial vehicle manufacturers around the world are on a technological journey to replace diesel with other energy sources, especially by electricity (De Assis et al., 2022a). The industry's focus was given to electric mobility, seen today as the most suitable solutions to mainly eliminate carbon dioxide (CO2) and carbon monoxide (CO) emissions (De Abreu et al., 2023). Even with all the efforts made by the automobile industry, there is still a lot of work to be done, especially for what is proposed in terms of electromobility (Da Costa et al., 2022).

In order to carry out the decarbonization process in the transport sector, one of the main measures to be considered is the adoption of electric vehicles (MCKINNON, ALLEN AND WOODBURN, 2011), where the light vehicle segment is considered the initial path for the process (IEA, 2020; WELCH, 2020). The implementation of electric trucks, intended for urban freight transport, is a reality in Brazil as well as in the world, and such a transformation is justified by the transport sector being responsible for more than 50% of the total consumption of diesel oil (IEA, 2016), and particularly the urban transport sector having a share of 18% in oil consumption, followed by road passenger transport (IEA, 2017).

Although it seems distant, the year 2050 is very close, even when one thinks of the estimated period for the road transport of freight and passengers to meet the global goal of the Paris Agreement to reach zero emissions, and one of those responsible for the emission of pollutants is the transport sector, motivated by the burning of diesel, the main fuel used by commercial vehicles. The use of vehicles with zero emission of pollutants to replace diesel-powered vehicles can help to achieve the established target.

The main objective of this review article is to search and analyze articles published on the web of science platform, which bring the behavior of the electric vehicle theme in urban freight transport in the last mile, and its proposal is to explore possible gaps in the themes related to the theme, and the way they are addressed. For this, in the following section a bibliometric analysis is presented, then the systemic analysis of the articles, after the results and discussions and finally the conclusion.

2. MATERIALS AND METHODS

In order to obtain state-of-the-art information on freight transport with electric vehicles in the last mile, a systematic review with a bibliometric approach was developed to identify and analyze relevant studies on the subject. As a result, the steps described below were adopted. In Step 1, the

most relevant keywords for the efficient development of the research were defined, as well as the definition of inclusion criteria, as explained in Table 1. It should be mentioned that the use of combinations between keywords directly linked to electric vehicles and last mile were considered relevant, and their choice was defined through a brainstorming process. Subsequently, the authors refined these words to provide more consistency in the study.

Table 1. Description of Search Strategies

CRITERION	**DESCRIPTION**
Database	Web of Science
Topics	*TS = ('Freight Transport' AND 'Last Mile' AND 'Electric Vehicle*') OR TS = ('Trucks' AND 'Last Mile' AND 'Electric Vehicle*')*
Search Method	Direct Search
Inclusion	(I) Time of coverage: (2018-2022); and (II) Source Relevance
Qualification	(I) Does the study address road freight transport with electric vehicles? (II) Does the study deal with the last mile? (III) Does the research present a well-founded literature review? and (IV) Are the Conclusions and Results consistent with the objectives?
Search Date	September 27, 2022

In Step 2, a direct search was carried out in the Web of Science database. We consider all your data/index sources. In addition, documentary research was carried out in important information bases of institutions and scientific initiatives that deal with the last mile and electric vehicles. Thus, the initial database consisted of 168 studies. Then a temporal filter was performed, considering articles from 2018, where 137 articles remained. Then, the articles with the highest JCR's were selected, limiting them to 57 articles. Considering a careful analysis and looking for those articles that were most aligned with the theme, 11 articles were reached. Step 3 presents data processing, which consists of consolidating and organizing the data for the preparation of technical information for the analysis of the use of electric vehicles in the last mile. Finally, Step 4 presents the development of the research report, here expressed in the form of an article, containing the knowledge produced from the research analyses.

3. BIBLIOMETRIC ANALYSIS

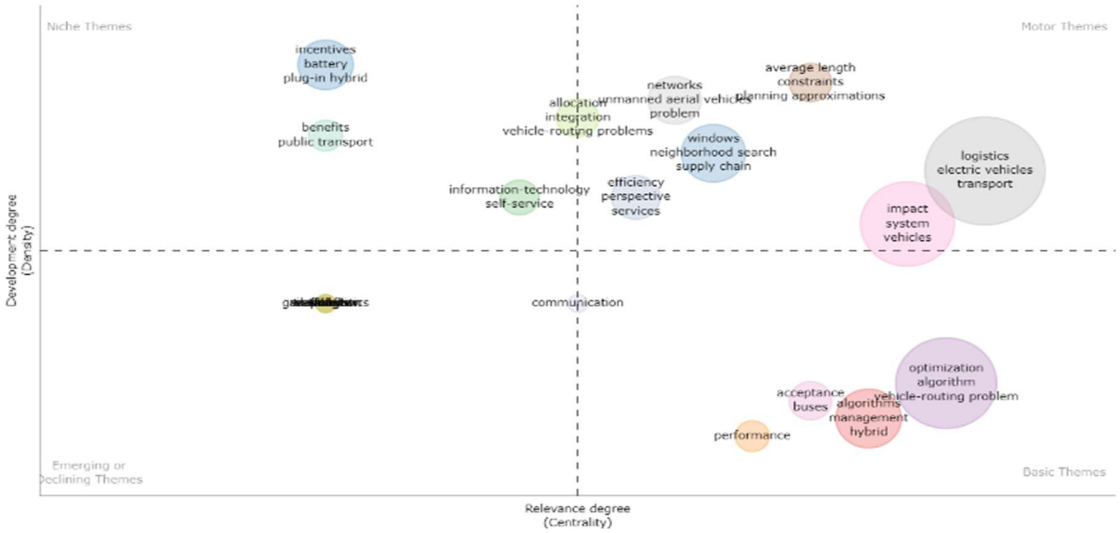
Su and Lee (2010) point to bibliometric analysis as a technique for analyzing the behavior of publications in a quantitative manner. The technique allows the visualization of data on the progress of the subject in a given time frame and possible gaps in research, potential forms of approach and journals for publication. Thus, to achieve the objective of this study, a combination of bibliometric and systemic research on the subject of study was carried out. RStudio® was used as an aid to organize the data of the papers found."Figure 1 visually showcases the most prominent keywords derived from the analyzed papers, providing valuable insights into the field of last mile operations. Notably, it highlights the prevalence of terms directly linked to the last mile, such as delivery, e-commerce, and cargo cycles. Furthermore, the figure accentuates the importance of keywords related to performance, acceptance, cost, and optimization, underscoring their

significance in evaluating and optimizing last mile processes. These findings shed light on key areas of focus and can inform strategies aimed at enhancing last mile operations efficiency and effectiveness.

Figure 1: Keywords cloud in the initial scope.

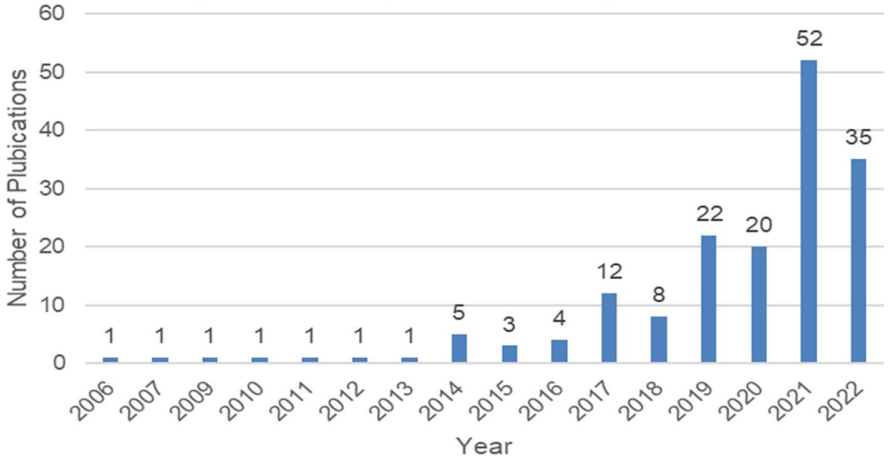
Furthermore, using RStudio®, it was observed that approximately 23 studies specifically addressed the logistics aspect, indicating the relevance of the chosen keywords in the initial search. The thematic map depicted in Figure 2 highlights clusters of keywords that are particularly significant in minimizing the environmental impact of road transportation, enhancing its performance and efficiency through various practices. These practices include the integration of information technologies, utilization of route optimization algorithms, and enhanced sector management. The emergence of these keyword clusters reflects a growing interest in mitigating environmental concerns and improving the overall sustainability of urban freight transport.

Figure 2: Thematic map of the initial scope.



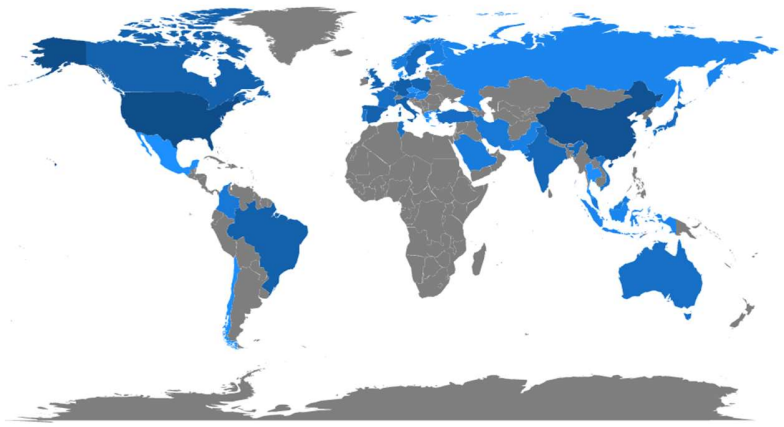
It was noted first, for this initial scope, the timeliness of publications, being 2006 the year of the first work entitled "Study on inter-operability unit for an automobile network" by Jung, Yang and Baek (2006). After this finding, the increase in publications was concentrated between 2017 and 2022, with 2021 being the year with the highest number of publications, proving that the discussion is relevant to the present day. Figure 3 shows in the graph the relationship between the number of publications over the years.

Figure 3: Quantity of Publications per Year.



In the geographical scope, it was noted that the scientific production around the world is well distributed, being null in the continent of Africa, part of South America, and North America. This result can be explained by several reasons, such as being developing countries, having delicate commercial and political relations, or predominance by another mode of transportation among other issues. Figure 4 illustrates this distribution.

Figure 4: intensity map of scientific publications distribution by country.



After the formation of the initial scope, filters were conducted for articles with alignment to the theme.From this new base, a database was organized for the organization and classification of the journals according to the Journal Citation Reports (JCR). The journals that stood out with JCR greater than 7.0, in this scope, are shown in Table 1.

Table 2: Indication of Journals by their Impact Factor.

Source Title	Number of Publications	Impact Factor	ISSN/e-ISSN
ENVIRONMENTAL SCIENCE & TECHNOLOGY	2	11.357	0013-936X
JOURNAL OF CLEANER PRODUCTION	1	11.072	0959-6526
JOURNAL OF RETAILING AND CONSUMER SERVICES	1	10.972	0969-6989
SUSTAINABLE CITIES AND SOCIETY	3	10.696	2210-6707
TRANSPORTATION RESEARCH PART E-LOGISTICS AND TRANSPORTATION REVIEW	2	10.047	1366-5545
IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS	2	9.551	1524-9050
JOURNAL OF ENERGY STORAGE	1	8.907	2352-152X
TRANSPORTATION RESEARCH PART B-METHODOLOGICAL	1	7.632	0191-2615
JOURNAL OF INDUSTRIAL ECOLOGY	1	7.202	1088-1980
COMPUTERS & INDUSTRIAL ENGINEERING	1	7.180	0360-8352
TRANSPORTATION RESEARCH PART D-TRANSPORT AND ENVIRONMENT	6	7.041	1361-9209

The results show that 36.84% of the sample of 57 articles have JCR greater than 7. They also indicate the adherence to the theme for the journal "TRANSPORTATION RESEARCH PART D-TRANSPORT AND ENVIRONMENT" with 6 publications, being the second largest journal in the scope with publications. Overall, it can confirm the relevance of the topic nowadays, given the increase in the number of publications over the years. The year 2021 presented almost 31% of the publications of the initial scope before the applied filters, proving the previous statement. The journals with adherence to the research theme are shown in the table in this section and indicate relevant journals for publications.

4. SYSTEMIC ANALYSIS OF THE PUBLICATIONS

As a complement to the first analysis, we sought to understand the content of the studies through a systematic review. This review allows identifying relevant information in these works and possible gaps for future work on the subject, as shown in the Table 2.

Table 3: Comprehensive overview of the key findings derived from the studies incorporated within the database.

Author (year)	Type of Approach	Main Contribution Points	Indications/ Measures	Gaps
Al-Dal & Celebi (2021)	Application / Mathematical Model	The results show that battery electric freight vehicles are cost competitive with conventional diesel vehicles, particularly for smaller (Class 3) light commercial vehicles. The study identified financial incentives were	The study shows that the last-mile freight sector, and especially parcel fleets, require these incentives to adopt zero-emission vehicles. But a more thorough study should be developed to improve the	The study mostly concentrated in assessing conditions in California.

Author (year)	Type of Approach	Main Contribution Points	Indications/ Measures	Gaps
		sufficient to offset additional purchase and fuel expenses, leading to lower total costs of ownership.	efficiency of the incentives available.	
Li et al (2021)	Application / Mathematical Model	Connected Automated Vehicle (CAV) power requirements and efficiency benefits largely offset each other, and automation has a moderate impact on life cycle GHG emissions.	Results are reported for three autonomous scenarios (conventional, partial, and full) with four vehicles (V125-ICEV, V125- BEV, V350-ICEV, and V350-BEV) for a total of 12 delivery system scenarios.	The study didn't consider optimal delivery performance across the ground and airborne systems based on package size, numbers of deliveries, customer density, vehicle fuel economy, weather restrictions, traffic restrictions, and contactless delivery demand.
Pahwa & Jaller (2022)	Mathematical Model	Potential reductions in emissions of GHG with more sustainable deliveries of e-commerce.		Test with more types of e-commerce.
Zhou et al (2020)	Questionnaire Application/ Mathematical Model	Evaluation of consumer behavior to self-service last mile delivery	-	Tests for larger instances.

Author (year)	Type of Approach	Main Contribution Points	Indications/ Measures	Gaps
Wang et al (2020)	Literature Review / Application	The results of the research shown high potential of electric vehicles and usefulness of electromobility in last mile deliveries. The business partner of the research is now on the stage of electric freight vehicles implementation into vehicles fleets.	The tested vehicle has proved very effective in handling courier deliveries. Practically there was no need to recharge the battery. Moreover, many time the vehicle was able to complete the work tasks stipulated for two working days before the battery needed recharging.	The study considers only one market segment, in this case, the postal service.
Garus et al (2022)	Literature Review/Mathematical Model	Investment in delivery droids could lead to significant savings on operational costs and a new way to improve the environmental performance of the system.	It's important to investigate whether the usage of delivery droids would be sustainable throughout the entire lifecycle, using the cradle to grave approach.	Sustainability in safety and equity.
Akeb et al (2018)	Mathematical Model/ Roteirization	It indicates the use of a mixed fleet as a value object for last mile deliveries. It also uses routing to assist in decision making and planning management.	Tests for larger instances using real data to adapt the model	Studies on the issue of operating costs of conventional and electric vehicles and battery life.
Jaller et al (2021)	Mathematical Model	Develops a last-mile distribution model using Continuous Approximation techniques.	Indication of the competitiveness of electric trucks in the last mile compared to diesel trucks and smaller, low-emission vehicles such as bicycles, as well as the possibility of crowdsourced and self-picked goods.	Omits inventory and operating costs, and does not consider crowdsourced drivers.

Author (year)	Type of Approach	Main Contribution Points	Indications/ Measures	Gaps
Shahmohammadi et al (2022)	Mathematical Model	Sheds light on crowd logistics applied to urban deliveries; Presents a new approach to model parcel delivery by individuals in urban areas.	Encourage citizens in the same neighborhood (these citizens are called "Neighbor Relays") to pick up and deliver packages to the final consumer when the buyer is away from home during delivery.	The acceptability by the different actors remains to be evaluated. The maximum distance that the neighbor or customer accepts to travel, the desired gain or the cost of this solution in relation to the cost of a second delivery by the carrier.
Shi et al (2020)	Mathematical Model/Algorithm	Developed a reinforcement learning based algorithm to provide ride-hailing services to communities with an EV fleet, developed a scalable off-policy reinforcement learning framework with decentralized learning and centralized decision-making processes.	-	The unknown customer trip requests and additional complexity of recharge demands make it difficult to develop a model-based optimization algorithm to solve the dynamic.
Iwan et al (2021)	Mathematical Model/Algorithm	Development of a last mile delivery application using private car trips to reduce costs and optimize this service.	Consider in the program the weather, a 4D model and information regarding the travel time. Better calibration methods regarding the costs involved in the proposal.	Use of more complex information for greater reality and program specification.

Al-dal'ain and Celebi (2021) claim that electric vehicles are great allies in the sustainable issue. The authors proposed in their paper an integrated model for routing and fleet composition decision making for the use of electric vehicles in urban freight distribution. The authors optimized the freight delivery routes to minimize the operational cost for different fleet compositions of electric and conventional vehicles. Then the results were used in a substitution model to find the best fleet composition. The goal of the modeling was to minimize the total cost of the vehicle configuration used, through plots such as: maintenance cost, fuel, and emissions.

Al-dal'ain and Celebi (2021) discuss the mixed fleet of conventional and electric vehicles as a source of overcoming the restrictions imposed by specific characteristics of electric vehicles. The work is interesting from a sustainable point of view and the results of the computational experiments demonstrate that efficient planning for the use of electric vehicles in urban operations can increase compared to conventional vehicles. The authors acknowledge the difficulty of applying the modeling when serving many customers, which makes the process more complex. Still, the main trend is the use of these vehicles in instances with real data for testing and adaptation of the model, as well as the analysis of the use and exchange of batteries in detriment to the useful life of the material. The work could assist managers in assembling fleets and analyze the costs of the operation and use of the vehicles.

Garus et al (2022) analyzes decision-making through multicriteria analysis, based on operational (service quality), economic (operational and production cost), environmental (pollutant emissions and energy efficiency) and social (development, security, equity). It is concluded that there is a significant gain in terms of sustainability, however, a financial cost-benefit analysis is relevant.

Pahwa (2022) discusses the opportunities and challenges associated with different strategies of the last mile for the delivery of e-commerce. Thus, the objective of this text is to develop a structure for the distribution of the last mile using techniques of Continuous Approximation (CA) to establish:

- The performance of different distribution strategies for the last mile in various delivery environments;
- The key factors for the economic and environmental viability of a distribution strategy; and
- The adequate market conditions for the implementation of a given distribution strategy.

In particular, Pahwa (2022):

- Estimates the efficacy of electric vehicles in the act of delivery, on the distribution of the last mile;
- Analyses the use of delivery services in crowdsourcing;
- Develops the case for micro-hubs attached to *freight* bikes for the delivery of the last mile; and
- Establishes the justification for customer pick up at the collection points.

The analysis developed in Pahwa (2022) reflects the structures of the industry, regulaments, geography, urban design and behavior of the consumers in the region Los Angeles. The results call attention to the competitiveness of electric trucks with regards to diesel trucks, vehicles of low volume and low pollution, like freight bikes, and the pros and cons of outsourcing the last mile to a fleet of crowdsourcing, or for them to be collected by the clients.As a result, the authors suggest the use of smaller vehicles, less polluting and with installations next to the market so they can give out quicker deliveries, at significantly lower costs and emissions. The analysis reinforces the case for the use of electric trucks for the delivery of the last mile, because the study states that a fleet of electrical trucks not only eliminates the emissions, but also reduces the costs of distribution in comparison to a fleet of diesel trucks.

Akeb (2018) investigates how to use the power of crowd logistics, focusing on making deliveries by a network of neighbors in the event of home delivery failure by the carrier (when the customer is not at home). Using the platform, the carrier delivers the package to the nearest neighbor who will guarantee the final delivery. For this, the authors intend to demonstrate a method of calculating the number of neighbors needed and their geographical position in order to collect and complete deliveries. The model studied offers last mile delivery service providers the basis to build a network of neighbors allowing the carrier to deal with the absence of the customer during delivery, and the parcel can be delivered to a member of the network. This alternative makes it possible to avoid new deliveries and additional costs related to the last mile in a dense urban area. From an environmental point of view, crowd logistics offers environmentally friendly solutions. By utilizing available resources and avoiding delivery failures, fewer operator trips are required, leading to less emissions and traffic.

This service is about the action of consumers in sending or picking up packages by automated parcel lockers, rather than transferring packages face-to-face with deliverers. In highlight, the authors state that last mile delivery occupies the most time and cost among all logistics operations, and has become the critical issue affecting the efficiency of logistics service. (Zhou et. al, 2020)

Shi et. al (2020) sought to develop an algorithm to optimize the Electric Vehicle fleet for delivery services, seeking to reduce social costs (including operating costs and customer waiting time) of service provision mobility. Interestingly, an attempt was made to optimize considering sharing vehicles, which resulted in a gain in service performance.

Iwan (2021) researched the operation of freight transport in terms of safety, air pollution or noise. In the development of the research, it was understood that one of the possible solutions to reduce negative environmental impacts is to make use of electric vans, being effective in reducing pollutant emissions. A limitation found was the autonomy of the batteries and the availability of infrastructure for recharging. The results showed a high potential of electric vehicles and the usefulness of electromobility in the last mile.

According to Shahmohammadi et. al (2020), variability in consumer practices and choices is not normally addressed in comparisons of the environmental impacts of traditional shopping and e-commerce, however, a model was developed to quantify the variability in GHG footprints. It turned out that purchasing electronically reduces GHG emissions, as the number of items purchased, and the distance traveled in the last mile are the main contributors to this variability in GHG emissions. Replacing diesel-powered vans with electric vehicles (bicycles) resulted in reduced emissions.

Wang et. al (2020) says that online shopping has brought great challenges to the logistics industry, in particular in last-mile parcel delivery. An intelligent last-mile delivery system was developed, called Car4Pac, where the journeys of private cars are used for delivery, with some criteria defined for selection, such as: travel time, driver qualification, energy efficiency, in addition to the cost of travel.

Li et. al (2021) comments that the rise of e-commerce and the demand for contactless delivery during the COVID-19 pandemic fueled interest in automating deliveries. GHG emissions were

evaluated considering three scenarios using the following equipment: Small and large freight vans with internal combustion engines and electric battery. The first scenario is a conventional human-driven vehicle with human delivery; the second scenario is a partially automated vehicle, driven by humans, with robot delivery; and third and last scenario, an automated vehicle and delivery performed by a robot. The results showed that vehicle electrification has a great impact on reducing GHG emissions, however the benefits of delivery automation have a moderate impact on the same issue.

Jaller et. al (2021) understands that last mile deliveries usually occur in urban areas where logistical operations increase congestion and emissions. The study evaluated the role of incentives for using low or zero emission vehicles in last mile operations, including the total cost of the operation and the environmental impacts caused by the activity. Several patterns were analyzed, based on data from truck trips in a real scenario in the State of California. The results suggest that deliveries should be characterized by short trips (95% less than 100 miles), with a high number of stops and lower average speeds compared to other forms of delivery. The results showed that electric vehicles are cost-effective (operational, environmental, etc.) competitive with conventional diesel vehicles, particularly smaller light commercial vehicles.

5. RESULTS AND DISCUSSION

It is noticed that the theme is interesting from the perspective of freight transport in the last mile and means gains in reducing greenhouse gas on the planet, a topic of great relevance and discussion in the last decade. It is noted that the theme has made significant gains in recent years in terms of results in reducing pollutant emissions, but when compared to developed countries, it still requires more research related to the sector.It is noted that the path is still long and it is believed that encouraging companies that use non-electric vehicles is important for the search to replace vehicles that still use polluting fuels. Furthermore, policymakers and stakeholders must recognize the importance of supporting and incentivizing sustainable practices in the last mile, including the use of non-electric vehicles. This can be achieved through the formulation and implementation of supportive policies, regulations, and incentives that encourage the adoption of eco-friendly technologies and practices. These measures should not only target businesses but also address the challenges faced by individual consumers and their behavioral patterns.

It can be seen that the world population is still not prepared for changes in energy use and lifestyle, because for most of the population, it is really difficult to change the current lifestyle. However, it seems that, little by little, some changes are taking place, mainly in the automobile industry, which has been seeking to develop models of cargo vehicles with low or zero CO2 emissions. By investing in research, fostering collaboration, and implementing supportive policies, the potential gains from sustainable last-mile freight transport can be fully realized. This will contribute to significant reductions in greenhouse gas emissions, improved air quality, and a more sustainable future for our planet.

6. CONCLUSION

In this work, we show that the decarbonization of freight transport has been the object of study in several countries, not restricted to just one continent. The BRICs (with the exception of South Africa) for example have researched on the subject, in addition to European countries and the USA. On the African continent, only one country had an article chosen within the pre-established criteria.

According to the research, some issues still need to be further explored, such as: battery charging, vehicle autonomy, the operating cost of using electric vehicles and the need for tests with e-commerce. Regarding the last mile, a difficulty is the distance between the supplier/distributor and the customer, because according to the results, the autonomy of electric vehicles influences the decision-making for which vehicle should be used. The objective of this work was achieved in presenting an overview of the theme regarding the approach of electric freight vehicles in the last mile on the world stage, including the BRICS, observing the growth and exploration of this theme in the scope of international publications and in the study of Technologies.

As a suggestion for future work, a study is suggested to identify the increase in production and registrations of electric trucks in a temporal analysis of 20 years, given the incentive of developed countries to acquire zero and low emission vehicles and as a proposal present in the document of agreement between the participating countries of the 26th United Nations Conference on Climate Change (COP-26) held in 2021 in the city of Glasgow - Scotland.

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