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REVISIÓN

The impact of the use of electric bicycles on the reduction of traffic congestion and pollution in Bogotá

El impacto del uso de bicicletas eléctricas en la reducción de la congestión en el tráfico y contaminación en Bogotá

Leidy Camila Parra-Hernández[1], Daniel Esteban Hurtado-Valbuena[1], Fredy Horacio Otalora-Torres[1]

[1]Corporación Unificada Nacional, Bogotá Colombia.

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Corresponding autor: Leidy Camila Parra-Hernández

ABSTRACT

Current trends in energy consumption for mobility in different countries around the world require varied approaches and solutions. Regardless of size or level of economic development, every nation faces increasing pressure to reduce energy consumption in mobility without compromising welfare, social and economic progress. The purpose is to deepen the understanding of the impact and potential of electric bicycles as an alternative means of transportation, with a specific focus on sustainable mobility. The methodology follows the guidelines of the PRISMA statement to conduct a systematic review. The results reveal the connection between mobility challenges in urban environments, urban growth and the development of suburban settlements, generating a significant increase in commuting and contributing to problems such as congestion. Discussions highlight the inadequacy of many initiatives to address the deep transformation needed. The conclusions suggest that the promotion of alternatives such as electric bicycles play a crucial role in building sustainable cities, improving the quality of urban life and addressing the challenges.

Keywords: Alternative Transport; Electric Bicycle; Urban Mobility; Congestion; Pollution; Sustainability.

RESUMEN

Las tendencias actuales en el consumo de energía para la movilidad en los distintos países del mundo requieren enfoques y soluciones variadas. Independientemente del tamaño o nivel de desarrollo económico, cada nación enfrenta una presión creciente para reducir el consumo energético en la movilidad sin comprometer el bienestar, el progreso social y económico. El propósito es profundizar en la comprensión del impacto y potencial de las bicicletas eléctricas como medio de transporte alternativo, con un enfoque específico en la movilidad sostenible. La metodología sigue los lineamientos de la declaración PRISMA para llevar a cabo una revisión sistemática. Los resultados revelan la conexión entre los desafíos de movilidad en entornos urbanos, el crecimiento urbanístico y el desarrollo de asentamientos suburbanos, al generar un aumento significativo en los desplazamientos y contribuir a problemas como la congestión. En las discusiones, se resalta la insuficiencia de muchas iniciativas para abordar la transformación profunda necesaria. Las conclusiones sugieren que la promoción de alternativas como las bicicletas eléctricas desempeñan un papel crucial en la construcción de ciudades sostenibles, al mejorar la calidad de vida urbana y afrontar los desafíos.

Palabras clave: Transporte alternativo; Bicicleta eléctrica; Movilidad urbana; Congestión; Contaminación; Sostenibilidad.

INTRODUCTION

Current trends in energy consumption for mobility in the region's countries require various approaches and solutions. Regardless of size or level of economic development, each nation faces increasing pressure to reduce energy consumption in mobility without compromising well-being or social and economic progress. Transport services and the associated infrastructure are crucial in regional integration in the global market. However, there is an apparent lack of effective policies to reduce and manage energy consumption and emissions in the region.[1, 2, 3]

The World Health Organization (WHO) states that approximately 37 % of premature deaths related to outdoor air pollution are linked to ischemic heart disease and stroke. In addition, 18 % and 23 % of deaths are attributed to chronic obstructive pulmonary disease and acute respiratory infections, respectively. Eleven percent of deaths are related to respiratory tract cancer. It is crucial to emphasize that people living in low- and middle-income countries are the most affected, accounting for 89 % of the 4,2 million premature deaths associated with air pollution.[4]

High pollution affects the health and mobility of citizens, so sustainable alternatives such as electric bicycles should be promoted. Projects such as Cicla con bicicletas eléctricas (Cycle with electric bicycles) can be set up, and private companies can run campaigns to encourage their purchase. Commuting time at peak hours also affects transporters' incomes, as traffic jams reduce the efficiency of their routes.[5, 6]

Sustainable mobility encompasses a series of initiatives and practices aimed at the conscious use of means of transport, whether private or public. Its fundamental purpose is to satisfy mobility demands with the least possible environmental impact.[7, 8, 9] Alternative modes of transport are geared towards solving the dilemmas associated with environmental pollution.[10]

These means of transport are characterized by their completely ecological nature, seeking to fulfill the function of covering moderate or short distances without causing negative impacts on the environment.[11, 12]. Electric bicycles are emerging as a sustainable alternative to using cars and public transport in urban areas. They focus on the users' perspectives regarding caring for the environment and improving health.[13, 14, 15]

In Bogotá, one of the most polluting cities in Latin America, air pollution contributes to an alarming 9,2 % of deaths yearly. To address this problem, a vehicle restriction called "pico y placa ambiental" has been implemented twice a year.[16] The city has exempted electric vehicles from taxes and has halved the cost of compulsory traffic accident insurance (SOAT) compared to combustion vehicles. In addition, electric bicycles are an ecological and economical option for getting around, as they are environmentally friendly and do not generate costs for their use.

It is essential to prioritize pedestrian mobility, followed by cyclist mobility, public transport, freight transport, and private vehicles, to achieve safe mobility and social distancing.[17, 18] Bogotá cannot expand its road infrastructure for private cars, so it is essential to promote alternatives such as bicycles, public transportation, and carpooling to reduce traffic congestion.[19, 20]

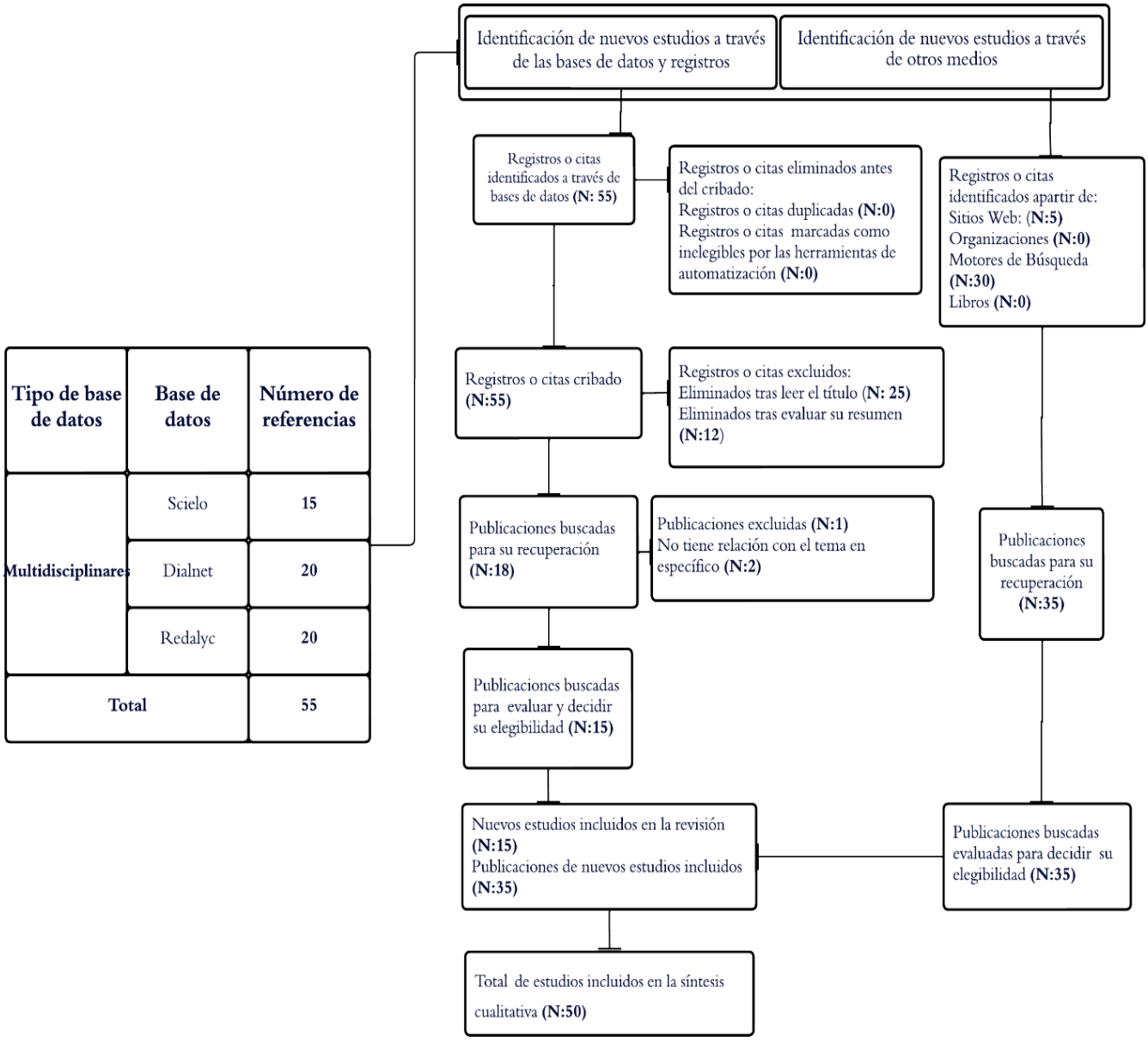
Cities such as Copenhagen in Denmark, Utrecht in the Netherlands, and Beijing in China have significantly impacted sustainable mobility by massively incorporating bicycles as a means of transportation. Cities have improved infrastructure, such as bike lanes, signage, and lighting, to encourage electric bicycles and reduce air pollution and accidents.[16]

Electric bicycle owners use private and public transportation less than other transportation users and opt for non-motorized transportation instead of motorized transportation. One of the common problems is that many citizens do not inform themselves or research sustainable means of transportation and, therefore, do not dare to change their current mode of transportation.[21, 22]

The overall objective of this research was to raise awareness of the perception of using electric bicycles as an alternative means of transportation in Bogotá so that people who move around the city can consider them an option in their daily lives. The specific objectives included showing the advantages of electric bicycles compared to mass transportation and analyzing the costs and benefits from a socio-environmental perspective. The study highlights the importance of considering electric bicycles as a sustainable alternative for mobility in Bogotá.

METHOD

The methodology used was based on a systematic and exhaustive review of the scientific literature that addresses the impact of the use of electric bicycles in reducing congestion and pollution over the last 5 years. This approach follows the guidelines established by the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement. This guide establishes standards for reporting in systematic reviews and meta-analyses.[23, 24] During this review process, various resources were examined, including scientific articles, conferences, books, and technical materials published in the last five years in education and environmental sustainability. Priority was given to including sources available free of charge in Spanish and English (see figure 1).



Tipo de base de datos	Base de datos	Número de referencias
Multidisciplinares	Scielo	15
	Dialnet	20
	Redalyc	20
Total		55

Figure 1. Compilation of scientific articles according to the PRISMA flowchart guidelines.

Table 1. Inclusion-exclusion criteria used.

Inclusion Criteria	Exclusion Criteria
Documents published in the last five years.	Information that did not meet the aforementioned inclusion criteria.
Sources available in open access in Spanish and English.	Documents not relevant to the field of education and environmental sustainability.
Research related to the topic.	Sources that were not freely available in Spanish and English.
Scientific articles, conferences, books and technical materials.	Publications prior to the last five years.

Various databases were used to optimize the search for relevant information, including Scielo, Dialnet, Redalyc, and the Google Scholar search engine. This comprehensive approach allowed for a complete and up-to-date compilation and analysis of relevant research on the topic in the period of interest.

To refine the search for information, keywords were used combined with logical operators, such as "(bicycles)

AND (electric) AND (reduction) AND (congestion) AND (pollution)". This strategy allowed the identification of documents relevant to the research. In addition, an inclusion and exclusion protocol was implemented in the study, where information that did not meet the predefined criteria was discarded. The inclusion and exclusion criteria were fundamental to guarantee the relevance and quality of the information collected in the study (see table 1).

RESULTS

In the growing concern for sustainability and the need to address the challenges associated with urban mobility, this article delves into a detailed analysis of the relationship between the use of electric bicycles and their impacts on reducing traffic congestion and air pollution. Based on an exhaustive search, 50 sources were identified, including 15 pieces of research that met rigorous criteria, 30-degree projects, and five miscellaneous sources, all converging in examining the aspect of sustainable mobility. These sources provide a solid basis for exploring the benefits of using electric bicycles, enriching the analysis with diverse approaches and perspectives. This article will offer points of analysis to understand better how to mitigate congestion and improve air quality in urban environments.

Current transportation scenario and its relationship to congestion and pollution

Excessive traffic congestion negatively affects health and the environment in urban environments; they are a multifaceted problem with various interrelations.[26] The lack of effective intervention by governments is one of the main contributors to the daily collapse of city public transport service. Although road congestion is evident and constantly increasing in all cities, the management to address this problem is insufficient.[27, 28]

Another challenge arising from frequent vehicular traffic is atmospheric changes. The emission of suspended particles, linked to the traffic of vehicles carrying passengers and cargo and using fossil fuels, hurts the ozone layer. This can lead to climate change and alterations in life cycles (Valeria, 2022).[29, 30] It should be noted that the risk associated with these particles is inversely proportional to their size since smaller particles have a greater capacity to penetrate the human organism, which represents a significant health risk.[31]

The mobility problem in urban environments is closely linked to rapid urban growth and suburban settlements in peripheral areas. These factors generate a notable increase in travel, thus contributing to significant mobility problems, particularly congestion. This phenomenon, understood as the demand for travel that exceeds available capacity, causes negative impacts on the urban environment.[32, 33]

These impacts are manifested through high consumption of energy from non-renewable sources, increased levels of air pollution, the emission of polluting gases, and the generation of noise.[34] These problems are characteristic of collective public transport systems that use buses on non-exclusive roads. In addition, there is an increase in the number of private vehicles in circulation in cities, which aggravates the situation and accentuates the challenges associated with urban mobility.[35, 36]

Sustainability in the city goes beyond the material; it implies educating the inhabitants on this issue. For this reason, it is imperative to implement sustainable urban policies that address physical aspects and actively involve citizens, inviting them to be part of this change for the common good.[37, 38] This quality defines a sustainable city as it seeks the integration of social, environmental, economic, and economic dimensions. This integration translates into developing, promoting, and disseminating projects and programs that benefit the city and contribute to the well-being of its inhabitants, satisfying their expectations and desires.[39]

Urban mobility: new perspectives

Since mobility represents the main challenge in today's city, it stands as the essential starting point for urban sustainability. This approach is materialized through a series of strategies that strengthen the city in each of its systems, promoting its organization for the benefit of the people.[40, 41] These strategies should be oriented towards protecting and multiplying resources, caring for human health and the environment, and improving means of transportation. In this way, specific policies are used to sustain the local economy.[19, 42]

In this sense, sustainable mobility is complemented by ecological mobility, which uses transportation systems that minimize environmental pollution and health impacts. Examples of this are electric vehicles, especially bicycles, which are non-motorized transportation. The data collected shows the evolution of the use of electric bikes in Bogotá. To begin the investigation, it shows the number of kilometers (km) of cycle routes built in Bogotá in the last 5 years.[43]

The transformation of urban mobility requires a close link with urban planning. The latter should be oriented towards a compact design with diverse uses to minimize travel times and change the perception that the automobile is indispensable in the city.[44, 45] It is essential to adopt a dual model in the medium term. This implies the implementation of segregated cycling infrastructures on appropriate roads, offering more excellent safety to the most vulnerable groups, including women. At the same time, on routes shared with motorized traffic, respect for speed limits on cycle lanes must be guaranteed using ordinances. It advocates the consolidation of a hierarchy of mobility in which pedestrians and cyclists have priority, thus displacing the traditional conception

that streets are exclusively for cars.[46, 47]

The bicycle is emerging as an alternative and environmentally friendly means of transportation, and the report highlights the urgent need to raise awareness of its benefits.[48] This should be a clear wake-up call for decision-makers, urging them to consider projects focused on promoting the bicycle as a priority for urban development.[49] It is essential to raise awareness of the importance of knowledge of traffic laws and the rights and obligations of cyclists when using public roads. This approach will improve road safety, solidify the bicycle as a sustainable mobility option, and promote its effective integration into the urban fabric of cities.[50]

In addition, public authorities can actively collaborate with private companies to find solutions that promote mobility by bicycle. A concrete example would be offering benefits to workers who use public bicycles. This collaboration makes it possible to encourage sustainable mobility and contribute to the construction of a more environmentally friendly city.

DISCUSSION

Electric mobility and the promotion of sustainable alternatives in transportation represent issues of growing importance in the current landscape. Examining these aspects provides valuable insights into challenges and opportunities. In the general context, the city of Bogotá emerges as a revealing example, highlighting the complex solutions inherent in implementing sustainability in urban environments.

It has become clear that, although, in theory, the fight against climate change is mentioned as one of the essential objectives, the plans and ordinances related to sustainable mobility in the city under study have given disproportionate importance to cars. The focus has been mainly on the electrification of these vehicles as a measure to counteract pollution and mitigate climate change. However, these initiatives seem insufficient as they do not adequately address the profound transformation of Bogotá. Temporary cycle lanes were introduced, and some are still in operation. Although some roads were reoccupied by traditional means of transport, these cycle lanes are partly attributed to the fact that more than 25 % of regular bicycle users decided to continue cycling to work or school after the pandemic. However, the public perceives the need to implement a more structured cycle route plan. This would consolidate the bicycle as an integral means of transport in the urban system while contributing significantly to reducing pollution in the city.[51, 52]

The current limitations of electric vehicles are focused on several key aspects, such as their limited range, the limited reserves of raw materials for their manufacture, the charging time, and the pollution associated with their manufacturing and recycling process (although this last aspect is primarily offset by the use of the electric vehicle within cities compared to a combustion vehicle).[53] Additionally, the scarcity of charging points is presented as a significant challenge, and from my perspective, one of the most critical aspects is that it does not provide a proper solution to the problem of traffic collapse in cities. Whether electric or combustion-powered, private cars occupy considerable space in urban areas on roads and in car parks.[54, 55]

In addition, electric vehicles face recent uncertainties, such as the emergence of new fuels promoted as less polluting, more economical, and more efficient alternatives to traditional fuels.[56] On the other hand, the mass adoption of electric vehicles could increase the cost of electricity and pose potential challenges, such as a possible collapse of public charging points and the electricity grid in general. These considerations underline the complexity and the need to comprehensively address the challenges associated with the transition to electric mobility.[57, 58]

In this research, several studies related to the subject were examined, emphasizing research focused on the perception of using electric bicycles as an alternative means of transportation in Bogotá. The study covered three fundamental aspects: the analysis of the growth of the electric bicycle market, the comparison with different means of transport, and the proposals for improvements in road infrastructure. The methodology used was quantitative comparative, evaluating the efficiency of electric bicycles and other means of transport in Barcelona. After analyzing consumption and costs over the years, it was concluded that mobility with electric bicycles is viable, showing continuous market growth. These bicycles are perceived as accessible and effective for improving mobility and health, reducing air pollution, and overcoming challenges like slopes and ramps.[59]

In Cuenca, Ecuador, research was carried out with the primary objective of comparing the electric bicycle, the conventional bicycle, and light vehicles, considering aspects such as consumption, air emissions, costs, and time. A mixed methodology was implemented based on worldwide studies to achieve this, using GPS devices in vehicles during random trips on various routes in Cuenca. Different mobility scenarios were analyzed and quantified daily, monthly, and annually. The results highlight the viability of the electric bicycle as a mobility option in the city.[60]

This means of transport contributes to improving air quality by avoiding the generation of polluting emissions, reduces the costs associated with traffic congestion, and decreases travel times compared to conventional vehicles. Furthermore, it stands out for its ability to access areas that are difficult to reach compared to traditional bicycles.

According to a financial feasibility analysis for electric bicycle rental in Cuenca, Ecuador, whose objective

was to provide an alternative service within the urban area and promote tourism and sustainable transportation, a quantitative methodology that included market and technical studies was applied. Surveys were conducted among the local population and tourists, and the city's existing cycle routes were analyzed. The results indicated interest among citizens and tourists in the electric bicycle rental service. However, limitations were found in the cycle routes and a lack of rental and recharging stations, leading to the conclusion that the project is not feasible.[61]

In another study on the comparative efficiency of the electric bicycle compared to mass public transport and the conventional bicycle, a quantitative and comparative methodology was used to analyze travel times between these three modes of transport. The information was collected using a smartphone application that recorded the time needed for each mode of transport on various routes in the city of Bogotá.[62]

The results revealed that, at peak times, the electric bicycle proved more efficient than public transport for distances of up to 10,5 kilometers. However, for distances of up to 11,5 kilometers, the conventional bicycle is shown to be the most efficient option due to the speed limitations of traditional bicycles.

Similarly, the electric bicycle is mentioned as an alternative vehicle with advantages for Bogotá. The objective was to identify the most efficient means of transport for a specific group of customers; electric bicycles are considered a viable option for getting around the city. A quantitative methodology was used, which included surveys of the local population and tourists and data provided by IDEAM and SIATA. The conclusions highlighted the increased air pollution in Bogotá and emphasized that electric bicycles do not emit polluting gases.[63]

Integrating bicycles into public transport is proposed by installing bicycle parking facilities at all Transmilenio stations and, in the future, in the metro system. In addition, it is suggested that users be allowed to take their bicycles with them on public transport.[64] This measure would encourage using bicycles as a complementary means of transport to the destination. This initiative would benefit users and offer significant advantages for Transmilenio. The current fare could be reduced, as the bicycle would function as a feeder to the system, reducing the need for the same number of feeder buses. This would not only be more efficient from an operational point of view but would also promote sustainable mobility and contribute to reducing congestion and pollution.[65, 66]

The absence of exclusive lanes for conventional and electric bicycle traffic is a fundamental requirement for its management. In this sense, the relevant authorities must guarantee safety, confidence, and adequate attention to facilitate its efficient circulation in collaboration with private entities.[67] Since traveling by bicycle tends to be slower, this limits its usefulness over considerably long distances. Therefore, the lack of an environment conducive to their use on busy roads could generate increasing problems. It is imperative to have specific spaces designed for their integration and adaptation, thus avoiding complications in the development of their daily use.[68]

However, it is essential to remember that electric assistance with a maximum power of 250 W on bicycles results in an average speed differential compared to conventional bicycles, which varies between 2 and 8 km/h faster. Although this higher speed can be an advantage for specific daily journeys and serve as an incentive to particular users, it also constitutes a risk factor in terms of road safety.[69] Several studies have confirmed that electric cyclists are more prone to experiencing collisions and near-collisions compared to conventional cyclists. These collisions mainly affect pedestrians (31 % of critical events), vehicles such as cars and vans (21 %), and other bicycles (18 %). It is crucial to address this duality between the speed advantage and the associated risks to develop strategies that mitigate accidents and promote safety in using electric bicycles.[70]

To achieve a more sustainable transport sector globally, it is imperative to implement a series of comprehensive measures. This includes improved city design, creating safe and comfortable facilities for pedestrians and cyclists, expanding public transportation systems, and promoting cleaner and more efficient road fleets, emphasizing integrating electric vehicles. These combined initiatives will reduce polluting emissions and encourage a more active and healthy lifestyle while improving urban mobility sustainably.[71, 72]

CONCLUSIONS

The need to consider solutions beyond the electrification of cars to effectively address the challenge of climate change is highlighted. Despite representing a considerable initial investment, electric bicycles emerge as an attractive option due to their low consumption and maintenance costs, making them a viable alternative to promote sustainable mobility in the city.

Furthermore, it is emphasized that the travel time on an electric bicycle can be comparable to or even less than that of public transport, which underlines its potential to improve efficiency in urban travel. However, challenges are identified in the infrastructure of the cycle paths in Bogotá, such as the lack of lighting, adequate signage, and priority for cyclists, which are crucial elements to encourage and facilitate sustainable mobility in the city.

It is essential to implement a support system for cycle routes and promote public awareness of the relevance

of cyclists on urban roads. In addition, the provision of protective measures for cyclists against variable weather conditions should be considered. The presence of street vendors obstructing cycle lanes due to the lack of adequate demarcation of the lanes represents an additional obstacle to the safe movement of cyclists in the city.

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CONTRIBUTION OF AUTHORSHIP

Conceptualization: Leidy Camila Parra-Hernández, Daniel Esteban Hurtado-Valbuena, Fredy Horacio Otalora-Torres.

Data curation: Leidy Camila Parra-Hernández, Daniel Esteban Hurtado-Valbuena, Fredy Horacio Otalora-Torres

Formal analysis: Leidy Camila Parra-Hernández, Daniel Esteban Hurtado-Valbuena, Fredy Horacio Otalora-

Torres.

Research: Leidy Camila Parra-Hernández, Daniel Esteban Hurtado-Valbuena, Fredy Horacio Otalora-Torres.

Methodology: Leidy Camila Parra-Hernández, Daniel Esteban Hurtado-Valbuena, Fredy Horacio Otalora-Torres.

Project administration: Leidy Camila Parra-Hernández, Daniel Esteban Hurtado-Valbuena, Fredy Horacio Otalora-Torres.

Resources: Leidy Camila Parra-Hernández, Daniel Esteban Hurtado-Valbuena, Fredy Horacio Otalora-Torres.

Software: Leidy Camila Parra-Hernández, Daniel Esteban Hurtado-Valbuena, Fredy Horacio Otalora-Torres.

Supervision: Leidy Camila Parra-Hernández, Daniel Esteban Hurtado-Valbuena, Fredy Horacio Otalora-Torres.

Validation: Leidy Camila Parra-Hernández, Daniel Esteban Hurtado-Valbuena, Fredy Horacio Otalora-Torres.

Visualization: Leidy Camila Parra-Hernández, Daniel Esteban Hurtado-Valbuena, Fredy Horacio Otalora-Torres.

Writing – original draft: Leidy Camila Parra-Hernández, Daniel Esteban Hurtado-Valbuena, Fredy Horacio Otalora-Torres.

Writing – review and editing: Leidy Camila Parra-Hernández, Daniel Esteban Hurtado-Valbuena, Fredy Horacio Otalora-Torres.