Research article

Public perceptions of vehicular traffic emissions on health risk in Lagos metropolis Nigeria: A critical survey

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A B S T R A C T

The perception and behavior of the public is key in reducing Traffic-related air pollution health burdens which has become an increasingly alarming problem in many cities across the globe. The study assessed the perception of the public about vehicle traffic emissions and the health hazard associated with them in Lagos, Nigeria using structured questionnaires. Multivariate statistical analysis and structural equation modeling were performed to determine the factors that were associated with the participant's perception of traffic air pollution and the health risks it presents. The findings revealed the majority (78.9%) of the respondents were aware of the haze air pollution from vehicles and its adverse effects on health. The regression model showed a significant relationship between age, education status, employment status, road proximity, vehicle ownership and air pollution awareness (P < 0.05). However, the structural equation model SEM revealed that age, gender, marital status, education, employment status, and road proximity showed statistical significance (p < 0.05) and indicated a linear relationship to vehicular emissions perception. The findings suggest the need to increase public education for all ages and especially for roadside residents on the effects of prolonged exposure and long-term effects of transport-related air pollution and associated risk. The result is applicable in many developing cities, especially in Sub-Saharan Africa.

1. Introduction

The efficient movement of people, commodities, and information throughout a country is critical because of its impact on economic, political, social, and cultural life [1]. The mismatching of the transport supply with the increasing demand due to increasing activities and continued urban expansion of cities has resulted in severe traffic congestion and environmental issues related to traffic emissions [2]. Emissions from vehicular traffic have become one of the key drivers of urban environmental air pollution, limiting the

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quality of the urban living environment by degrading the ambient air quality. The number of motor vehicles in Africa has increased with rapid population growth. This has resulted in premature deaths across cities, especially the low- and middle-income countries, which are highly engendered, with children, women, and the elderly being the most susceptible [3,4].

According to Ref. [5], 80% of the world's population lives in locations where average annual $PM_{2.5}$ concentrations exceed the WHO guidelines of 10 g/m^3. In 2017, it was estimated that exposure to ambient $PM_{2.5}$ was linked to 2.9 million premature deaths worldwide, accounting for nearly 9% of all deaths, of which about 80,000 resulted from an ischemic heart ailment in the West Africa region [6]. The problem is particularly serious in Nigeria, which had the highest number of untimely deaths (11,200) due to $PM_{2.5}$ levels in the west African region, especially in Lagos, the country's business capital and one of the rapidly growing megacities worldwide [7]. Despite growing concern about air pollution in Lagos, there is no reliable estimate of the impact of ambient air pollution nor a public perception survey of vehicle emission and its related health burden. However, there are many studies on the perception of air pollution from other sources of pollution besides the road corridor. Road transport, industrial emissions, and power generation are major contributors to air pollution in Lagos. The first viewpoint of reducing the impact of vehicle emissions on public health understands the public's perception towards this pollution and its health risk burden. The public's feelings, awareness, knowledge, and attitude about pollution from road transport have yet to be investigated despite growing concern about air pollution and the associated health burden in Lagos.

Many studies have investigated the concentration of pollutants on the road but failed to assess the impact on the public's health through an effective perception survey, e.g. Refs. [8–13]. Furthermore, many public awareness studies have been done on other air pollution anthropogenic sources such as domestic, industrial, agricultural and power generation. However, more research must be carried out on air pollution from road transport and its relative health risk, especially in Lagos. A study by Ref. [14] assessed the public perception of the environmental pollution profile for water, air and soil in Warri Township, Nigeria. Data were acquired by administering 80 questionnaires among the study area residents using a random sampling method and descriptive statistics. Similar studies were conducted in the Kano metropolis, north-western Nigeria air pollution Ref. [15]. Recently [16], examined community perception of air pollution and public health in Ewekoro and Remo-north communities in Ogun State, Nigeria, using systematic random sampling techniques and 200 structured questionnaires to elicit information on air pollution and health, and descriptive and inferential statistics for the analysis. The limitation of the study is the limited number of questionnaires which cannot effectively represent the large population in the community, and descriptive research needs to be more adequate to assess the community perception and impact on health.

However, studies have yet to be able to assess public perception of the road corridor [17], assessed air pollutant concentrations near major roads in residential, commercial and industrial areas in Ibadan City, Nigeria. They concluded that the level of SO_2 exceeded World Health Organization limits within this short duration and recommended long-term air quality monitoring with a sustainable plan for air pollution management. They did not link the measured pollutants to the public's health or a public perception survey. A similar study was conducted to investigate the impact of vehicular traffic in the selected junction of Port Harcourt city Ref. [18]. [19] overcome this limitation by critically examining the environmental attitude of drivers towards vehicle emission in Alimosho Local Government Area, Lagos, Nigeria. 402 respondents (drivers) generated the data analyzed involved descriptive and regression statistical tools. They reported a significant association between respondents' sex, occupation, education and environmental attitudes. They used a predictive model to assess perception and supply critical information on the awareness levels of drivers. This study, however, was limited to only drivers and did not consider other public at large. Many people use the road daily as commuters to assess socioeconomic opportunities, as residents near road corridors are also exposed to the hazards of these air pollutants emanating from vehicles whose perception ought to be evaluated. There is a need for an inclusive study to effectively examine the impact of these pollutants on the population for policy. The health risk burden disease is a public concern engendered more, with the most susceptible groups being young children and the elderly. Also, the study was limited to only social demographic factors to predict their awareness levels. It is imperative to examine other non-sociodemographic factors and their interaction using methods which have yet to be used, such as structural equation modelling.

Another critical survey on the knowledge, attitudes, and perceptions of air pollution in Accra by Ref. [20] revealed that the majority (70.5%) of respondents were aware of the haze from vehicular traffic pollution and its adverse health effects, supported by a significant relationship between the socio-demographics and air pollution awareness (P = 0.01). There was also a correlation between residents' age, educational level, length of stay, marital status, and knowledge/awareness rate of air pollution (P < 0.05). In another study in Ibadan, Nigeria, a cross-sectional comparative study Ref. [21] found that motor park sellers were more susceptible to carboxyhemoglobin levels (COHb) and are more prone to risks of poor health resulting from CO exposure. The study corroborated that men were less knowledgeable about air pollution than women [22]. surveyed 450 traders in La Nkwantanang Municipality, Ghana, to investigate the effects of distance from the emission source on health outcomes. It revealed that many respondents were aware of the health consequences of their exposure to pollution but were hesitant to migrate due to a lack of financial resources and urban space shortage [23]. examined the effects of traffic noise, air pollution, and cardiovascular events. They deduced that noise and NOx exposure had a good association, with Pearson r = 0.68 and annual correlations ranging from 0.62 to 0.71. Although this study's sample size was limited to men, the biological mechanisms underlying the links between noise and cardiovascular disease are unlikely to be gender-specific.

The public perception survey is critical in understanding their feelings about the incidence of air pollution regarding their health and how this affects their lives and daily activities. There is a need to investigate how the perception of air pollution affects their socioeconomic activities, especially for roadside dwellers. Therefore, the following research questions are essential for the practical assessment of the public perception of the impact of air pollution from vehicles in Lagos.

i. What is the public's level of perception and awareness about vehicle emissions and the health risk it poses? What is the public's attitude and knowledge about vehicle emission and their relative health risk?

ii. What factors affect the public perception of vehicle emissions and their health risk burden?

iii. What impact does the perception of vehicle emissions have on the socioeconomic activities of local road residents?

To understand and be able to assess the effects of vehicular emission exposure on the well-being of the public, there is a need to evaluate or investigate public perceptions of vehicle emissions. Therefore, the study seeks to examine the public's perception of vehicle emissions and their health risk in the Lagos metropolis through a critical survey and modelling of factors that affect their awareness level across all ages and gender. The responses to the research questions will be provided through a critical literature survey, assessment and investigation of other factors that affect their awareness level. An insight into these factors can inform the decisions of agencies, transport engineers or managers and bus operators on policies and pollution reduction strategies to provide sustainable transport and reduce the impact of vehicle emissions on public health. The results of the study seek to contribute to the United Nations Sustainable Development Goals (SDGs) 3, 9 and 11, which by 2030; that all together, seek to develop safe, inclusive and resilient cities and ensure healthy lives and well-being for persons of all ages through adequate sanitation and air pollution prevention [24].

2. Materials and methods

2.1. Study area

Lagos is the largest city in Nigeria and the second most populous city in Africa, with a population of 10.4 million as of 2015. It is one of Nigeria's most important and highly populated cities with severe air pollution problems [7]. Lagos is a prominent African financial centre and the economic hub of Lagos State and Nigeria. As Nigeria's leading commercial capital city, it accounts for about 70% of its industries and economic activities, making it the most economically significant state of the country [25]. Lagos State, located in southwest Nigeria, contains 20 Local Government Areas (LGAs), although only 16 of these LGAs make up Lagos Metropolis, the study area. With a land area of 3475.1/km2 (1341.7/m2) and a population density of 2593.7/km2 (6718.8/m2), Lagos Metropolis had an estimated population of over 13 million in 2013. Ref. [26].

The study covered the 16 local government areas in Lagos metropolis: AGEGE, AJEROMI-IFELODUN, ALIMOSHO, AMUWO-ODOFIN, APAPA,ETI-OSA, IFAKO IJAYE, IKEJA, KOSOFE, LAGOS ISLAND, LAGOS MAINLAND, MUSHIN, OJO, OOSHODI-ISOLO, SHOMOLU, SURELERE. Fig. 1 shows the map of Lagos LGA in the metropolis.

2.2. Data collection

Tara Yamane's method [28] was employed to estimate the sample size for the population. With a 95% confidence level, the sample size n was estimated to be 1000. The sample size estimated for the study is adequate to give a good representation of the population of Lagos metropolis, which was estimated to be as ten million in 2022 [26].

$$n = N(1 + N(e^{)}) \tag{1}$$

n = sample size.

N = population under study = 10,000,000

E = margin error = 3.0%

The survey employed a method that combined simple randomness with cluster sampling. Cluster sampling is the most effective type of probability sampling and is frequently used when large populations, mainly geographically dispersed populations [29]. A total of 1000 structured questionnaire instruments were distributed throughout the Lagos metropolis. Households and neighbourhoods of

Fig. 1. Map of Lagos metropolis showing the local governments areas. Source [27].

communities, offices, banks, shopping malls, schools (primary and secondary), and residents in the 16 local governments of Lagos were considered for sampling. Traders, garage workers, passengers, drivers, traffic officers, hawkers, and construction workers are among those who live near major highways. The local government areas were divided into five groups, each receiving two hundred (200) respondents for the study. Included are respondents from online and social media platforms who completed an online survey instrument in Google form that was created and shared on social media platforms for prospective respondents who live in the Lagos metropolis. The distribution of the questionnaire in Lagos is shown in Table 1. The questionnaire was divided into three main sections, each of which included both closed-ended and open-ended questions, to investigate the respondents' level of perception. These sections were as follows: (a) social demographics, including age, gender, educational level, employment status, marital status, and income; (b) car ownership and mode choice, including type and age, status at purchase, registration status and manufacture year, and engine type and maintenance; and (c) trip, traffic congestion, and emission; and (d) trip (purpose and usual mode, frequency of trips, duration, days, traffic congestion awareness, awareness of vehicle emission from owned vehicle and other vehicles during trip, emission inhalation duration and health risk of the emission). Data were gathered for a period of six weeks through the use of in-person interviews and an online database. The distribution of the questionnaires is detailed in Appendix 1.

2.3. Data quality

Data were collected by trained observers and enumerators using the interview protocols. Field inspection of questionnaire data was carried out daily after the interview was conducted, and any errors were immediately corrected. The principal investigators were readily available to answer any questions that arose during data collection. Respondents' verbal and written consent was sought before data collection. They were told what the study was about and that participation was voluntary. They were also told that refusing to engage in the study would result in no penalties and no influence on their jobs. The study participants were assured of their anonymity. Once collected, personal identifiers were deleted from the summary data to maintain anonymity and ambiguity. Ethical clearance was obtained from the Committee, Human Research Publications and Ethics, School of Medical Sciences, Kwame Nkrumah University of Science and Technology Kumasi, Ghana.

2.4. Data analysis

Data from the surveys were analyzed using SPSS 22.0, a statistical program for the social sciences. There were four stages to the analysis: Two types of statistical analysis were performed: (a) descriptive statistics to characterize the respondents and their responses (frequency counts, means, and standard deviations); and (b) bivariate associations to evaluate the bivariate cross-tabulation between these variables (chi-squared test). All tests were two-tailed, and significance was set at a level of alpha = 0.05 or lower; (c) multinomial regression, also known as a multivariate logistic model, was used to predict the outcome of air pollution awareness (yes = 1, no = 0, and can't say), controlling for all independent variables that were significant at the bivariate level. Given its simplicity, clarity in interpretation, and usefulness in training, Multinomial Logistic Regression (MLR) was chosen as the analysis approach for this investigation because it does reveal the direction of the relationship between variables (positive or negative).

The independent variables in the model are grouped into two: the social demographics factors and other factors. The social demographic factors from previous studies include respondents, age, gender, education, employment status, and marital status. The other factor proposed to be investigated in the model are; traffic congestion experience, vehicle ownership, and proximity to the road corridor. Traffic congestion and vehicle ownership affect vehicle emissions on the road corridor. Studies have shown that traffic congestion increases air pollution on the road, e.g. Refs. [30–32]. Most secondhand cars in West African cities' fleets are imported from Europe and the United States. These old vehicles often lack emission and noise reduction technology. Income primarily affects vehicle ownership, thus putting more pressure on the consumption of old and imported vehicles, especially in low and middle-income countries. Recent studies have found that motorists, commuters, and people who live or work near significant highways have higher rates of illness and mortality Ref. [33].

2.5. Structural model equations

Structural equation modelling (SEM) is a powerful multivariate technique increasingly used in scientific investigations to test and evaluate multivariate causal relationships among variables. SEMs are distinct from other modelling approaches because they

Table 1
Questionnaire Administered for public perception in Lagos.

S/N	Name/Location	Details	Copies
1	AGEGE,AJEROMI-IFELODUN, ALIMOSHO, AMUWO-ODOFIN,	Households, communities, Neighbourhood, Offices, banks, Shopping Malls, schools and road corridors	200
2	APAPA, ETI-OSA, IFAKO IJAYE, IKEJA		200
3	KOSOFE, LAGOS ISLAND, MUSHIN, OJO		200
4	LAGOS MAINLAND, OOSHODI-ISOLO, SHOMOLU, SURELERE		200
5	Online	Professional WhatsApp group pages, emails	200

investigate the direct and indirect effects of factors previously assumed to be causally related to Refs. [34,35]. SEM examines linear causal relationships among variables while considering measurement error [36]. Fig. 2 shows the proposed SEM model for the latent and observed variables for the vehicle emission perception prediction. The latent variables adopted in the model are gender, age, education, employment, traffic congestion experience, vehicle ownership, and proximity to road corridors. The R studio statistical tool determined the SEM and estimates for each variable.

2.5.1. SEM evaluation

The fundamental focus of structural equation modelling, as stated by Ref. [37], is how well a proposed model "fits" or adequately explains the sample data. To assess how well the fitted model fit the observed data, it was examined and tested for suitability using several indicators. There should be a minimum of four tests that are satisfactory with the model fit, as described in the study by Refs. [38–40]. The indicators utilized were the Chi-square, goodness-of-fit index, modified goodness-of-fit index, comparative fit index, normed fit index, and root mean square error of approximation (RMSEA). The acceptable limit of these indices is shown in Table 2.

3. Results and discussion

3.1. Socio-demographic characteristics of respondents

The socio-demographics related to respondents' social status and location are shown in Table 3. Altogether, 370 respondents were males (41.0%), and 540 were females (59.0%). The survey respondent age groups were as follows: More than half (52.7%)of the respondents fall within the middle-aged (31–40 years), 17.8% were in the group 41–50 years, the 16–20 years age group 12.6%, the elderly group (51–60 years) were 7.1%, and the under 15years age group were 5.5% and older folks (more than 60 years) were 4.2%. There were more females than males among the age group respondents. The breakdown of marital status indicated that 59.1% are married, and 40.9% are single. 88.1% of the respondents have formal education, while 12.0% have no formal education. Also, regarding employment status, the results show that civil servants constitute 39.8%, business owners/self-employed were 21.8%, 24.2% were traders, pensioners and retirees were 5.5%, and 8.8% of respondents were unemployed.

Further analysis revealed the respondent's period of stay and daily work duration at the road corridor as presented in Figs. 3 and 4. 45.0% of the respondents have spent between 5 and 10 years, while 35.0% have spent less than five years, and 1.0% have spent above 20 years. Almost all respondents earn their income undertaking daily activities for at least 8 h within or near the road corridor.

A statistical analysis of the cross-tabulations reviewed the relationship between the two variables examined; gender and social demographics. The chi-square test for independence was used to test if there is a bivariate association between two categorical variables. As presented in Table 4, the result reveals a greater chi-square value for employment and education status and a p-value <0.05, which implies a strong association between gender and age, gender and employment status, gender and education status but a weak association between gender and marital status (p > 0.05). The result revealed the impact of gender on age, education and employment status.

3.2. Knowledge and awareness level of respondents

Respondent's knowledge of various behaviours is usually indicated or measured using rating scales. The most widely used is the Likert scale. The Likert scale is a four- or five-point scale that allows individuals to express how much they agree or disagree with a particular statement. It indicates their positive-to-negative strength of agreement or strength of feeling regarding the question or statement [41]. Tables 5–8 present the cross-tabulation of the sample data indicating the level of awareness or agreement with various information about vehicle pollution and its characteristics. The result showed a different level of understanding, knowledge and feeling regarding vehicle emission and its health risk for males and females. The result revealed that a more significant percentage strongly agreed with the knowledge of vehicle emissions and health risks.

When asked the respondent how they reacted to the exposure to pollution, it is interesting to know that 90.0% of the respondents indicated that they did nothing about it nor took any action. In comparison, 6.0% complained, 3.0% covered their noses, and 1.0% left the location. The resident near the roadways affirmed that they could not relocate from the pollution zone due to the economic gain and profits, and they have no other place to go. The implication is that socioeconomic characteristics affect respondents' perception
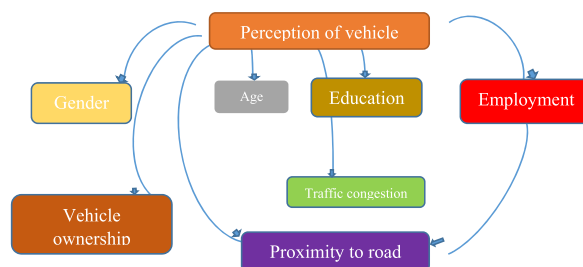

Fig. 2. The proposed SEM for the vehicle emission perception.

Table 2

Acceptance limit of the indices of model adequacy.

Index	Recommended limit
Chi-square	p-value >0.05
Goodness-of-fix index (GFI)	>0.9
Adjusted goodness-of-fit index (AGFI)	>0.8
Comparative fit index (CFI)	>0.95
Normed fit index (NFI)	>0.9
Root mean square error of approximation (RMSEA)	<0.05 (good fit)
	<0.06 (acceptable)

Table 3

Socio-demographic results of respondents.

Variables	Category	Gender Male	Gender Female	Total	Percent (%)	sig. value	Person chi-square
Age	<15	20	30	50	5.5	0.000	78.373
	16–20	47	68	115	12.6		
	31–40	192	288	480	52.7		
	41–50	68	94	162	17.8		
	51–60	25	40	65	7.1		
	>60	18	20	38	4.2		
Education	Illiterate	73	36	109	12.0	0.065	8.866
	Basic	72	348	420	46.2		
	Tertiary	225	156	381	41.9		
	Civil-Servant/Employee	159	203	362	39.8		
	Business Owners	89	109	198	21.8		
	Traders	77	143	220	24.2		
	Unemployed	35	45	80	8.8		
	Retired/Pensioner	10	40	50	5.5		
Marital Status	Single	158	214	372	40.9	0.000	139.8
	Married	212	326	538	59.1		
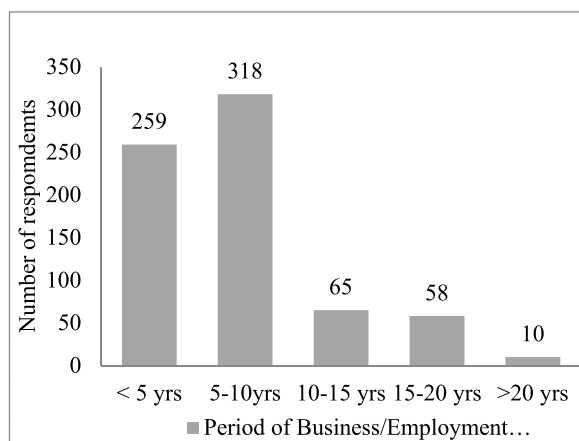
Fig. 3. Respondent's period of business.

level near the road corridors. Further analysis indicated that 78.9% are aware of vehicle emissions and health risks, while 21.1% are unaware of vehicle emissions and their relative health effects.

3.3. Factors affecting vehicle emission perception

The multinomial logistic regression model was used to predict and assess a nominal dependent variable given one or more independent variables. Table 9 presents the dependent and independent variables used in the prediction model. Table 10 shows the model's coefficient estimate or regression weights, significance levels, and standard error. The independent variables were the social demographics and other proposed factors. Literature [42–46] has shown that social demographics variables such as age, gender, marital status, educational status and employment status are the major factors for predicting perception studies. However, recent studies, e.g. Refs. [47–49], have shown that traffic congestion, vehicle ownership and road proximity affect the pollution levels on road corridors.
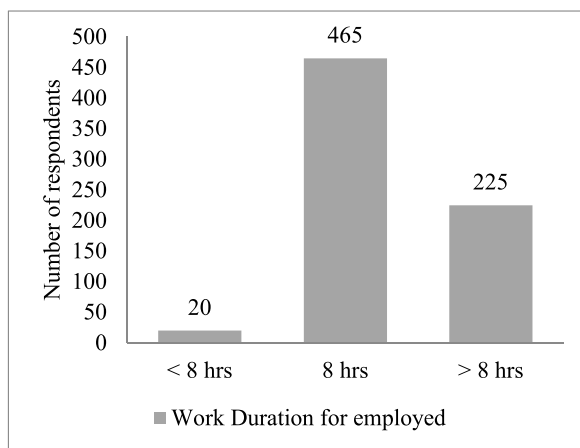
Fig. 4. Work duration of the employed.

Table 4
Cross-tabulation charcateristics between gender and social-demographics variables.

S/N	Variables	Statistical findings.
1	Age * Gender	$\chi^2 = 21.053$, $df = 5$, $p < 0.05$
2	Education * Gender	$\chi^2 = 180.985$, $df = 2$, $p < 0.05$
3	Employment status * Gender	$\chi^2 = 18.532$, $df = 5$, $p < 0.05$
4	Marital status * Gender	$\chi^2 = 2.406$, $df = 2$, $p > 0.05$

Table 5
Respondents' awareness of vehicle characteristics.

Vehicle characteristics: Old and used vehicles emit more air pollutants than the brand new ones.

Ranking	Frequency	Male (%)	Female (%)
Disagree	182	54.0	46.0
Somewhat Agree	208	61.5	38.5
Agree	236	43.5	56.5
Strongly Agree	284	45.0	55.0
Total	910		

Table 6
Respondents' awareness of Traffic emission.

Vehicular Traffic emission is one of the primary sources of environmental air pollution and has degraded the quality of the air we breathe.

Ranking	Frequency	Male (%)	Female (%)
Disagree	114	55.5	45.5
Somewhat Agree	233	42.5	57.5
Agree	210	40.5	59.5
Strongly Agree	353	46.5	53.5
Total	910		

Table 7
Respondents' awareness of air pollutants.

Particulate matter emitted from vehicles is associated with premature deaths from ischemic heart disease, stroke, lung cancer, lower respiratory infection, and asthma

Ranking	Frequency	Male (%)	Female (%)
Disagree	192	62.0	38.0
Somewhat Agree	236	45.0	55.0
Agree	238	41.0	59.0
Strongly Agree	244	47.0	53.0
Total	910		

Table 8
Respondents' awareness of traffic congestion.

Vehicular emission is high during traffic congestion			
Ranking	Frequency	Male (%)	Female (%)
Disagree	97	45.5	54.5
Somewhat Agree	228	52.0	48.0
Agree	235	58.0	42.0
Strongly Agree	350	49.5	50.5
Total	910	100.0	

Table 9
Description of dependent and independent variable.

Variables	Value	Definition
Perception of vehicle emission and its health risk	2	Yes
	1	No
	0	Can't say
Age	1	<15
	2	16–20
	3	31–40
	4	41–50
	5	51–60
	6	>60
Gender	1	Female
	2	Male
Educational status	1	Illiterate
	2	Basic
	3	Tertiary
Marital status	1	Married
	0	Single
Employment status	1	Civil-Servant/Employee
	2	Business Owners
	3	Traders and
	4	Unemployed
	5	Retired/Pensioner
Vehicle ownership	1	Owned vehicle
	2	Not owned vehicle
Traffic congestion experience	1	Yes
	2	No
Road Proximity	1	Yes
	2	No

The latter factors were also added to the model with the sociodemographics variables. As presented in Table 8, the statistically significant ones to predict the Yes and No outcome (p-value <0.05) are age, employment status, education status, proximity to road corridors, and vehicle ownership. These variables are considered factors that affect the perception of the public toward vehicle emissions. However, gender, marital status, and traffic congestion experience were not statistically significant (p > 0.05) in the model.

3.3.1. Social demographics variables - regression estimates

The results highlighted the critical aspects of the social demographics variables that affect the perception of vehicle emissions; respondents' age, work status, and educational status, as shown in Table 10. The persons in the age group 31–40 and 41–50 are more likely to be aware of the impacts of vehicular emissions and their respective health concerns than infants and teens (less than 15 and 16–20) and the elderly group (50–60 and above 60). The elderly in the age band (51–60) and above 60 exhibited statistically significant (p-value <0.05) in the "No" prediction outcome. This suggests that the elderly have a reduced perception of vehicle emissions. Furthermore, Employment status, business owners, and traders showed statistical significance in predicting the Yes outcome. Due to the nature of their work, the business owners/self-employed and traders who do their economic activities close to the road corridors are more aware than the unemployed, the retiree or pensioner, and the civil servant groups. Further research reveals that those with formal education, both primary and tertiary, are more aware of vehicle emissions than the illiterate group.

3.3.2. Other factors

The other significant factors in the model include vehicle ownership and proximity to the road corridor. Vehicle characteristics are one of the germane factors that inhibit the emission levels of vehicles [50]. Vehicle owners are more likely to understand the effects of vehicle age, fuel type, maintenance levels, and the impact of vehicle trips on air pollution than those who do not own a motor vehicle. Vehicle ownership as a variable in the model is one of the significant predictors of the perception of vehicle emission and its health risk. Persons who own motor vehicles are more likely to predict a Yes. When asked if the respondents owned a vehicle, 52.0% indicated

Table 10
Regression estimates and standard error.

Characteristics		B	Std. Error	Sig.
Yes	Intercept	40.240	596.8	.946
	Vehicle Emissions1	-5.023	137.5	.971
	[Is your Workplace close to the road?=1]	-13.439	425.3	**.000**
	[Do you experience traffic congestion on your trip?=1]	0ᶜ	.	.
	[Do you own a vehicle?=1]	2.138	122.9	**.000**
	[Gender=1]	-.288	123.3	.998
	[Gender=2]	0ᶜ	.	.
	[Age=1]	-28.465	1335.6	.983
	[Age=2]	-12.389	578.3	.983
	[Age=3]	-2.772	388.9	**.000**
	[Age=4]	.035	416.6	**.032**
	[Age=5]	0ᶜ	.	.
	[Age=6]	0ᶜ	.	.
	[Education status=1]	-30.427	.000	.
	[Education status=2]	1.886	227.1	**.000**
	[Education status=3]	4.886	452.1	**.000**
	[Employment status=1]	-16.487	567.8	.977
	[Employment status=2]	-12.847	670.2	**.021**
	[Employment status=3]	-11.968	1196.9	**.034**
	[Employment status=4]	-25.399	339.3	.940
	[Employment status=5]	-12.096	732.45	.987
No	Intercept	61.267	6379.3	.992
	Vehicle Emissions1	30.171	143.3	.833
	[Is your Workplace close to the road?=2]	-136.213	6383.2	.983
	[Do you experience traffic congestion on your trip?=1]	0ᶜ	.	.
	[Do you own a vehicle?=1]			
	[Do you own a vehicle?=2]	.629	140.8	**.000**
	[Gender=1]	-5.216	200.1	.979
	[Gender=2]	0ᶜ	.	.
	[Age=1]	-63.547	1467.9	.965
	[Age=2]	-134.810	810.5	.868
	[Age=3]	-29.300	561.9	.958
	[Age=4]	0ᶜ	.	.
	[Age=5]	-.486	479.8	**.024**
	[Age=6]	-.317	412.6	**.033**
	[Education status=1]	18.329	424.1	**.001**
	[Education status==2]	6.262	205.5	.976
	[Employment status=1]	76.883	711.7	.914
	[Employment status=2]	-14.039	6330.5	.998
	[Employment status=3]	78.548	809.0	.923
	[Employment status=4]	71.460	676.7	**.020**
	[Employment status=5]	86.090	1229.3	**.000**

c: Reference "can't say".

owning a vehicle, while 48.0% did not. The vehicles owned are motorcycles, tricycles, cars or taxis, minibuses or vans, large buses, trucks, and lorries. Passenger cars were the majority (42%) of the vehicles owned by the respondents, followed by minibuses (23.0%), motorcycles (14.0%), tricycles (11.0%), trucks (4.3%), large buses (3.8%) and least is about 1% lorries. Vehicles in Lagos are mostly passenger cars, followed by yellow minibuses mainly used for commercial activities in different areas of the Lagos Metropolis [51]. 52.0% of the respondents undertake their employment or education activities around the road corridor, while 35.0% reside away from it. Those near the road corridor include; traders, hawkers, shop owners, school children, drivers or bus conductors, office staff, and police/traffic officers. Fig. 4 presents the proportions of the roadside population in the study. These persons stay in the road corridor for more than five days per week and over 8–13 h daily undertaking their school and work-related activities. Recent studies have shown excess morbidity and mortality for drivers, commuters, and individuals living or working near major roadways [33].

3.3.3. Traffic congestion characteristics

Respondent's awareness of the proposed trip characteristics and traffic congestion during trip-making is vital to inform their perception of vehicle emissions [52]. In the model, the traffic congestion experience is not statistically significant ($p > 0.05$) to predict the respondent's perception of vehicle emission and health risk. However, there is a need to analyse respondents' congestion experience. Most respondents on their trip stay between 20 and 60 min in traffic congestion during peak periods between 7 and 9 am, 4–6 pm, and 6–9 pm. The most congested day of the week is Friday. Fig. 5 revealed the awareness of respondents regarding air pollution during the trip. 55.0% of respondents reported that the severity of the pollution increased during traffic congestion, 45.0% reported that vehicle emission increases when a vehicle on a trip is at low speed, 31.0% affirmed that it increased when vehicles accelerate, 20.0% of respondents reported when vehicles are not in motion, and 9.0%reported the air pollution is increased for vehicles accelerating. The implication of this survey is to affirm that pollution severity increases during traffic congestion Refs. [2,53,54].
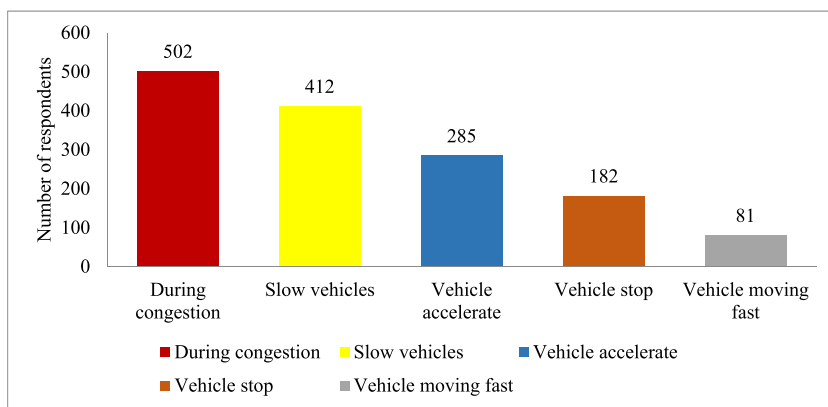
Fig. 5. Respondent's perception of vehicle operation with severe emission.

3.4. Model assessment

Table 11 is the classification table to evaluate the predictive accuracy of the logistic regression model. The model chi-square tests whether the model represents a significant increment in fit relative to a null/baseline/intercept-only model. The chi-square test result indicates that our model significantly improves fit relative to an intercept-only model, χ^2 (24) = 74.933, p < 0.001. The overall percentage correct indicates the percentage of cases with an observed outcome correctly predicted (in terms of the outcome) by the model.

The percentages in the first two rows provide information regarding the model's sensitivity and specificity in predicting group membership on the dependent variable.

Overall, the accuracy rate was very modest at 89.9%. The model exhibits good sensitivity since among the perceived pollution indication = Yes, 91.7% were correctly predicted. The model exhibits poor specificity for perceiving smoke pollution = No, 60.9%.

3.5. Structural equation modelling (SEM)

Structural equation modelling (SEM) estimated the proposed structural model, which individually tests the significance of the relationships among the variables, as shown in Fig. 6. SEM shows the linear relationship between the variable and the error term. The latent variable, which implies the variables which can not be measured directly, are demographic indices (DI) and other factors (OF). In contrast, the observed variable is vehicle emission perception (VEP), as presented in the model in Fig. 6. The contributing factors to the latent variable DI are Age (Ag), Gender (Gnd), Marital (Mrt), Education (Edc) and Employment status (Emp). The contributing factors for OF are Road proximity (RP) and Vehicle ownership characteristic (VO). Moreover, another critical piece of information the measurement model gives is the interactions (correlations or covariances) between the various dimensions of the contributing factors that affect vehicle emission perception. "However, a correlation is indicated by an arrow in both directions and demonstrates a bi-directional relationship between the latent variables, DI and OF, with a weak positive value of 0.04. That causal weak positive relationship between the latent variables suggests that they do not influence each other. These variables (OF and DI) that are unaffected by one another are called exogenous variables [46]. Moreover, the direct impact of the latent variables on the observed one is the most important in the measurement model.

Practically, vehicle ownership and road proximity affect the perception of vehicle emissions. This further explains that persons who own a vehicle exhibit more positive perceptions of vehicle emissions than those without a car. Likewise, residents who engage in activities close to the road corridors will be more aware of vehicle emissions and associated health risks than those far from the pollution hotspot. The model also showed the contributing factors' positive and negative direct impacts on the latent variables. Furthermore, Table 12 indicates that DI and OF significantly predicted VEP with a p-value of < 0.001. RP and VO positively impacted OF, with 0.28 and 1.00, respectively. Also, Mrt and Emp negatively affected DI, while Edc, Age and Gnd had a positive effect.

Table 11
Predictive accuracy for the regression model.

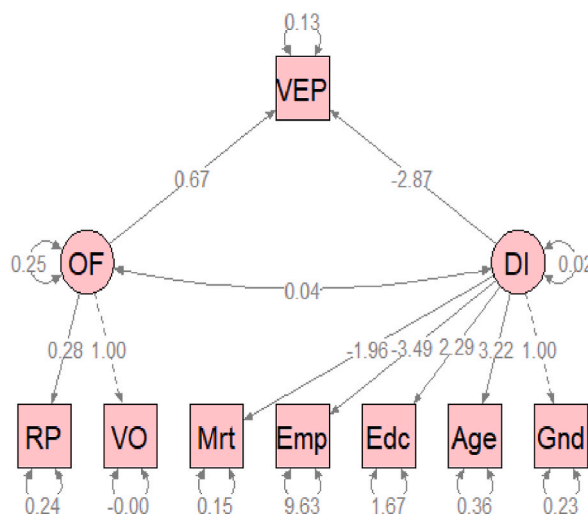| Observed	Predicted				
	Yes	No	Can't say	Incorrect	Percent Correct
Yes	616	0	0	0	91.7
No	0	157	0	0	60.9
Can't say	0	0	37	0	4.1
Incorrect	0	0	0	92	10.1
Overall Percentage	91.7%	60.9%	4.1%		89.9

Fig. 6. The measurement model.

Table 13 shows that all contributing factors, which include age, gender, marital, education, employment, vehicle ownership, and road proximity, are statistically significant at p = 0.00. On the other hand, the correlations between the contributing factors and the respective latent variables are also statistically significant, at p = 0.00, except for the VO (vehicle ownership), which has a p-value of 0.975.

The measurement model exhibited acceptable goodness of fit. Even though the chi-square p-value was significant (<0.05) and the CFI and NFI values of 0.87 and 0.84, respectively, were marginally below the minimum threshold, the AGFI value of 0.76 and RMSEA value of 0.065 achieved were within the acceptable range. Based on the number of indices that met the acceptable threshold and the chi-square p-value is sensitive to sample size, making it hard to obtain a p-value >0.05 with a large sample size, the model fit results are considered a good fit for the data. Therefore, the model adequately explains the relationship between the underlying factors and the measured variables.

4. Conclusion

Vehicle emissions have become one of the leading causes of environmental air pollution that reduces the quality of life in cities by lowering air quality. The study assessed the public's perception of the implications of vehicular emissions on the health of roadside dwellers and residents in the Lagos metropolis. The social demographics survey revealed that air pollution perception increases with respondent age, education, and employment status (P = 0.01). Furthermore, the proposed other factors, such as vehicle ownership and proximity to the road corridor, are also statistically significant ($p < 0.05$) with the respondent's perception of vehicle emissions. The structural equation model SEM which defines the relation between the observed and latent variables, revealed that age, marital status, education and employment status and road proximity showed statistical significance ($p < 0.05$) and indicated a linear relationship to vehicular emissions perception.

Further analysis indicated that 78.9% are aware of vehicle emissions and health risks, while 21.1% are unaware of vehicle emissions and their relative health effects. However, residents who engage in activities close to the road corridors will be more aware of vehicle emissions and associated health risks than those far from the pollution hotspot. Therefore, the perception of the public is critical in understanding their feeling about the incidence of air pollution from vehicle emissions as regards their health and how this affects their lives and daily activities. Further studies are needed to predict the health risk of health burden disease for residents' exposure to air pollutants the road corridors. Although the sampling method in the study was targeted at the public in the Lagos metropoplis which is not a representative of the population of Lagos, there is also need for the sampling method be targeted only at the population of residents or dwellers near the roadways. Although this model shows a good fit for prediction purposes, it only incorporated the impact of social demographics indices and the proposed factors such as vehicle ownership and road proximity but does not take into consideration socio-economical characteristics, especially for residents near the road corridor such as respondent work schedule, work duration, income on the job, years spent on the job.

Table 12
Overall regression estimate.

Terms	Direct effects	Estimate	Standard error	z-value	p-value
DI	Demographics impacts	−2.871	0.499	−5.757	0.000
OF	Other factors	0.670	0.172	3.904	0.000

Table 13
Latent variables estimates.

Terms	Direct effects	Estimate	Standard error	Z-value	P-value
DI	**Demographics impacts**				
Gnd	Gender	1.000			
Age	Age	3.221	0.426	7.562	0.000
Edc	Education	2.294	0.433	5.294	0.000
Emp	Employment	−3.485	0.898	−3.880	0.000
Mrt	Marital	1.960	0.261	−7.499	0.000
OF	**Other factors**				
VO	Vehicle Ownership	1.000			0.975
RP	Road proximity	0.279	0.059	4.736	0.000

4.1. Policy implications

There is a need to understand the public's perception towards vehicle emissions and provide emission data on road transport to comprehensively quantify the impact of air pollutants on the public's health. However, the result affirms the need for targeted education and awareness, especially for the illiterate group, women, and children. For roadside residents, businesses, and persons who stay in the road corridor for considerable hours daily and weekly, their understanding of the effects of long-term exposure to pollutants could be the focus of their education and awareness. The results also highlight that city governments should regulate the development and businesses adjacent to busy, congested roadways to reduce the adverse impact on those who engage in economic activities. Also, to set policies that will gradually reduce the importation of old and used vehicles that could serious health risks for the public. The deployment of devices that alert the general public of the pollutant concentration levels near the roadside and display the implications could also be explored to create more awareness. There is a need to provide strict policies on importing old and used vehicles, gradually removing these vehicles, and replacement with low-carbon emission vehicles. The results apply to other cities in developing countries, especially sub-Saharan Africa.

Authors' contributions

Samuel A. Ajayi have conceived the idea/concept of this study and the experiments was designed by Charles A. Adams. Samuel A. Ajayi and Adekunle Kehinde performed the experiments while the data was analyzed and interpreted by Samuel A. Ajayi, Charles A. Adams, Gift Dumedah and Williams Ackaah. Samuel A. Ajayi, Atinuke Adebanji and Augustus Ababio-Donkor contributed materials and analysis tool for the data. The final report and manuscript were written, edited, and confirmed by Samuel A. Ajayi, Charles A. Adams, Gift Dumedah, Atinuke Adebanji, Augustus Ababio-Donkor, Williams Ackaah and Adekunle Kehinde.

Data availability statement

Data will be made available on request.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

Annex 1. Questionnaire survey for public perception of vehicular emissions in Lagos

SECTION A: PARTICIPANTS INFORMATION

1. Do you currently live in Lagos?
   - ➢ Yes
   - ➢ No
   - ➢ Sometimes
   - ➢ Pls specify where … … … … … … … … … ….
2. If Yes is your answer in (1), which neighbourhood of Lagos do you live?
3. If Yes is your answer in (1), which neighbourhood of Lagos do you work?
4. GENDER; which category below includes your gender?

- ➢ Male
- ➢ Female

5. AGE; which category below includes your age?
   - ➢ Less than 15 years
   - ➢ 16–20 years
   - ➢ 21–40 years
   - ➢ 41–50 years
   - ➢ 51–60 years
   - ➢ Above 60 years

6. EDUCATIONAL STATUS; what is your highest level of education qualification?
   - ➢ No formal education
   - ➢ Elementary/primary school certificate
   - ➢ Secondary/high school certificate
   - ➢ Diploma certificate
   - ➢ First degree
   - ➢ Postgraduate qualification (e.g. Master's degree, PhD, law, medicine, etc.)
   - ➢ Others (please specify) ….

7. EMPLOYMENT STATUS; which category below includes your employment status?
   - ➢ Students
   - ➢ Civil servants
   - ➢ Business owner
   - ➢ Professional driver
   - ➢ Trader
   - ➢ Unemployed
   - ➢ Retired/Pensioner
   - ➢ Others (please specify) ….

8. MARITAL STATUS;
   - ➢ Single
   - ➢ Married
   - ➢ Prefer not to say

9. LOCATION OF BUSINESS; how close in time is your business or workplace location to the road corridor
   - ➢ 5 min
   - ➢ 6–10 min
   - ➢ 11–30 min
   - ➢ above 30 min

10. PERIOD OF BUSINESS; how long have you been in your business or workplace?
    - ➢ Less than 5 years
    - ➢ 5–10 years
    - ➢ 10–15 years
    - ➢ 15–20 years
    - ➢ Above 20 years

11. FREQUENCY OF INCOME ON THE JOB/WORK/BUSINESS
    - ➢ Daily
    - ➢ Weekly
    - ➢ Monthly
    - ➢ Yearly
    - ➢ Prefer not to say

12. INCOME ON THE JOB/WORK/BUSINESS
    - ➢ No profit
    - ➢ Less than N30,000
    - ➢ N30,000 – N100,000
    - ➢ N100,000 – N200,000
    - ➢ N200,000 and above

13. WORK/BUSINESS PERIOD; what is the average daily hours you spent at work?
    - ➢ Less than 8 h
    - ➢ 8 h
    - ➢ 8 h above

14. WORK SCHEDULE; how often do you go to work?
    - ➢ Everyday
    - ➢ Monday to Friday
    - ➢ Once a week

➢ Twice a week
➢ Three times a week
➢ Prefer not to say

SECTION B: CAR OWNERSHIP, VEHICLE XTICS AND MODE CHOICE

➢ Do you own a vehicle?
  ➢ Yes
  ➢ No
  ➢ Lease
  ➢ Prefer not to say
➢ If YES is your answer in (1), state the type of vehicle?
  ➢ Motorcycle
  ➢ Tricycle
  ➢ Car/taxi
  ➢ Minibus/trotro/van
  ➢ Large bus
  ➢ Truck
  ➢ Lorries
➢ If YES is your answer in (1), what is the status of your vehicle when bought?
  ➢ Brand new
  ➢ Used (second hand)
➢ If your vehicle is used, what type?
  ➢ Imported
  ➢ Nigerian used
➢ If YES is your answer in (1), what year is your vehicle manufactured? Pls specify the year … … … … … … … … … ….
➢ If YES is your answer in (1), what year did you buy or import your vehicle? Pls specify the year … … … … … … … … … ….
➢ If YES is your answer in (1), what is the status of your vehicle registration?
  ➢ Registered
  ➢ Not registered
  ➢ Prefer not to say
➢ If YES is your answer in (1), how old is your vehicle now?
  ➢ Less than 5 years
  ➢ 5–10 years
  ➢ 10–15 years
  ➢ 15 years above
  ➢ Prefer not to say
➢ If YES is your answer in (1), what is the main purpose of your vehicle?
  ➢ workplace
  ➢ business
  ➢ family
  ➢ religious
  ➢ Others (please specify) ….
➢ If YES is your answer in (1), what fuel does your vehicle use?
  ➢ Petrol
  ➢ Diesel
  ➢ Gasoline
  ➢ Others (please specify) ….
➢ Do your vehicle emits more emission from it's exhaust than normal?
  ➢ Yes
  ➢ No
  ➢ Cant say
➢ What is the current state of your vehicle now?
  ➢ Good condition (engine)
  ➢ Faulty
  ➢ low performance (engine)
➢ If NO is your answer in (1), what is the purpose of the mode of transport?
  ➢ work
  ➢ business
  ➢ family
  ➢ religious

➢ Others (please specify) ….
➢ Do you drive?
  ➢ Yes
  ➢ No
➢ what is your usual mode of transport?
  ➢ Motorcycle
  ➢ Tricycle
  ➢ Car/taxi
  ➢ Minibus/trotro/van
  ➢ Large bus

SECTION C:TRIP, TRAFFIC CONGESTION, POLLUTION & HEALTH

1. Purpose of your trip/journey
   ➢ Work/business/school
   ➢ Recreation
   ➢ Religious
   ➢ Prefer not to say
2. How often do you make your trip in a week
   ➢ Daily
   ➢ Once in a week
   ➢ Twice a week
   ➢ Thrice a week
   ➢ More than thrice in a week
3. Do you take your personal vehicle for your trip
   ➢ Yes
   ➢ No
4. Do you go by public transport?
   ➢ Yes
   ➢ No
5. Do you experience traffic congestion on your trip/
   ➢ Yes
   ➢ No
   ➢ Can't say
6. How often do you experience congestion?
   ➢ Daily
   ➢ Once a week
   ➢ Twice a week
   ➢ Thrice and above
   ➢ Cant say
7. Which day of the week do you experience traffic? Choose as applicable. You can choose more than one option.
   ➢ Monday
   ➢ Tuesday
   ➢ Wednesday
   ➢ Thursday
   ➢ Friday
   ➢ Saturday
   ➢ Sunday
8. How long do you stay in a traffic congestion?
   ➢ Less than 10 min s
   ➢ 10–20 min
   ➢ 20–60 min
   ➢ 60min and above
9. What time of the day do you experience congestion
   ➢ 7–9 am
   ➢ 10–12 pm
   ➢ 4–6 pm
   ➢ 6–9 pm
10. Do you perceive emission from the vehicle during your trip?
    ➢ Yes
    ➢ No

➢ Cant say

11. Do you perceive emission from other vehicles during your trip?
    ➢ Yes
    ➢ No
    ➢ Cant say
12. Do you hear loud disturbing noise from your vehicle during your trip?
    ➢ Yes
    ➢ No
    ➢ Cant say
13. Do you hear loud disturbing noise from other vehicles during your trip?
    ➢ Yes
    ➢ No
    ➢ Cant say
14. What type of vehicle do you typically perceive emission coming out from? (Multiple choice)
    ➢ Motorcycle
    ➢ Tricycle
    ➢ Car/taxi
    ➢ Minibus/Van
    ➢ Large Bus
    ➢ Truck
    ➢ Lorries
15. What type of vehicle do you typically hear loud disturbing noise coming out from? (Multiple choice)
    ➢ Motorcycle
    ➢ Tricycle
    ➢ Car/taxi
    ➢ Minibus/trotro
    ➢ Bus (space)
    ➢ Truck
    ➢ Lorries
16. When do you typically perceive the emission? (Multiple choice)
    ➢ When vehicle slow down
    ➢ When vehicle is in congestion
    ➢ When the vehicle accelerate
    ➢ When vehicle hit a pot hole
    ➢ When vehicle stop
    ➢ When vehicle is moving fast
17. How long do you often perceive the emission? (Multiple choice)
    ➢ Less than 5 min
    ➢ 5–10 min
    ➢ 10–30 min
    ➢ 30 min above
    ➢ Throughout the entire journey
    ➢ Others (please specify) ….
18. When do you often hear the loud disturbing noise?
    ➢ During traffic congestion
    ➢ When vehicle slow down
    ➢ When vehicle hit a pot hole
    ➢ When vehicle accelerate
    ➢ When vehicle stop
    ➢ When vehicle is moving fast
    ➢ Others (please specify) ….
19. What do you do when you inhale the emission inside the vehicle on your trip?
    ➢ Complain
    ➢ Avoid it
    ➢ Leave the spot
    ➢ Do nothing
    ➢ Visit the clinic
20. Are you aware about the health risk of the emission to human health?
    ➢ Yes
    ➢ No
    ➢ Cant say

21. Is your Workplace/school close to the road corridor?
    - ➢ Yes
    - ➢ No
    - ➢ Cant say
22. If your answer is YES in 21 above. How close is your workplace or school to the road corridor
    - ➢ Less than 50 m away
    - ➢ 50–100 m away
    - ➢ 100–300 m away
    - ➢ 300 m and above
23. If your answer is YES in 21 above. What is the nature of your work around the road?
    - ➢ Traders
    - ➢ Hawkers
    - ➢ Shop owners
    - ➢ School children
    - ➢ Drivers/conductor
    - ➢ Office staff
    - ➢ Police/Traffic officer
    - ➢ Others (please specify) ….
24. If you are one of 22 above, when do you typically perceive the emission?
    - ➢ During traffic congestion
    - ➢ When vehicle slow down
    - ➢ When vehicle stop
    - ➢ When vehicle is moving fast
    - ➢ Cant say
25. If you are one of 22 above, how long is your working hours
    - ➢ Less than 8 h
    - ➢ 8 h
    - ➢ 8–12 h
26. How often do you come to work in the week
    - ➢ Daily
    - ➢ 5 times in the week
    - ➢ Less than 5 times daily
27. If you are one of 22 above, how long do you often inhale the emission?
    - ➢ Less than 15 min s
    - ➢ 15min–60 min s
    - ➢ Throughout your working hours
28. If you are one of 22 above, what do you do when you inhale the emission?
    - ➢ Complained
    - ➢ Cover the noise
    - ➢ Leave the spot
    - ➢ Do nothing
    - ➢ Visit the clinic
29. If you are one of 22 above, are you aware about the health risk of the emission to human health?
    - ➢ Yes
    - ➢ No
    - ➢ Cant say

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