



**SOCIETAL PERCEPTION AND SOCIOECONOMIC
VULNERABILITY TO TRAFFIC-INDUCED-AIR POLLUTION IN THE
RAPIDLY URBANIZING CITY OF KUALA LUMPUR, MALAYSIA**

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Abstract

Traffic activities from a high volume of automobiles are the main cause of urban air quality deterioration that affects public health. This study focuses on the link between socioeconomic status and their perception of the causes of urban traffic pollution from motor vehicles and traffic activities in the equatorial city of Kuala Lumpur, Malaysia. Several statistical techniques, including chi-square and exploratory factor analysis, analyzed the survey data of 200 residents. The results showed more than half of the respondents perceived a basic knowledge of traffic pollution and over 70% were aware of the negative impact of air pollution on human health. However, only 58% of the residents positively identified the technical processes of the sources of traffic pollution. Instead of emissions from motor vehicles, most of the respondents perceived that environmental factors are significant contributors to urban pollution. Furthermore, the residents' awareness and attitudes towards vehicular traffic pollution are influenced by socioeconomic aspects, such as the level of education, gender, and age. Understanding the impact of socioeconomic status differences among the residents is crucial in addressing the issue of deteriorating urban air quality and reducing the negative impacts faced by vulnerable urban low-income communities.

Keywords: Urban Traffic Pollution, Societal Perception, Socioeconomic Status, Statistical Analysis, Kuala Lumpur, Malaysia

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INTRODUCTION

Urbanization and rapid economic development in cities worldwide have significantly increased the reliance on vehicles, leading to high levels of traffic-induced air pollution. This issue is prevalent in many urban centers globally, particularly in densely populated cities, where vehicular emissions are a major source of fine particulate matter (PM_{2.5}), nitrogen oxides (NO_x), and other air pollutants (Ali et al., 2021). Traffic-induced air pollution affects public health by increasing the risk of respiratory and cardiovascular diseases and contributes to climate change and environmental degradation. Furthermore, the perception of air pollution among urban residents is shaped by socioeconomic factors such as income, education, and occupation, which vary across regions and demographics (Mahmood et al., 2022).

Globally, there is a growing recognition of the importance of understanding public perception as part of a holistic approach to tackling air pollution. Research has shown how residents' perception of air pollution affects their willingness to engage in mitigation efforts and support policy measures. For instance, studies conducted in Europe, North America, and parts of Asia have demonstrated that socioeconomic characteristics significantly influence the perception of traffic-induced air pollution and the acceptance of measures like congestion charges and emissions regulations (Shen et al., 2023). Despite this, disparities remain in how these perceptions are studied across regions, with limited focus on rapidly urbanizing cities in developing nations.

In Southeast Asia, particularly in cities like Kuala Lumpur, Malaysia, the issue of traffic-induced air pollution is compounded by rapid urban growth and insufficient public transportation systems. Despite the global emphasis on achieving sustainable urban development as outlined in the United Nations Sustainable Development Goal (SDG) 11, there remains a gap in the literature regarding how socioeconomic factors shape the perception of air pollution in this region (Ismail et al., 2023). Most studies on urban air pollution have focused on its technical aspects, such as emission inventories and health impacts, while neglecting the socioeconomic and behavioural dimensions. Addressing this gap is crucial for developing inclusive policies that integrate public perceptions and foster collective action toward sustainable urban development.

Moreover, the socioeconomic characteristics of urban residents often determine their exposure levels to air pollution, as well as their coping mechanisms. For example, low-income groups are more likely to live in areas with higher levels of pollution, such as near major highways or industrial zones, and may have limited access to healthcare or air-purifying technologies (Rahman et al., 2023). These disparities emphasize the importance of studying public perception in the context of socioeconomic vulnerability, as it can provide

insights into the unequal distribution of environmental risks and the necessity for targeted interventions.

The findings from studies on socioeconomic influences on air pollution perception could also aid in designing tailored awareness campaigns and urban planning strategies. Public perception shapes the political will to implement environmentally friendly policies, such as promoting the use of electric vehicles or improving public transportation systems. By integrating socioeconomic perspectives into urban environmental management, policymakers can address both the technical and social dimensions of traffic-induced air pollution, thereby ensuring sustainable urban development in cities like Kuala Lumpur. This study investigates the impact of socioeconomic characteristics on urban residents' perceptions and attitudes toward traffic-induced air pollution in Kuala Lumpur, Malaysia. This emphasizes the importance of understanding public perceptions for the successful implementation of technologies and promoting environmentally friendly policies. The findings can support the design of awareness campaigns and urban planning strategies, addressing disparities in socioeconomic status and promoting integrated awareness campaigns. This approach can protect vulnerable communities and foster sustainable urban development in Kuala Lumpur. This study offers a novel contribution by integrating socioeconomic vulnerability, environmental perception, and behavioural awareness within a rapidly urbanising Malaysian metropolis. Unlike previous studies that primarily emphasise technical emission assessments or health impacts, this research highlights the social and perceptual dimensions of traffic-induced air pollution, providing context-specific evidence to support inclusive urban environmental governance in Southeast Asia.

DATA AND MATERIALS

The study area selected for this research is Kuala Lumpur, situated in the Klang Valley region of Peninsular Malaysia, covering an area of 24,221 hectares (Figure 1). Kuala Lumpur City Hall (KLCH), a governmental body under the Federal Ministry, manages development in Kuala Lumpur. The city comprises six strategic zones: Sentul-Manjalara, Wangsa Maju-Maluri, Bandar Tun Razak-Sungai Besi, Damansara-Penchala, and Kuala Lumpur City Centre. The population of Kuala Lumpur was estimated at 1.9 million in 2019 (KLCH, 2023).

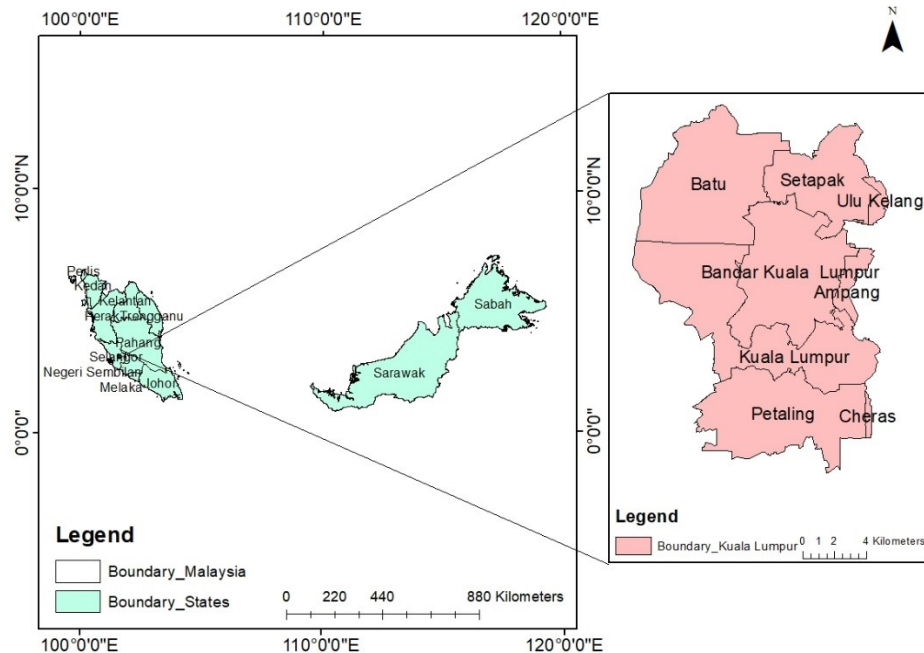


Figure 1: Map of Six Strategic Zones in Kuala Lumpur

A socioeconomic survey was conducted with a sample size of 200 Kuala Lumpur residents, determined using a simple random sampling technique. This method, which ensures each individual in a large population group has an equal chance of being selected, is straightforward and produces a structured study output. However, it can be resource-intensive and complex. A sufficiently large sample size was chosen to address the study objectives. The questionnaire included three sections: (1) background profile, (2) knowledge of traffic pollution, and (3) public awareness of traffic pollution. Several statistical methods were employed. The cross-tabulation technique identified relationships between various socioeconomic variables (Smith et al., 2022), meanwhile, the relationship between socioeconomic status and public perception and awareness was analyzed using the chi-square test. The significance of multivariate relationships among measured variables was examined using exploratory factor analysis (EFA). The chi-square test was selected due to its suitability for examining associations between categorical socioeconomic variables and perception indicators. Exploratory factor analysis was employed to identify latent constructs underlying respondents' perceptions and awareness patterns. These techniques were preferred over regression-based approaches due to the categorical nature of the data and the exploratory objective of this study.

The chi-square analysis is a statistical method that uses frequency data to evaluate significant relationships between categorical variables. The hypothesis testing for the chi-square test of independence involves computing a test statistic, which is compared to a critical value determined by the significance level ($p < 0.05$) and degrees of freedom (Lee & Tan, 2021). In this study, differences in socioeconomic status influencing residents' perceptions of traffic pollution were analyzed based on gender, age, race, education level, and income. Socioeconomic differences were examined in relation to factors such as causes of traffic pollution, pollution levels, exposure, environmental and health impacts, and mitigation efforts to address short- and long-term effects of traffic pollution.

Exploratory factor analysis (EFA) was employed to identify, reduce, and organize questionnaire items into specific constructs under one dependent variable. In the EFA process, each questionnaire item was treated as a factor. The process included three stages: identifying correlations between factors, factor extraction, and factor rotation (Nguyen, 2023). Principal Component Analysis (PCA) was used for factor extraction to minimize the number of factors while explaining the maximum variance. Orthogonal rotation using Varimax with Kaiser Normalization was conducted in SPSS software to clarify relationships between items and factors and distinguish factor relationships. Interpretation of results depended on the researcher's judgment to define the constructs measured by each factor. While EFA is data-driven and can vary in its outcomes, it requires three key conditions: an appropriate measurement scale, a sufficient number of questionnaire items, and a sample size that represents normality.

RESULTS AND DISCUSSION

The Demographic Background of Kuala Lumpur Residents

As shown in Table 1, the majority of respondents belong to low-income households, indicating a high level of socioeconomic vulnerability. In summary, the majority of the respondents are Malay males between the ages of 31 and 50 years old and acquired a secondary level of education (Table 1). They mostly work in the private sector and earn less than RM 2,000 a month. In terms of income, 37% earn less than RM2,000 (USD 484) while 33% earn between RM2,000 to RM3,000 per month. This shows that 96% of the respondents earn less than RM4,000 (USD 725) a month. According to the Household Income and Basic Facilities Survey conducted by the Department of Statistics Malaysia, the median household income for the B40 income group is RM 3,000 while the median income for the Federal Territory of Kuala Lumpur is RM 7,620 for M40 in 2022 (Department of Statistics Malaysia, 2022). The term B40 represents the bottom 40% of the lowest income group, while M40 represents the middle 40% of the income group. In this light, approximately 96% of the respondents are from the low-income group or the urban poor, based on the median value of income in

the Federal Territory of Kuala Lumpur. The urban poor constitute a quarter of Kuala Lumpur's households (Ridzwan & Idris, 2020). Nearly 63% of respondents live in the major areas of the city, 29% live in the suburbs, and 9% live in newly developed areas.

Table 1: Demography Profile of Respondents in Kuala Lumpur

Item		N	Percentage (%)
Gender	Men	114	57
	Women	86	43
Race	Malay	114	72
	Chinese	19	9.5
	Indian	32	16
	Others	5	2.5
Age	Younger (<18 - 30 years)	71	35.5
	Adult (31 – 50 years)	101	50.5
	Elderly (51 - > 60 years)	28	14
Level of Education	School (Primary and Secondary)	99	49.5
	Pre-Graduated (Diploma and First Degree)	87	43.5
	Post-Graduated (Masters and PhD)	14	7
Occupation sector	Government	42	21
	Private	94	47
	Self-employed	63	31.5
	Housewife	1	5
Income	< RM2000	87	43.5
	RM2000 - RM4000	105	52.5
	> RM4000	8	4

The Influence of Socioeconomic Background on the Respondents' Perceptions, Knowledge, and Awareness

The determination of the significant relationship between variables utilizes the Chi-square test and exploratory factor analysis (EFA). The cross-tabulation analysis summarized that the educated middle-aged masculine gender in Kuala Lumpur, between the ages of 31 and 50 years significantly influenced the level of perception and awareness against urban traffic pollution (Table 2).

Table 2: Respondent's socioeconomic background influencing the perception of urban traffic pollution in Kuala Lumpur

No.	Details/Questions	Respondent's Socioeconomic Background			of
		Gender (Men)	Age (Middle age between 31-50 years)	Level of education (Secondary School)	
<i>Basic knowledge on traffic pollution (%)</i>					
1.	What is the sources/causes of traffic pollution?	51.8	62.9	49.5	
2.	What is the main pollutant of traffic pollution?	90.4	91.4	89.5	
3.	Where is the highest pollutant released?	86.8	84.3	87.4	
4.	What are the main components of a motor vehicle that emit pollutants?	99.1	100	100	
5.	What is the main driving pattern that emitted highest of pollutants?	78.1	85.7	83.2	
6.	What is the average speed of a vehicle releasing maximum traffic pollutants?	66.7	78.6	62.1	
7.	When does traffic pollution occur seriously?	65.8	60	50.5	
<i>Information and definition of RON (%)</i>					
8.	RON is a mixture of two basic elements namely octane and pentane which complement the properties of petrol?	66.7	65.7	41.1	
9.	Does a higher RON value result in more powerful engine performance?	96.5	92.9	93.7	
10.	Does RON97 provide more acceleration power but more efficient in terms of combustion rate than RON95?	98.2	97.1	96.8	
11.	Does RON97 have a more positive impact on the environment than RON95?	98.2	97.1	95.8	
12.	How do RON differences have a positive impact on the environment?	54.4	64.2	64.2	

No.	Details/Questions	Respondent's Socioeconomic Background		
		Gender (Men)	Age (Middle age between 31-50 years)	Level of education (Secondary School)
13.	What is the main choice of fuel among the population?	75.4	71.4	87.4
14.	What are RON95 and RON97 petrol selection factors?	76.3	75.7	88.4
<i>Human health effects (%)</i>				
15.	Does traffic pollution have a serious impact on an individual's health?	98.2	98.6	96.8
16.	Do different types of pollutants determine the differences in diseases experienced by individuals?	91.2	88.6	84.2
17.	What are the most high-risk traffic pollutants against individual diseases?	67.5	75.7	73.7
18.	Who are the most vulnerable and high-risk groups?	27.2	45.7	31.6
<i>Physical factors of motor vehicles emitted the air pollutants (%)</i>				
19.	Emissions from exhaust under stable thermal engine operation	42.1	42.9	44.2
20.	Emissions from the exhaust during vehicle operation	63.2	70	60
21.	Direct emissions from the process of evaporation of fuel	63.2	64.3	58.9
22.	Particle emissions from vehicle movement operations from the road surface	41.2	40	43.2
<i>Ambient environmental factors of air pollutants emissions (%)</i>				
23.	Wind speed	69.3	72.9	67.4
24.	Wind direction	65.8	57.1	67.4
25.	Topography	55.3	57.1	56.8
26.	Building position along the road	64	65.7	67.4
27.	Green surfaces in urban areas	56.1	54.3	51.6

No.	Details/Questions	Respondent's Socioeconomic Background			of
		Gender (Men)	Age (Middle age between 31-50 years)	Level education (Secondary School)	
<i>Types of diseases and health effect to the population (%)</i>					
28.	Pneumonia	72.8	78.6	72.6	
29.	Born of premature and under weight babies	37.7	47.1	46.3	
30.	Childhood leukaemia	48.2	51.4	47.4	
31.	Premature infant deaths	50.9	57.1	57.9	
32.	Increase of allergy risks	36.8	45.7	43.2	
33.	Lung cancer	65.8	61.4	66.3	
34.	Asthma	68.4	65.7	78.9	
<i>Strategies and control measures of traffic pollution (%)</i>					
35.	Use effective and conducive public transport	68.4	70	76.8	
36.	Incentives / rewards for public transport users	70.2	72.9	74.7	
37.	Carpooling in major cities	67.5	68.6	73.7	
38.	Increase fuel prices (petrol & diesel)	39.5	37.1	33.7	
39.	Imposes high charges on drivers who use congested and busy roads during peak hours	36.0	31.4	36.8	
40.	Invention of high performing engines	53.5	67.1	47.4	
41.	The use of high technology catalytic converter	61.4	71.4	52.6	
42.	Improve chemical processes in petrol and diesel fuels	46.5	52.9	43.2	
43.	Vehicles with Hybrid technology	68.4	72.9	68.4	
44.	Electric powered vehicles	69.3	72.9	69.5	

Chi-Square Test Analysis

Gender

This section seeks to determine the role of gender in influencing the perception of traffic pollution. The chi-square test was tested with the null hypothesis that there was no relationship between gender and the question posed. There is a significant relationship among the male population of Kuala Lumpur with a value of $p = 0.016$ regarding the question of "RON is a mixture of two basic elements

namely octane and pentane" (Table 3). In addition, men were significantly knowledgeable when answering the question on "Exhaust from the exhaust during engine operation" with a value of $p = 0.03$. The male gender is more knowledgeable about the physicality of the vehicle and the fuel used in the vehicle movement process.

In terms of the health effects of traffic pollution on the population, male respondents still showed a significant result with $p = 0.041$ to the question on the type of pollutants that determine the differences in diseases experienced by the population. Male respondents also demonstrated significant findings on "the most high-risk traffic pollutants against disease" with $p = 0.015$. These results prove that male respondents are aware of the negative impact of traffic pollution on health.

Table 3: Chi-Square Test Analysis Result Based on Gender, Age, And Education Level

No.	Details/Questions	Significance level ($p < 0.05$)
Gender		
<i>Knowledge on RON</i>		
1.	RON is a mixture of octane and pentane	0.016
<i>Effects on human health</i>		
1.	The type of pollutants determines the type of diseases	0.041
2.	High-risk traffic pollutants	0.015
<i>Vehicle physical factors that influence traffic pollutants</i>		
1.	Emission from vehicle's exhaust during engine operation	0.03
Age		
<i>Effects towards human health</i>		
1.	Traffic pollutants have adverse effects on human health	0.029
2.	The type of pollutants determines the type of diseases	0.045
<i>The effect on Ambient Environment on Traffic pollution</i>		
1.	Diverse use of city land	0.012
<i>Types of diseases and health effect to the population</i>		
1.	Premature infant deaths	0.005
2.	Increase of allergy risks	0.014
The level of education		
<i>Cause of traffic pollution</i>		
1.	Location with the highest number of pollutants.	0.024
2.	Vehicle component which emit pollutants	0
3.	Average vehicle speed, which emits the maximum traffic pollutants.	0.049

Age

Residents aged between 31 to 50 years are knowledgeable on the ill effects of traffic pollution to health, with a significant p-value of 0.029. This age group is also aware of the differences in the types of pollutants related to the type of diseases with a significant p of 0.045. In addition, there is also a strong relationship between the maturity of the middle-aged population and the effects of ambient environmental factors, specifically due to the diversification of urban land use ($p = 0.012$). They are also aware of the health complications brought by traffic pollution, including premature infant death and increased risk of allergies, with significant values of $p = 0.005$ and 0.014 , respectively.

Level of Education

There is a strong link between the level of education and the perception of the residents toward traffic pollution as well as issues brought by traffic pollution, specifically health effects and risk of diseases. The question of whether urban roads recorded the highest level of pollutants showed a significant result with a p-value of 0.024. Concurrently, the exhaust being the main vehicle component that emits pollutants is significant at a p-value of 0. The respondents also provide a significant answer to the question of whether a vehicle speed of > 70 mph will release the highest level of pollutants with a value of $p = 0.049$.

EXPLORATORY FACTOR ANALYSIS (EFA)

Table 4 summarises the factor loadings derived from the EFA, highlighting the dominant environmental and behavioural perception patterns. Based on the results of the EFA, the main factors are identified to uncover the underlying structure of a set of variables. Factor 1 contains various items in the questionnaire selected by residents that refer to sources of traffic pollution from non-vehicles with the highest eigenvalue of 3.780 (Table 4). Factor 2 consists of three items, namely on the knowledge of exposure to pollutants with an eigenvalue of 2.478. Factor 3 recorded the lowest eigenvalue of 1.401, which refers to the sources of emissions of pollutants from vehicles. The overall combination of variance for the three factors is 69.62%, with 34.364% for factor 1, factor 2 = 22.523%, and factor 3 = 12.733%. The results of the analysis on the residents' exposure to traffic pollutants in Kuala Lumpur explained that the level of knowledge and perception on the contributing factors to traffic pollution is low, particularly on the physical factors of traffic pollution. Factor naming was based on theoretical relevance, dominant item loadings, and conceptual coherence with established literature on urban environmental perception and exposure behaviour.

Table 4: Knowledge on Traffic Pollution in Kuala Lumpur

Questionnaire Items	Factor		
	1	2	3
1. Position of buildings along the road	0.869		
2. Topography and the earth's landscape	0.857		
3. Wind direction	0.755		
4. Diversity of urban land use	0.673		
5. Wind speed	0.665		
6. Green surface in urban areas	0.603		
7. Walking along the road without wearing a mask		0.929	
8. Cycling along the road without wearing a mask		0.919	
9. Driving a vehicle while opening the vehicle window		0.903	
10. Emission from the exhaust during temporary engine operation after the engine started			0.709
11. Direct emission from the process of fuel evaporation			0.672
Eigenvalue	3.780	2.478	1.401
% Variance	34.364	22.523	12.733
Cumulative Variance	34.364	56.887	69.620

Table 5 shows the results on the impact of traffic pollution on public health and the proposed measures to control traffic pollution in Kuala Lumpur. In total, there are three main factors with a total percentage variance of 68.493% consisting of factor 1 at 28.51%; factor 2 at 23.329%, and factor 3 at 16.654%. Factor 1 relates to the health issues regarding the types of diseases with the highest eigenvalue of 3.421. Factor 2 refers to the proposed implementation measure with a high eigenvalue of 2.799. The respondents agreed on four items related to implementation measures, including high-performance engine design, and the use of electric and hybrid vehicles to reduce traffic pollution.

Table 5: The Impact of Traffic Pollution on Kuala Lumpur Residents

Questionnaire Items	Factor		
	1	2	3
1. Premature infant deaths	0.884		
2. Born of premature and under weight babies	0.851		
3. Childhood leukaemia	0.850		
4. Increase in allergy risk	0.800		
5. Lung cancer	0.661		
6. Invention of high performing engines		0.861	
7. The use of high technology catalytic converter		0.829	
8. Electric powered vehicles		0.719	
9. Vehicles with Hybrid technology		0.686	
10. Effective and conducive public transport			0.899

Questionnaire Items	Factor		
	1	2	3
11. Incentives / rewards for public transport users			0.892
12. Carpooling in major cities			0.786
Eigenvalues	3.421	2.799	1.999
% Variance	28.510	23.329	16.654
Cumulative Variance	28.510	51.839	69.493

Factor 3 is the regulatory strategy that generated the lowest agreement from the respondents. The respondents chose three main items to control the impact of urban traffic pollution, which are provisioning effective public transport, incentives for using public transport as well as car-pooling. The residents argued that the public transport system is unreliable and inefficient. As a result, they need to spend more time traveling using public transport, which causes significant inconveniences to them.

The three dominant factors identified in determining the views of the residents on the traffic pollution in Kuala Lumpur highlighted by the EFA are the perception on the causes of air pollution that are not related to vehicles but the environment, exposure to pollutants without any protection and the sources of emissions from vehicles. Thus, the attitude and level of knowledge of the population on the causes of pollution, the concentration of pollutants, and its negative effects on health also play a role in the success and efforts of the local authorities in controlling the level of ambient pollution. This situation further determines the level of awareness and acceptance of the population on proposed traffic pollution mitigation and implementation measures implemented to control the impact of pollution.

Sustainable transportation planning is crucial for achieving sustainable urban development in Kuala Lumpur and Malaysia. The integration of green transportation initiatives not only addresses environmental concerns but also enhances the quality of life for urban residents. This discussion elaborates on the strategies and measures necessary to foster sustainable transportation and urban development. One of the primary strategies for sustainable transportation is the enhancement of public transportation systems. Kuala Lumpur has made significant strides in this area with the development of the Mass Rapid Transit (MRT) system. The MRT has improved accessibility and reduced traffic congestion, contributing to sustainable urban growth (Man et al., 2024). The expansion of the MRT network and the integration of other public transport modes, such as buses and light rail transit (LRT), are essential for creating a comprehensive and efficient public transportation system (Man et al., 2024). This approach aligns with global trends in sustainable urban planning, where efficient public transit systems are pivotal in reducing reliance on private vehicles and mitigating urban congestion (Gössling, 2017). Additionally, the Green Mobility:

Public Transit initiative in Kuala Lumpur focuses on expanding public transit routes, implementing bus rapid transit systems, and integrating bike lanes and pedestrian walkways to encourage active transportation and reduce greenhouse gas emissions (SDG Centre Kuala Lumpur, 2023).

Low emission zones (LEZs) are designated areas where access by certain polluting vehicles is restricted or deterred to improve air quality. These zones typically favor vehicles that produce lower emissions, such as bicycles, micromobility vehicles, alternative fuel vehicles, hybrid electric vehicles, plug-in hybrids, and zero-emission vehicles like all-electric vehicles (Clean Cities Campaign, 2024). The Kuala Lumpur Low Carbon Society Blueprint 2030 aims to implement LEZs to decrease emissions by 70% by 2022 compared to 2015 levels (KLCH, 2017). These zones restrict the entry of high-emission vehicles, encouraging the use of cleaner transportation alternatives (KLCH, 2017). LEZs have been successfully implemented in various global cities, demonstrating their effectiveness in improving air quality and public health (Holman et al., 2015). For instance, in Central London, the introduction of LEZs has led to a reduction in nitrogen dioxide (NO₂) concentrations by up to 46% (Clean Cities Campaign, 2024).

LEZs are particularly successful at reducing nitrogen dioxide (NO₂) concentrations by around 20% in a wide range of conditions. In addition to improving air quality, LEZs contribute to reducing carbon emissions, mitigating congestion, and incentivizing the transition to zero-emission vehicles (ZEVs) (Clean Cities Campaign, 2024). The number of active LEZs in Europe grew from 228 in 2019 to 320 in 2022, with over 500 expected by 2025 (Clean Cities Campaign, 2024). The implementation of LEZs involves several key components, including a clear definition of objectives, area, scope, and timeline; a vision for zero-emission urban mobility; extensive communication; effective and fair enforcement strategies; monitoring schemes; targeted support for the most vulnerable; and complementary measures to promote active and public transport. These elements ensure that LEZs are not only effective in reducing emissions but also equitable and inclusive. In summary, LEZs are a critical tool in urban environmental management, promoting cleaner air and healthier living conditions for city residents. The success of LEZs in various global cities underscores their potential to significantly improve air quality and public health in Kuala Lumpur and other urban areas.

Active transportation, such as walking and cycling, plays a vital role in sustainable urban development. Creating pedestrian-friendly infrastructure and dedicated cycling lanes can promote healthier travel choices and reduce traffic congestion. Public awareness campaigns and educational programs are necessary to encourage the adoption of active transportation modes (The Star, 2023). Studies have shown that active transportation not only reduces emissions but also

improves public health by increasing physical activity levels (Sallis et al., 2016). Active transportation significantly contributes to public health by promoting physical activity. Walking and cycling are forms of exercise that help reduce the risk of chronic diseases such as obesity, cardiovascular diseases, and diabetes. This study also found that cities with robust pedestrian and bicycle infrastructure experience lower levels of obesity and cardiovascular diseases, as residents are more likely to engage in regular physical activity. Additionally, active transportation can improve mental health by reducing stress and anxiety levels.

Moreover, active transportation reduces greenhouse gas emissions and air pollution. By replacing short car trips with walking or cycling, cities can significantly decrease their carbon footprint. Non-motorized transport modes such as walking and biking can dramatically reduce air pollution, noise, and urban heat islands. This reduction in emissions contributes to global climate change goals and improves overall air quality (Ohlund et al., 2021). Investing in pedestrian and bicycle infrastructure can also have positive economic impacts. A study by Portland State University's Transportation Research and Education Center found that improvements such as bicycle and pedestrian infrastructure had either positive or non-significant impacts on the local economy as measured through sales and employment. For example, bike lanes installed on Central Avenue in Minneapolis led to a 12.64% increase in retail employment and a 52.44% increase in food sales (Liu, 2020). These findings suggest that active transportation infrastructure can boost local businesses and create job opportunities.

Furthermore, active transportation helps reduce traffic congestion by decreasing the number of vehicles on the road. Cities with well-developed pedestrian and bicycle infrastructure experience less traffic congestion, leading to more reliable travel times and increased public transit ridership. The World Resources Institute for year 2021 reported that cities in Southeast Asia lose 2 to 5% of their annual GDP to congestion, with Manila suffering the worst loss at \$67 million per day. Improving walking and cycling infrastructure can help lessen congestion and the associated economic losses (Ohlund et al., 2021). Finally, active transportation fosters a sense of community and social interaction. Pedestrian-friendly infrastructure and dedicated cycling lanes create safer and more inclusive urban environments. These spaces encourage social interactions and community engagement, contributing to a higher quality of life. The development of such infrastructure also promotes equity by providing affordable and accessible transportation options for all residents (Ohlund et al., 2021).

Integrating land use and transportation planning is essential for sustainable urban development. Mixed-use developments that combine residential, commercial, and recreational spaces can reduce the need for long commutes and promote the use of public transportation. The Kuala Lumpur Smart

City Plan 2021-2025 emphasizes the importance of such integrated planning to create a more sustainable and livable city (JASCA, 2021). This approach aligns with the principles of smart growth, which advocate for compact, transit-oriented, and walkable urban environments (Ewing & Hamidi, 2015). The Kuala Lumpur Structure Plan 2040 (KLSP2040) further supports this by integrating long-term land use with infrastructure and transportation planning, provision of affordable housing, and public and recreational facilities to meet the needs of the population while improving the quality of the environment and urban space (InvestKL, 2020).

Recent studies have highlighted the importance of integrating land use and transportation planning. For instance, Yusoff et al., (2021) examined the sustainable transport policy framework in the Klang Valley, emphasizing the need for a holistic approach that includes infrastructure provision, technological improvements, regulation, information, awareness, education, and pricing and taxation. Their findings indicate that while the current framework meets sustainable development criteria, there is still a need for greater public adoption of rail-based services (Yusoff et al., 2021).

Improving fuel quality standards is another measure to reduce vehicular emissions. The implementation of Euro 5M fuel standards in Malaysia by 2025 will lower the benzene content and NOx emissions, contributing to better air quality. These standards align with international benchmarks and demonstrate Malaysia's commitment to environmental sustainability. Enhanced fuel quality standards are critical for reducing the health impacts of air pollution, particularly in urban areas (WHO, 2016). The Department of Environment Malaysia has outlined the specifications for Euro 5 petrol and diesel, which include lower sulphur levels and other stringent requirements to ensure cleaner fuel (DOE, 2025).

Public awareness and education are crucial for the success of sustainable transportation initiatives. Environmental education programs should be incorporated into school curricula to raise awareness about the benefits of sustainable transportation and the impact of traffic pollution on health (Salleh et al., 2018). Engaging the public through campaigns and community events can also foster a culture of sustainability (The Star, 2023). Education and awareness are key drivers of behavioral change, which is essential for the adoption of sustainable transportation practices (Steg & Vlek, 2009). For instance, initiatives like the "Green Mobility: Public Transit" program in Kuala Lumpur aim to educate the public on the benefits of using public transportation and reducing reliance on private vehicles (SDG Centre Kuala Lumpur, 2023).

LIMITATIONS

This study has several limitations that should be considered when interpreting the findings. The dominance of respondents from the B40 income group reflects the socioeconomic structure of selected residential areas but may limit the representativeness of higher-income populations. Consequently, caution should be exercised when generalising the findings to other socioeconomic groups and urban contexts. Firstly, the sample size of 200 residents, while adequate for the research objectives, may not fully capture the diversity of Kuala Lumpur's population. A larger and more diverse sample in future studies could enhance the generalizability of the findings, providing a more comprehensive understanding of public perceptions across different demographic groups. Secondly, the focus on Kuala Lumpur may limit the applicability of the findings to other cities with different socioeconomic and environmental contexts. Comparative studies across multiple urban centres' could offer broader insights and help identify common patterns and unique challenges in various settings. Thirdly, the data collected represents a specific point in time, and changes in socioeconomic conditions, public policies, and environmental factors over time could influence public perceptions and attitudes. Longitudinal studies that track these changes over time are needed to capture the dynamic nature of public perceptions and provide a more accurate assessment of the long-term impacts of traffic-induced air pollution. Additionally, the reliance on self-reported data through surveys may introduce biases such as social desirability bias or recall bias, where respondents might provide answers, they believe are socially acceptable or struggle to accurately recall past experiences. Employing mixed methods, including qualitative approaches like interviews or focus groups, could provide deeper insights and help mitigate these biases. Lastly, while the study examines key socioeconomic variables, other factors such as cultural influences, media exposure, and personal experiences with air pollution were not explored. Future research could incorporate these additional dimensions to provide a more comprehensive analysis, considering how cultural contexts and media narratives shape public perceptions and attitudes toward traffic-induced air pollution.

CONCLUSION

This study underscores the significant influence of socioeconomic characteristics on urban residents' perceptions and attitudes toward traffic-induced air pollution in Kuala Lumpur, Malaysia. This study extends existing literature by demonstrating how socioeconomic disparities shape environmental awareness and behavioural responses to traffic-related air pollution in Kuala Lumpur, offering empirical insights that remain limited in regional urban environmental research. The research reveals that factors such as income, education, and occupation are pivotal in shaping how the public perceives and is aware of air

pollution. These findings highlight the necessity of incorporating public perceptions into urban environmental management to formulate inclusive policies that address both the technical and social dimensions of traffic-induced air pollution. By understanding how socioeconomic factors influence public perception, policymakers can design targeted awareness campaigns and urban planning strategies that promote sustainable urban development and protect vulnerable communities. This approach ensures that policies are not only technically sound but also socially equitable, fostering a collective effort towards mitigating air pollution and enhancing the quality of urban life.

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DATA AVAILABILITY

Data used in this research are available upon request.

DECLARATIONS

Conflict of Interest - The author declares no competing interests.

ETHICAL CONSIDERATIONS

This study involved voluntary participation, and all respondents were informed about the purpose of the research before data collection. Informed consent was obtained from all participants. Personal identifiers were not collected, and all responses were treated anonymously and confidentially. The study adhered to standard ethical practices for social science research.

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