DINASTI INTERNATIONAL JOURNAL OF MANAGEMENT SCIENCE (DIJMS)
E-ISSN : 2686-522X
P-ISSN : 2686-5211
DINASTI PUBLISHER
https://dinastipub.org/DIJMS dinasti.info@gmail.com +62 811 7404 455

DOI: https://doi.org/10.31933/dijms.v5i1
Received: 19 October 2023, **Revised:** 24 November 2023, **Publish:** 28 November 2023

The Most Optimal Transportation Policy to Address Carbon Emissions: A Bibliometric Analysis, Benchmarking, and Future Research Plan

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Abstract: This research article examines the role of transportation policies in reducing carbon emissions, focusing on various cities in Indonesia. The study aims to identify the most optimal transportation policies to address carbon emissions and promote environmentally friendly urban development. Bibliometric methods quantitatively analyzed scholarly literature on transportation policies and carbon emissions, while benchmarking methods compared transportation policies worldwide based on carbon emission data and air quality. A total of 100 articles were found in the Scopus database using the keywords 'transportation policy city carbon emission' from 2018 to 2023. The selection was refined to 50 articles with the highest citations and further narrowed down to 31 articles, then to 10 articles focusing on specific city research, and finally to the top 5 articles in Scopus Q1 journals (journals with the highest academic quality and impact) based on benchmarking results as the basis for policymaking. The research results indicate four optimal transportation policy recommendations to address carbon emissions: urban-scale fossil fuel consumption calculations, spatial planning prioritizing sustainable transportation, the use of micro-electric vehicles (micromobility), and increased energy efficiency in transportation. The study also identified under-researched variables related to carbon emission reduction efforts, such as urban airports, climate change mitigation, low-carbon mobility transition, and other future research formulation plans that can be further investigated. This research underscores the urgency of prioritizing the development of sustainable transportation policies to reduce carbon emissions and improve air quality in Indonesian cities.

Keyword: Benchmarking, Bibliometric Method, Carbon Emissions, Transportation Policy

INTRODUCTION

Urban areas contribute the most to carbon gas emissions, accounting for a total of 75% of global carbon emissions, with the transportation and building sectors being the largest contributors (United Nations Environment Programme, n.d.). The transportation sector is responsible for a quarter of the total greenhouse gas emissions. Over the two decades from 2000 to 2019, carbon emissions from the transportation sector increased in all regions, except for Europe. Asia is the largest carbon emitter, with the most significant increase in carbon emissions. In 2021, the United Nations reported that carbon (CO2) emissions from the transportation sector in developing countries reached up to 30% of the total carbon emissions (United Nations, 2021).

Several researchers have published their studies on the impact of carbon emissions. Carbon emission levels have an impact on land surface temperature. The pattern of carbon emissions also affects temperature dynamics in urban areas. In other words, there is a linear correlation between carbon emission releases and spatial dynamics of land surface temperature (Dewa & Buchori, 2023). Furthermore, regional-scale research using econometric methods through regression analysis shows the influence of carbon emissions on public health, including an increase in the number of outpatient and inpatient visits, increasing health risks, and premature deaths (Dong et al., 2021), (Rafaj et al., 2018).

Interventions in the form of transportation policies are one of the efforts to reduce carbon emission production. This study aims to investigate the role of transportation policies in reducing carbon emissions and environmental impacts in urban areas. Urban mobility has become a leading cause of increased carbon emissions in various countries, threatening global environmental sustainability. This research attempts to understand how transportation policies can be an effective tool in changing urban mobility behavior towards more environmentally friendly solutions.

The research results are expected to provide valuable insights for policymakers in designing more effective transportation strategies to reduce carbon emissions. Additionally, this research is also expected to help urban communities understand the importance of changing their mobility behaviors in addressing pressing environmental issues. Thus, this study contributes to global efforts to maintain urban environmental quality and reduce the negative impacts of climate change.

Problem Statement

1. What are the most optimal transportation policy recommendations to address carbon emissions in various cities in Indonesia?
2. What are the future research plans to tackle carbon emissions in various cities in Indonesia?

Research Objectives

1. To identify best practices for reducing carbon emissions in various cities in Indonesia through the implementation of transportation policies using a systematic and quantitative bibliometric and benchmarking method.
2. To formulate effective future research plans to address carbon emissions in various cities in Indonesia based on systematic and quantitative bibliometric analysis.

METHOD

This study applies two methods sequentially, as illustrated in Figure 1.

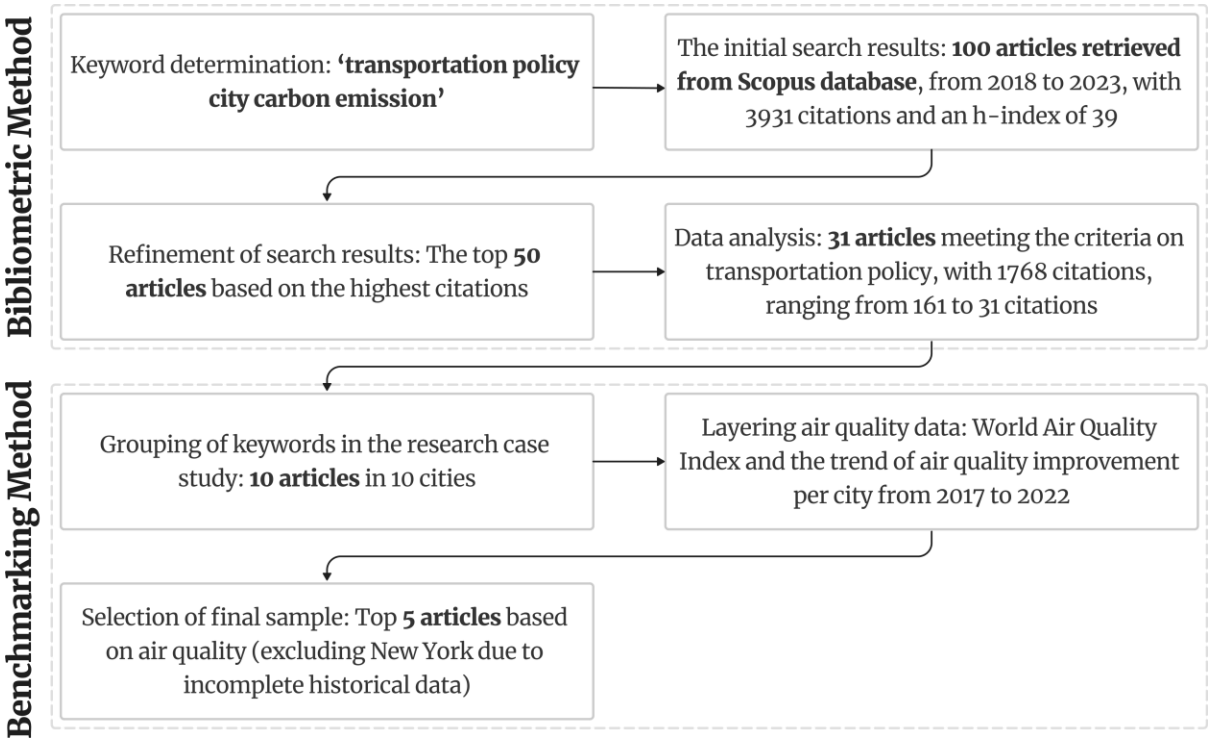

Figure 1. Research Stages
Source: Research Findings

Bibliometric Method

This research employs the bibliometric method for measuring literature using statistical approaches, making it a form of quantitative analysis (Sidiq, 2019). Bibliometric network analysis is a set of methodologies used to analyze all related publications on a specific topic. This type of review methodology can provide a more relational, contextual, and holistic intellectual landscape of a particular topic (Han et al., 2020).

Bibliometric mapping is beneficial for both the scholarly community and the general public as it can help transform publication metadata into maps or visualizations, which are more easily managed for processing to obtain useful insights. For instance, visualizing keywords to identify research themes or clusters in a specific discipline, mapping author affiliations from specific journals to identify journal geographic coverage, and mapping institutional collaboration and international collaboration as part of a framework to identify emerging technologies (Tanudjaja & Kow in (Sidiq, 2019)).

Several indicators in bibliometrics have been proposed, with the H-index being the most popular. Based on the set of publications and their citation counts, the H-index assesses the number of published papers (N) that have been cited N times or more. Hence, this value combines the quantity (number of papers) and quality (number of citations) of publications. The H-index is widely regarded as a factual and accurate parameter for measuring a researcher's scholarly output (D'iaz et al., 2016). The research is conducted in the following stages:

1. Keyword determination

Literature searches were conducted in September 2023 using Harzing's Publish or Perish (PoP) software, with a database from Scopus used to collect data. The keywords entered in the software's Keywords column were 'transportation policy city carbon emission,' with a search limit set to 100 results.

2. Initial search results

From the Scopus database, we obtained 100 publication results that were published within the last 5 (five) years, from 2018 to 2023. A search on PoP with the Scopus source yielded metrics depicted in Table 1.

Table 1.
Search Metrics Results on PoP

Query	Source	Papers	Citations	Years	Cites/Year	Cites/Paper	Cites/Author	Papers/Author	Authors/Paper	h_index
transportation policy city carbon emission from 2018 to 2023	Scopus	100	3931	5	786.2	39.31	3931	100	1	39

3. Refinement of search results

In this stage, we refined the search results by limiting the study to 50 articles based on the highest citations and excluding articles that did not meet the criteria as illustrated in Table 2.

Table 2
. Selection Criteria for Search Results

Criteria	Number of Articles
Literature Review	4
Technical Review	8
Sociological study	2
Topic of economics	2
Health & pandemic topics	3
Transportation policy topics	**31**

From the initial 100 search results, we selected 50 articles with the highest citations and then obtained 31 articles after selecting according to transportation policy topic criteria. After examining the titles and abstracts, 19 articles were excluded due to criteria suitability reasons. Table 3 shows the metric comparison of the initial search and the purification of search results with selection criteria.

Table 3.
Comparison of Metrics Between Initial Search and Purified Search Results

Data	Initial Search	Search Refinement
Number of articles	100	31
Citation	3931	1768

4. Data Analysis

The analysis results using the bibliometric method with the keyword 'transportation policy city carbon emission' from the Scopus database were narrowed down with the topic criteria of 'transportation policy' through the screening of article titles and abstracts. Bibliometric analysis in this research uses the PoP software, with the initial search results comprising 100 articles with 3931 citations. Refinement of the search results based on the predetermined criteria yielded 31 articles, with the number of citations changing to 1768 and the largest citation range being 161 and the smallest 31.

Benchmarking Method

Benchmarking is an ongoing comparison and measurement process for an organization with leading organizations worldwide to obtain information that can help the organization take actions to improve its performance (American Productivity & Quality Center in Peli, 2019). This research includes secondary data analysis using strategic benchmarking to compare aspects related to strategic needs such as mission, vision, strategy, policies, goals, and intended to transform strategic goals.

The scope of this research is various cities from around the world that have implemented various types of transportation policies to reduce carbon emissions. The data includes the use of public transportation, facilities for cyclists, facilities for pedestrians, the use of private cars, and other transportation policies. Additionally, this research will also evaluate the impact of these policies on carbon emissions and air quality in urban environments.

At this stage, the refined search results from bibliometric analysis are layered with carbon emission data and historical air quality data for each city where the research case study is conducted. Carbon emission data uses World Bank output data, an international development organization comprising 189 member countries with the goal of addressing various issues in reducing poverty and creating well-being in developing countries (The World Bank, n.d.). Meanwhile, for current air quality data, the output data from The World Air Quality Index is used, which has the advantage of real-time data retrieval from 30,000 stations in 2,000 major cities in 130 countries (The World Air Quality, 2008). Air quality data is supplemented by historical ranking data for 7,323 cities from 131 countries worldwide over a 5-year period, from 2017 to 2022, taken from IQAir to see the trend of increasing air quality per city (IQAir, n.d.). The above data is then grouped by city to obtain a conclusion in the form of coherence between transportation policies and carbon emissions and air quality, with the following steps:

1. City grouping in the research case study

31 articles resulting from the refinement were grouped according to the cities where the research study was conducted. The results of the grouping are depicted in Table 4. In the next step, we excluded articles that were classified as 'undefined', which included (1) theoretical research, (2) research conducted at the national level, or (3) research conducted at multiple locations. From the grouping results, we obtained 10 articles that clearly mentioned a single research location.

Table 4.
Grouping by City

City	Number of Articles
Undefined	21
Changzhou	1
Paris	1
Tokyo	1
Shanghai	1
New York	1
Shenzen	1
Beijing	1
Taipei	1
Delhi	1
Natal	1

2. Layering Air Quality Data

We re-layered the 10 articles grouped by city with the current air quality data using the output from The World Air Quality Index and the trends in air quality improvement per city based on historical rankings over a span of 5 years, from 2017 to 2022, taken from

IQAir. The layered results were then rearranged according to the air quality rankings depicted in Table 5.

Table 5.
Layering Air Quality Data Per City

Cites	Authors	City	WAQI	Air quality trends	2022	2021	2020	2019	2018
48	Long & Yoshida, (2018)	Tokyo	Good	Improving	9.2	9.1	10.1	11.7	13.1
44	M. Isik	New York	Moderate	Improving	9.9	10	-	-	-
40	Wang et al., (2018)	Taipei	Moderate	Improving	9.9	13	12.6	13.9	14.9
53	De Bortoli & Christoforou, (2020)	Paris	Moderate	Improving	12.7	13.7	12.2	14.7	15.6
43	D. Dong et al., (2018)	Shenzen	Good	Improving	15.7	17.9	19	23.4	24.2
48	Du et al., (2018)	Shanghai	Moderate	Improving	25.4	27.7	31.5	35.4	36
42	R. Huang	Beijing	Unhealthy for sensitive peoples	Improving	29.8	34.4	37.5	42.1	50.9
61	R. Zhang	Changzhou	Good	Improving	33.1	36	38.7	44.7	50.3
36	A.D. Bhanarkar	Delhi	Unhealthy	Improving	92.6	96.4	84.1	98.6	113.5
35	A.L.L. Toledo	Natal	-	-	-	-	-	-	-

3. Selection of Final Sample

To select the final sample, we used the top 5 articles based on air quality rankings, excluding New York due to incomplete data availability. Thus, we obtained 5 articles (see Table 6) with a total citation of 232.

Table 6.
Comparison of Initial Search Metrics with Final Sample

Cites	Authors	Title	City	WAQI	Air quality trends	2022
48	Long & Yoshida, (2018)	Quantifying city-scale emission responsibility based on input-output analysis – Insight from Tokyo, Japan	Tokyo	Good	Improving	9.2
40	Wang et al., (2018)	Can spatial planning really mitigate carbon dioxide emissions in urban areas? A case study in Taipei, Taiwan	Taipei	Moderate	Improving	9.9
53	De Bortoli & Christoforou, (2020)	Consequential LCA for territorial and multimodal transportation policies: method and application to the free-floating e-scooter disruption in Paris	Paris	Moderate	Improving	12.7
43	D. Dong et al., (2018)	Towards a low carbon transition of urban public transport in megacities: A case study of Shenzhen, China	Shenzen	Good	Improving	15.7
48	Du et al., (2018)	System dynamic modeling of urban carbon emissions based on the regional National Economy and Social Development Plan: A case study of Shanghai city	Shanghai	Moderate	Improving	25.4

This final sample is used as a benchmarking material for transportation policies in reducing carbon emissions, consisting of 5 articles in Scopus Quartile 1 journals, which are journals with the highest quality and significant impact in the academic field. The comparison of metrics between the initial search results and the final sample is depicted in Table 7.

Table 7.
Comparison of Initial Search Metrics with Final Sample

Data	Initial Research	Final Samples
Number of Articles	100	5
Citation	3931	232

RESULTS AND DISCUSSION

Quantification of urban-scale fossil fuel consumption

Long & Yoshida, (2018) recommend the quantification of multi-regional input-output (MRIO) on an urban scale to evaluate energy consumption. Tokyo serves as a representation of a contemporary urban area where carbon emissions are a crucial consideration in formulating urban-scale carbon mitigation policies. The transportation sector is the largest contributor to direct emissions in Tokyo, posing a significant challenge in climate change mitigation due to fossil fuel use, thus necessitating a transition toward sustainable development. The research results emphasize recommendations for emission improvements and reductions as top priorities. This methodology can be applied to other major cities, likely yielding similar outcomes, and aiding in the development of programs and local and regional emission reduction targets. Implementation of transportation policies, such as the substitution of fossil fuels with alternative fuels like biodiesel, is suggested.

Urban Planning

Wang et al., (2018) in their research state that urban planning plays an increasingly significant role in climate change mitigation efforts through energy-efficient settlements and the use of renewable energy sources. The impact of urban spatial planning on carbon emissions is seldom discussed. Carbon emissions have a spatial dimension related to heterogeneous land use activities and urbanization in urban areas. Therefore, changes in spatial planning affect the urban form, thus influencing carbon emissions through changes in traffic density and energy consumption.

Carbon emissions from the transportation sector do not correlate with population density. The organization of settlement spatial planning needs to be understood as an efficient and effective strategy in mitigating greenhouse gas emissions. Urban spatial planning should implement sustainable transportation such as public transportation options, cycling, walking, and reducing the use of private vehicles.

Urban spatial planning is one of the efforts to achieve a low-carbon future through the application of new technologies in creating new urban forms and carbon emission mitigation through rational land use allocation to improve energy efficiency. It also aims to reduce uncontrolled urban growth and energy consumption in the transportation sector. Urban forms have the potential for a significant impact on energy use, resource consumption, and the region's capacity for climate change mitigation.

Micro Electric Vehicle (Micromobility) Usage

De Bortoli & Christoforou, (2020) explain that the transportation system has undergone dramatic changes in the last 15 years, especially in urban areas, with the presence of shared vehicles (taxis, ride-sharing services) and micro-vehicles (electric bikes, e-scooters). The environmental profile of standard fuel-powered transportation is estimated globally with precision by only considering vehicle usage and resulting emissions. Transportation use

contributes 85 to 90% of greenhouse gases from buses, private cars, motorcycles, as well as taxis and ride-sharing services.

As an option, micromobility such as e-scooters has high environmental potential. E-scooters and similar micro-vehicles have the potential to reduce the carbon footprint of urban mobility. However, these types of vehicles must be carefully developed with adequate regulations according to regional characteristics, especially considering existing mobility systems and energy sources used. The carbon footprint of e-scooters ranges from 50 to 12 gCO2eq/km, which is still higher compared to fast trains with a carbon footprint of 8.9 gCO2eq/km and walking with a carbon footprint of 1.9 gCO2eq/km. Meanwhile, shared transportation such as taxis and ride-sharing services is the most carbon-emitting transportation mode in a case study in Paris, with a carbon footprint of 299 gCO2eq/passenger-km.

E-scooters have a positive environmental effect, especially in relation to population density issues, public transportation, and carbon intensity of electricity. Cities with high carbon intensity in electricity and high mobility supported by electric-powered mass rapid transit (MRT) will benefit more from the presence of e-scooters in terms of climate change reduction.

Improving Energy Efficiency

The need for the development of low-carbon urban transportation systems in large Asian cities faces significant challenges due to the increasing motorization with population growth and economic development. Sustainable urban public transportation (UPT) plays a crucial role in meeting ambitious carbon emission reduction targets. D. Dong et al., (2018) reveal in their research that carbon mitigation in Shenzhen through green transportation modes has low effectiveness. Total carbon emissions from UPT in Shenzhen increased from 0.70 Mt in 2005 to 1.74 Mt in 2015, caused by the rapid growth in transportation turnover volume with an average annual growth rate of 10.4%. Carbon emissions from UPT contribute 24% of the total carbon emissions from the transportation system in Shenzhen, while the subway and buses contribute more than 95%.

Large cities need to improve the energy efficiency of electric buses as a public transportation tool. This effort includes increasing battery life, reducing battery charging time, and strengthening fundamental supporting facilities. In addition, clean alternative energy must also be increased to reduce emissions. Large cities should also prioritize the development of underground trains as a mode of public transportation.

In line with D. Dong et al., (2018), Du et al., (2018) recommend energy efficiency policies more generally without limiting them to the public transportation sector alone. With the growth rate of urbanization, cities face double pressure to maintain economic growth while reducing carbon emissions. Cities play a key role in finding solutions to these pressures. Operating buses with routes on the city's road network is one of the basic scenarios for reducing carbon emissions. However, the implementation of energy efficiency policies is a fundamental basis that has a significant impact on total carbon emissions. The development and innovation of energy conservation technologies, with research and application in energy conservation and emission reduction technologies, are also driving factors.

Future Research Plan to Address Carbon Emissions in Various Cities in Indonesia

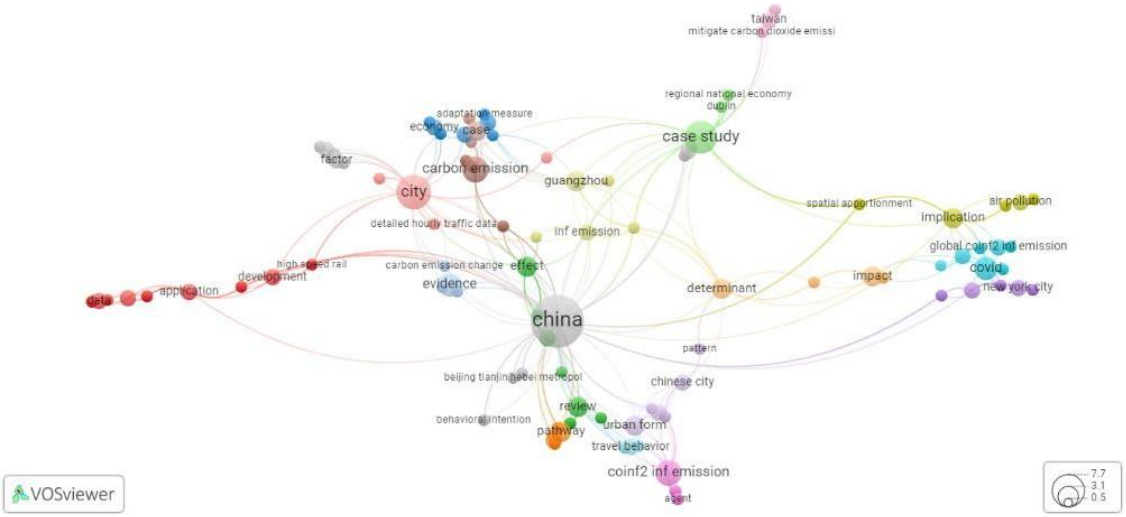

Figure 1. Visual Mapping of Networking by VOSviewer
Source: Research Results

The results of bibliometric analysis show several variables that have minimal research related to efforts to reduce carbon emissions. Therefore, a comprehensive future research plan can be formulated to address carbon emissions in various cities in Indonesia. These variables include:

1. City airport
2. Megacity
3. Climate change mitigation
4. Pathway
5. Urban form
6. Bike-sharing scheme
7. Public transport
8. Low carbon mobility transition
9. Multi-resolution Emission Inventory
10. Road transport
11. Economy
12. Alternative energy type
13. Mitigate carbon dioxide emission
14. Collective transport mode choice
15. Multi-agent transport
16. Travel behavior
17. Carbon Neutral Society
18. Environmental impact
19. Traffic data
20. Aggregate carbon intensity

CONCLUSION

This research aims to investigate the role of transportation policies in reducing carbon emissions in various cities in Indonesia. Given the significant increase in carbon emissions over the past two decades, this study seeks to understand how transportation policies can be an effective tool in transforming urban mobility behavior towards more environmentally friendly solutions.

The research methodology consists of two main stages: bibliometric analysis and benchmarking. Bibliometric analysis is used to quantitatively and measurably analyze scientific literature related to transportation policies and carbon emissions. Meanwhile, benchmarking is employed to compare transportation policies in various cities based on carbon emission and air quality data. Through these two methods, the researchers successfully identified various variables that need further investigation as part of a transportation policy development plan to reduce carbon emissions in different cities in Indonesia.

The research results indicate that transportation policies can have a significant impact on reducing carbon emissions, especially when applied judiciously. The study proposes four optimal transportation policy recommendations to address carbon emissions: urban-scale fossil fuel consumption calculations, spatial planning prioritizing sustainable transportation, the use of micro-electric vehicles (micromobility), and improved energy efficiency in transportation.

Furthermore, the research outlines future research plans for subsequent researchers on addressing carbon emissions in the transportation focus areas, including urban airports, megacities, climate change mitigation, pathways, urban forms, bike-sharing schemes, public transportation, low carbon mobility transition, multi-resolution emission inventory, road transport, the economy, alternative energy types, mitigating carbon dioxide emissions, collective transport mode choices, multi-agent transport, travel behavior, carbon-neutral societies, environmental impact, traffic data, and aggregate carbon intensity.

Beyond providing insights for policymakers to design more effective transportation policy strategies for reducing carbon emissions, this study is expected to raise awareness among urban populations about the importance of changing their mobility behavior in response to pressing environmental issues. Thus, this research makes a positive contribution to global efforts to preserve the quality of the urban environment and reduce the negative impacts of climate change.

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