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Examining the Potential of Micromobility to Reduce Urban Air Pollution and Associated Health Hazards

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Abstract

This study examines the relationship between micro-mobility usage and air quality across six major cities in Turkey, highlighting the environmental benefits of sustainable transportation systems. Micro-mobility, including e-scooters and bicycles, has emerged as a promising alternative to traditional fossil fuel-dependent modes of transport. To quantify the adoption of micro-mobility, a Micro-Mobility Usage Index (MMUI) was developed, using data on user frequency from the Moovit platform. Air quality indicators, PM2.5 and PM10, were derived from the World Air Pollution platform. Among the cities studied, Antalya displayed the highest MMUI score (61.4) and the lowest PM2.5 (54.7) and PM10 (51.2) levels, suggesting a strong link between high micro-mobility adoption and improved air quality. In contrast, Ankara had the highest PM2.5 concentration (99.2) and a lower MMUI (20.3). The Pearson correlation coefficients indicated a strong negative relationship between MMUI and air pollution levels, with values of -0.8932 for PM2.5 and -0.8364 for PM10. These findings underscore the potential of micro-mobility systems to mitigate urban air pollution, though challenges such as infrastructure and cultural acceptance remain critical.

Key words: Sustainable transportation, Health hazards, Air quality

1. Introduction

Worldwide, increasing environmental problems cause serious problems on human health. Especially air and water pollution, which are essential elements for human life, have an important place among these situations [1]. Air pollution, which occurs as a result of changes in the natural composition of the air, occurs with the increase of solid, liquid and gaseous foreign substances in the atmosphere. Air pollution, which increases with factors such as population growth, energy consumption, industrial development and urbanization, can harm human health, natural life, ecological balance and the environment.

The causes of air pollution include meteorological factors, location and topographical structure as well as foreign substances entering the atmosphere. Unplanned urbanization, lack of green areas and the use of fossil fuels are also among the important factors affecting air pollution. Air pollution causes problems at local, regional and global levels. In particular, climate change is an important global consequence of air pollution. A large proportion of human activities accelerate climate change by causing an increase in greenhouse gases [2].

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Excessive use of fossil fuels, deforestation and polluting habits pose a serious threat to the world. Although various measures have been taken to protect forest areas, adequate measures have not yet been taken regarding the use of petroleum products. The rapid increase in the number of motor vehicles based on petroleum products in the transportation sector also increases air pollution [3].

In recent years, economic and incentive measures have been taken to reduce the reliance on petroleum products and to move towards environmentally friendly transportation systems. In this framework, alternative transportation methods such as electric vehicles or public transportation systems, walking and cycling are encouraged instead of individual cars. These policies, referred to as sustainable transportation policies, adopt the main objective of discouraging the use of motor vehicles and increasing the use of more environmentally friendly modes of transportation [4].

There are many studies in the literature that address air pollution from transportation and examine the impact of sustainable transportation systems applied to reduce this pollution. Looking at the content of the studies, it is seen that studies on electric vehicles, pedestrian transportation, public transportation and micro mobility vehicles stand out [5-7]. Thanks to these studies, the environmental damage caused by fossil fuel-consuming vehicles is more clearly revealed, while the environmental advantages of alternative transportation sources are also revealed [8, 9].

In one of the studies, Bikis and Pandey conducted air quality measurements at public transportation stations in order to reveal the air pollution caused by public transportation systems. As a result of the measurements, it was determined that the PM2.5 value was quite high. In addition, it was determined that approximately 45% of the people living around the public transportation stations faced diseases related to air quality. As a result of the study, it was revealed that air pollution is higher at public transportation stations and people living in areas close to these stations have a higher risk of disease [10].

In a study examining the impact of electric vehicles on air pollution, Ferrero et al. conducted some experiments on a highway section in Milan, Italy. In these experiments, traffic emissions, meteorological parameters and chemical concentrations were measured. By simulating the measurement results with various scenarios, it was found that electric vehicles significantly reduce air pollution. In addition, even if the rate of electric vehicle use is low, it is determined that the preference of these vehicles during periods of intense air pollution will be significant in improving air quality [11].

The widespread use of pedestrian transportation not only has significant positive impacts on air pollution but also provides economic gains. In their study, revealed the distribution of harmful gases emitted by road transportation in Erzurum province of Turkey in a year according to vehicle types. The amount of fuel consumed annually was also determined according to the specified vehicle types and fuel type. As a result of the results obtained, it has been revealed that encouraging pedestrian transportation will provide significant advantages in terms of both air pollution and fuel consumption [12].

The effects of micro-mobility vehicles (such as bicycles and electric scooters) on air pollution and human health have been examined in various studies in recent years. For example, a health impact assessment study conducted in Barcelona found that increased use of e-scooters and e-bikes increased physical activity and contributed to preventing premature deaths. The same study also reported that the use of these vehicles reduced air pollution exposure and lowered risks related to traffic accidents [13]. Similarly, a study in Taipei showed that bicycle and e-scooter users are exposed to lower levels of air pollutants compared to vehicle commuters [14]. These findings highlight the role of micromobility tools in sustainable transport systems and their potential health benefits, but also suggest that their environmental impacts should be carefully considered.

Although micro-mobility solutions offer many advantages in terms of sustainable transportation, the potential negative impacts of these vehicles must be assessed in a more comprehensive and multidimensional manner. In particular, the production processes of electric scooters and bicycles raise questions about environmental sustainability in terms of battery-related carbon footprints and supply chain emissions. Additionally, the random abandonment or improper use of these vehicles within cities can lead service providers to use fossil fuel-powered vehicles to reposition them, thereby increasing local traffic congestion and emissions. The frequency of these redistribution processes varies depending on the type of vehicle used and logistics strategies, but it can lead to outcomes that contradict carbon-neutral goals, especially during periods of high demand. Additionally, the unplanned integration of micro-mobility infrastructure can lead to issues such as sidewalk obstruction, reduced pedestrian safety, and conflicts with other modes of transportation. As this mode of transportation becomes more widespread in the future, it is crucial for policymakers to address the aforementioned issues more clearly.

Existing studies in the literature reveal the importance of sustainable transportation systems in reducing air pollution. When the studies are examined, there is no study that clearly demonstrates the effect of the frequency of use of sustainable transportation modes on air quality in cities. It is especially important to reveal the extent to which the frequency of micro-mobility use contributes to sustainable transportation systems and thus to the reduction of air pollution. In this study, it is aimed to clearly reveal the relationship between the frequency of micro-mobility use and air quality in different cities in order to make an important contribution to the literature.

2. Materials and Method

2.1. Case study

The cities of Adana, Ankara, Antalya, Bursa, Bursa, Istanbul and Izmir in Turkey were selected as the study area. These cities are among the most populous cities in the country. Another common feature is that they have data on both the frequency of micro-mobility use and air quality indices. The diversity of the data distribution of these cities is very important in order to interpret the results of the study more efficiently. The population and locations of the cities in the study area are given in Table 1 [15].

Table 1. List of cities

No	City	Population (Million)	Latitude/longitude
1	Adana	2.270	36.59◦ N / 35.19◦ E
2	Ankara	5.803	39.56◦ N / 32.50◦ E
3	Antalya	2.696	36.54◦ N / 30.43◦ E
4	Bursa	3.250	40.11◦ N / 29.40◦ E
5	İstanbul	15.656	41.01◦ N / 29.00◦ E
6	İzmir	4.479	38.24◦ N / 27.10◦ W

Turkey, situated between Europe and Asia, has a highly developed road transportation network due to its strategic location on major trade routes. However, the cities within the country differ in terms of climate, economic activities, and transportation infrastructure.

Adana is located in the southern part of Turkey and has a hot Mediterranean climate. The average annual temperature is around 20°C, with heavy rainfall in December and January. The city is predominantly known for its agricultural production. Adana’s transportation system is well-structured, with a developed road network supporting intra-city and regional travel.

Ankara, the capital city, plays a key role as an administrative center. It has a continental climate, characterized by snowy winters and rainy spring months, with an average annual temperature of 11°C. The city's transportation system is well developed, particularly in terms of road and rail networks. Traffic congestion often occurs in areas close to government institutions.

Antalya, like Adana, is located in the south and lies on the Mediterranean coast. It is a major tourism destination, with a population that increases significantly in the summer months. The city has an average temperature of 20°C and receives winter rainfall. While road transportation dominates, its overall transportation network is less developed compared to cities of similar size.

Bursa, situated in the Marmara Region, experiences a generally mild climate with an annual average temperature of 15°C. Rainfall is more frequent in the winter months. The city is a hub for industrial activities, particularly in automotive, textile, and furniture sectors. In addition to road transport, a light rail system is actively used within the city.

Istanbul is Turkey’s most populous city and a major global center, especially in trade. The city has a 14°C average annual temperature and significant rainfall in December and January. Divided by the Marmara Strait, Istanbul connects the continents via bridges, tunnels, and maritime transport. Although it has an extensive transportation network including road, rail, and sea routes, traffic congestion remains a major issue due to the high number of vehicles.

Izmir, located on the Aegean coast in the western part of the country, is an important city for trade and tourism. Its port plays a key role in commercial activities, and the population rises during the summer months due to tourism. The city has an average temperature of 18°C and receives rainfall mostly in the winter. Transportation modes including highways, railways, and maritime lines are all well developed. Figure 1 illustrates the geographical locations of the cities discussed.

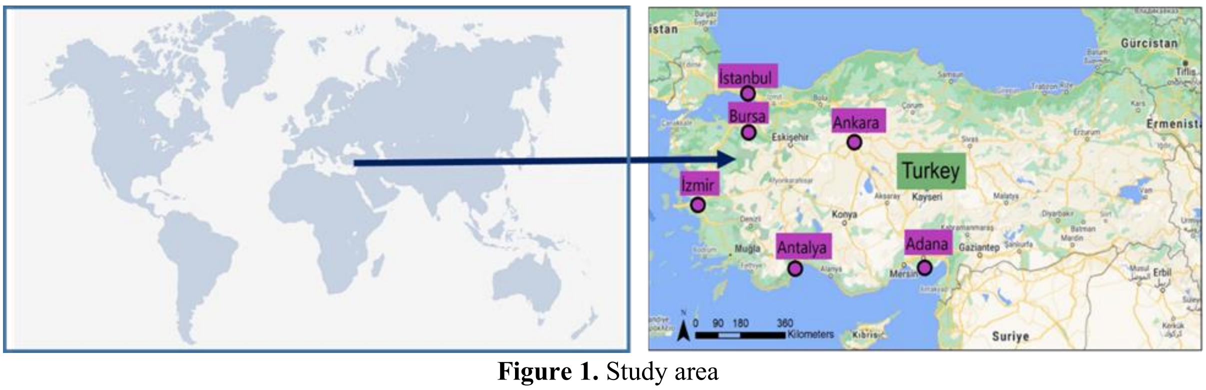

Figure 1. Study area

2.2. Method

In order to determine the relationship between the frequency of micro-mobility use and air quality, the study needed the frequency of use of micro-mobility vehicles in each city and the PM10 and PM2.5 levels measured in these cities. Data on the frequency of use of micro mobility vehicles was obtained from the Moovit platform. As a result of its investigations in the study area, this platform has proportionally revealed the frequency of bicycle and e-scooter use by people in 2022. The PM10 and PM2.5 values, which are the most prominent pollutants among the daily air quality indices for 2022, were obtained from the World Air Pollution platform. Particulate matter, known as PM10 and PM2.5, remain suspended in the air and can reach the lungs through inhalation. These two pollutants are very dangerous for human health. The air quality index value in a region is calculated using Equations 1 and 2.

$$AQI = \max\ (IAQI_1\,, IAQI_2, \dots \dots .. IAQI_n) \tag{1}$$

$$I_{AQI} = \frac{I_h - I_l}{C_h - C_l} \times (C - C_l) + I_l \tag{2}$$

Where I_{AQI} = the Individual Air Quality Index, n=the pollution project (PM2.5 and PM10), I_h *and* I_l = AQI limits, C_h *and* C_l = the pollutant concentration limits, C = the input value, the pollutant concentration [16]. Table 2 shows PM2.5 and PM10 air pollutant concentration limits.

Table 2. PM2.5 and PM10 air pollutants concentration limits [17]

AQI value of index	PM2.5 concentration (µg/m3)	PM10 concentration (µg/m3)	Air pollution level
0–50	0–12	0–54	Level 1
51–100	12.1–35.4	55–154	Level 2
101–150	35.5–55.4	155–254	Level 3
151–200	55.5–150.4	255–354	Level 4
201–300	150.5–250.4	355–424	Level 5
301 and Higher	250.5–Higher	425–Higher	Level 6

The Pearson correlation coefficient is a statistical measure used to assess both the direction and the magnitude of the linear association between two variables. It is commonly applied to evaluate how a variation in one variable may be associated with changes in another. This coefficient ranges from −1 to +1, where positive values indicate a direct (positive) linear relationship, and negative values signify an inverse (negative) linear relationship. Values approaching +1 or −1 suggest a stronger correlation. The formula for Pearson's correlation coefficient is given below in Equations 3.

$$r = \frac{\sum_{i=1}^{n}[(x_i - \bar{x}) \times (y_i - \bar{y})]}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2} \times \sqrt{\sum_{i=1}^{n}(y_i - \bar{y})^2}} \tag{3}$$

In this context, x_i and y_i correspond to the low-frequency impedance at 0.01 Hz ($|Z|_{0.01}$Hz) and the phase angle (θ), respectively. For interpreting the correlation strength, the criteria outlined in Table 3 are typically considered.

Table 3. Interpreting Correlation Coefficient [18]

Absolute Magnitude of the Observed Correlation Coefficient	Interpretation
0.00–0.10	Negligible correlation
0.10–0.39	Weak correlation
0.40–0.69	Moderate correlation
0.70–0.89	Strong correlation
0.90–1.00	Very strong correlation

3. Results

Urban areas have increasingly embraced micro-mobility solutions such as e-scooters, bicycles, and shared mobility systems as sustainable alternatives to traditional transportation. Moovit, a leading mobility platform, has categorized micro-mobility usage into five distinct frequency levels to better understand user behavior: "Daily," "Frequently," "Occasionally," "Rarely," and "Never." These categories provide a comprehensive perspective on how residents in different cities utilize micro-mobility options, reflecting variations in infrastructure availability, cultural attitudes, and commuting habits. For instance, individuals categorized as "Daily" users heavily rely on these solutions as part of their routine, whereas "Occasionally" and "Rarely" users might consider these options situationally or as backups to other transportation methods.

In the article titled An Assessment of the Relationship Between Micro-Mobility Use and Air Quality in Selected Cities, a detailed index—known as the Micro-Mobility Usage Index (MMUI)—was developed to quantify the extent of micro-mobility adoption in urban environments [19]. This formula aggregates usage frequency across populations by assigning weighted values to each frequency category:

$$MMUI=(365\times N_D)+(156\times N_F)+(60\times N_O)+(4\times N_R)+(0\times N_N) \quad (4)$$

Here, N_D, N_F, N_O, N_R, and N_N represent the number of individuals in the categories "Daily," "Frequently," "Occasionally," "Rarely," and "Never," respectively. This weighted approach allows for the translation of qualitative frequency data into a quantitative measure that can be compared across different urban areas, providing insights into how intensively cities embrace micro-mobility. Figure 2 shows the micro-mobility usage frequency by cities.

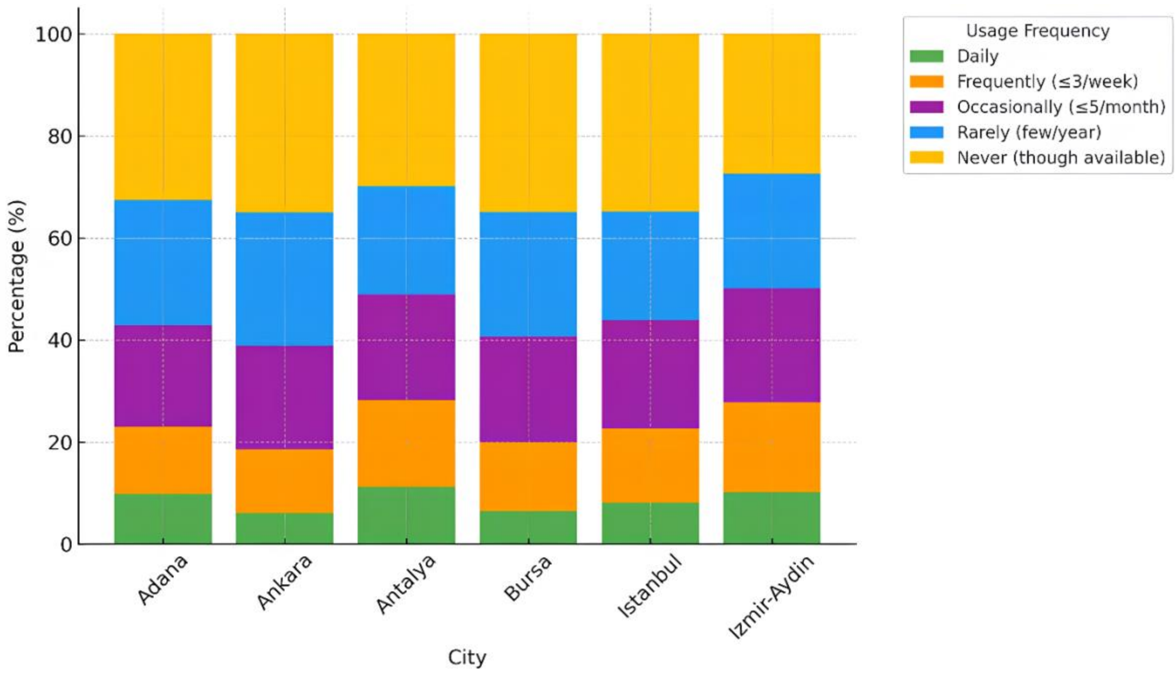

Figure 2. Micro-mobility usage frequency by cities

The chart illustrates the frequency of micro-mobility usage across six major cities in Turkey. Antalya stands out with the highest percentage of "Daily" users at 10.4%, reflecting a stronger integration of micro-mobility into daily routines compared to other cities. Similarly, the city also has a higher percentage of "Frequently" (10.4%) and "Occasionally" (10.45%) users, suggesting a broader acceptance and accessibility of micro-mobility solutions. In contrast, cities like Bursa and Adana have the largest proportions of "Never" users, at 63.4% and 63.2% respectively, indicating potential barriers such as lack of infrastructure or cultural reluctance to adopt such modes of transport.

Interestingly, Izmir exhibits a relatively balanced distribution across the categories, with significant usage even among the "Occasionally" (10.35%) and "Rarely" (35.8%) groups. This distribution may point to growing interest but insufficient adoption for daily use. Istanbul, despite being Turkey's largest city, has a notable proportion of "Rarely" (26.7%) and "Never" (58.1%) users, reflecting possible limitations in integrating micro-mobility into a complex urban environment. Overall, the data highlights significant regional disparities in micro-mobility adoption, shaped by factors such as infrastructure availability, cultural preferences, and urban planning.

The relationship between micro-mobility use and air quality has been a subject of growing interest. Increased adoption of micro-mobility solutions can potentially lead to reduced dependence on fossil fuel-based vehicles, thereby lowering urban air pollution levels. Cities with higher MMUI scores may exhibit improved air quality, as micro-mobility options provide an eco-friendly alternative for short-distance commutes. However, the impact is not universally positive; shared e-scooters and bicycles, if not well-integrated into urban planning, might contribute indirectly to traffic congestion or emissions during their production and maintenance cycles. Further research is essential to fully understand this dynamic and optimize the integration of micro-mobility systems for both environmental and social benefits. Figure 3 shows the relationship between micro-mobility usage frequencies and air quality indices for cities.

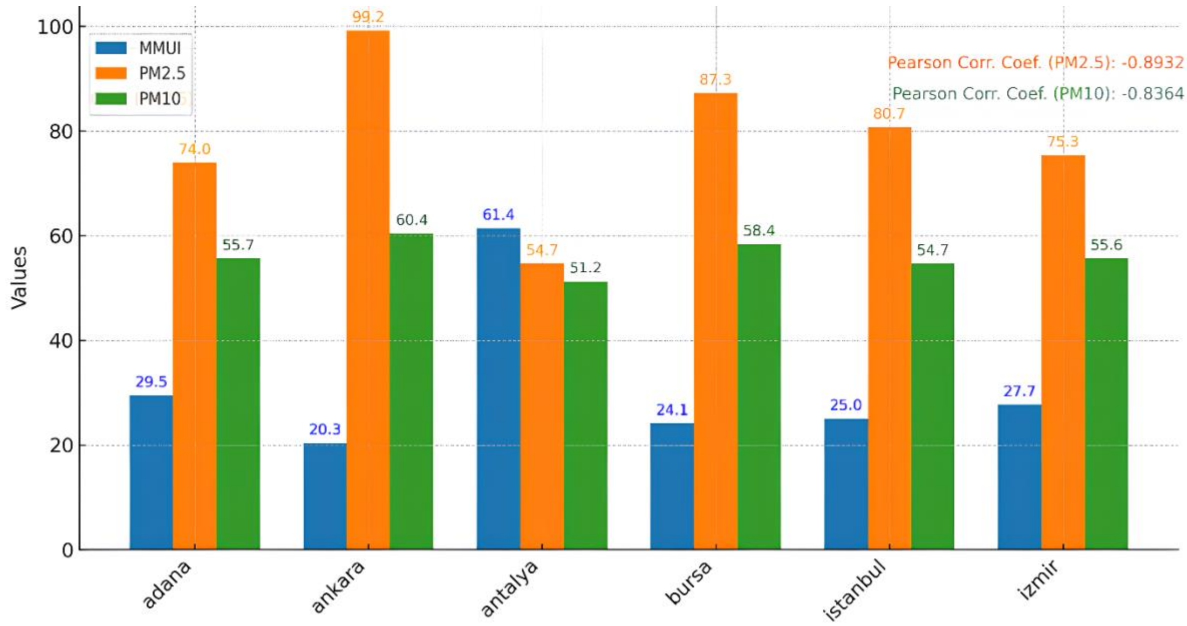

Figure 3. Air Quality and MMUI analysis

The provided chart illustrates the relationship between micro-mobility usage intensity (MMUI) and air quality indicators (PM2.5 and PM10 levels) across six cities in Turkey: Adana, Ankara, Antalya, Bursa, Istanbul, and Izmir. The MMUI values, represented by blue bars, indicate the extent of micro-mobility adoption, while orange and green bars correspond to air pollution levels of PM2.5 and PM10, respectively.

Ankara stands out with the highest PM2.5 concentration (99.2) and relatively low MMUI (20.3). Similarly, Bursa has high PM2.5 (87.3) but a low MMUI (24.1), suggesting that these cities might rely more on traditional transportation modes, contributing to higher pollution. Conversely, Antalya, with the highest MMUI (61.4), shows significantly lower PM2.5 (54.7) and PM10 (51.2) levels, indicating a possible positive impact of micro-mobility on air quality. Adana and Izmir exhibit moderate MMUI and pollution levels, while Istanbul, despite its dense urban population, maintains mid-range pollution levels with relatively low MMUI.

The Pearson correlation coefficients reveal a strong negative relationship between MMUI and both PM2.5 (-0.8932) and PM10 (-0.8364). These coefficients suggest that increased micro-mobility use is associated with reduced particulate matter levels, emphasizing the potential role of sustainable transportation in mitigating urban air pollution.

4. Discussion

This analysis highlights significant urban variations in micro-mobility usage and air quality, underscoring the complex interplay between transportation modes and environmental factors. The strong negative correlation between MMUI and particulate matter levels suggests that promoting micro-mobility can be an effective strategy for improving air quality. Cities like Antalya demonstrate the potential benefits of integrating micro-mobility into urban transport systems, as reflected in lower pollution levels and higher MMUI.

However, cities such as Ankara and Bursa, with high PM2.5 and PM10 levels, illustrate the challenges of reducing air pollution in urban areas heavily dependent on conventional transport. These findings emphasize the importance of policy interventions, such as infrastructure development, subsidies for micro-mobility services, and public awareness campaigns, to encourage the adoption of sustainable transport solutions. Additionally, air quality improvement initiatives must address other sources of pollution, such as industrial emissions and energy production, to achieve comprehensive results.

One important limitation of the study is related to the data source used for estimating micromobility usage. The Moovit app data may not fully represent the entire population, especially in cities where app usage is low or unevenly distributed among different socioeconomic groups. Therefore, the MMUI values should be interpreted with caution, as they may reflect app user behavior rather than the general population's actual micromobility usage. Future studies may consider combining multiple data sources to increase representativeness.

Future research should explore the causal mechanisms linking micro-mobility adoption to air quality improvements. Longitudinal studies could help determine whether increasing MMUI directly leads to reduced pollution or if other factors, such as city-specific policies and infrastructure investments, play a more significant role. Moreover, qualitative research could provide insights into user behavior and barriers to adoption, enabling cities to tailor interventions effectively.

This study underscores the critical role of sustainable transportation in achieving urban environmental goals. While the data shows promising trends, addressing systemic challenges and ensuring equitable access to micro-mobility services are key to maximizing their environmental benefits.

5. Conclusions

This study emphasizes the critical role of micro-mobility in reducing urban air pollution. The findings highlight significant variations among the six studied cities in Turkey, illustrating the environmental advantages of adopting sustainable transportation systems. Antalya, with the highest MMUI score, stands out as a model city, demonstrating the potential benefits of widespread micro-mobility use. The significant negative correlation between MMUI and air pollution levels reveals the effectiveness of micro-mobility in reducing harmful particulate matter concentrations.

The results suggest that cities with higher micro-mobility adoption rates tend to experience better air quality, as evidenced by lower PM2.5 and PM10 levels. This relationship underscores the importance of investing in infrastructure to support micro-mobility, such as dedicated bike lanes and e-scooter parking areas. Additionally, public awareness campaigns and incentives can play a pivotal role in encouraging greater adoption of sustainable transportation modes.

To strengthen the policy implications of this study, city-specific recommendations should be considered in alignment with the existing infrastructure and socio-cultural context of each urban area. For instance, Adana, with its relatively flat topography and wide roads, is well-suited for the rapid deployment of protected bike lanes and shared e-scooter networks, particularly in central business districts. In Ankara, where micro-mobility usage remains limited due to steep gradients and car-centric planning, investment should prioritize multimodal integration—such as secure e-bike parking at metro stations and subsidized transfers between modes—to enhance usability. Antalya, already performing well in micro-mobility adoption, can serve as a pilot site for smart mobility innovations like geofenced zones and dynamic pricing to manage usage and prevent sidewalk clutter. Bursa, with its industrial layout and dispersed settlement structure, would benefit from establishing inter-district micro-mobility corridors and targeted awareness campaigns to shift perceptions about vehicle alternatives. In Istanbul, given its population density and traffic congestion, a zoning-based regulatory framework that limits private car access and prioritizes micro-mobility in selected areas (e.g., historic districts, coastal promenades) could yield significant environmental gains. Lastly, Izmir should capitalize on its ongoing sustainable transport initiatives by expanding its existing bike-sharing system to underserved neighborhoods and integrating it with real-time transit apps to facilitate journey planning. These localized strategies provide a more actionable roadmap for advancing urban air quality goals through micro-mobility integration.

Future research should explore the causal mechanisms behind the observed correlations, focusing on longitudinal analyses to determine the direct impact of micro-mobility on air quality. Furthermore, qualitative studies could provide valuable insights into user behavior and barriers to adoption, helping policymakers design more effective strategies. Overall, this study contributes to the growing body of evidence supporting the integration of sustainable transportation systems into urban planning to combat air pollution and promote healthier living environments.

Conflict of Interest

No conflict of interest declared by the Author.

Author Contribution

The whole paper is prepared by one Author.

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