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The perception of air pollution exposure from commuting in Ho Chi Minh City, Vietnam

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Abstract

With rapid industrialisation and motorisation, air pollution is a serious problem for many emerging economies in the Global South. Studies of air pollution are limited in Vietnam, especially studies about the perception of air pollution and its association with transport. Knowledge of how the public perceive pollution and their concerns about air pollution could be the missing link in garnering public support for effective sustainable transport policies and strategies (e.g. mode shift from motorised transport to active travel) that help reduce emissions. This study aims to gain insight into perceived air quality and negative impacts of exposure to air pollution while commuting. 222 respondents from 24 urban districts in Ho Chi Minh City (HCMC) were surveyed. Data collected include socio-demographic, travel characteristics and psychometric measures of travel-related air pollution. Air quality in HCMC is widely perceived to be poor, with most respondents reported exposure to air pollution during travel is negatively affecting their health in three different measures (affecting general health (E1), as a barrier of active travel (E2) and causing cardiovascular disease (E3)). Binary logistic regression modelling results suggest proximity to busy traffic, industrial/commercial/transport land use, old age (50 years older), higher levels of environmental concern and poor self-rated health are statistically associated to perceived health and travel impacts due to air pollution during commutes. Better environmental, transport and land use policies are urgently needed in HCMC to address air pollution. Perceptions can be managed by improving information dissemination of air pollution levels and their effects.

Keywords: air pollution; perception; exposure; psychometric survey; traffic-saturated city

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1. Introduction

Emerging economies are experiencing rapid economic development. There is, however, limited capacity to address growing environmental issues – this is contributing to an "urban transport crisis" (Pojani and Stead, 2016; Pucher et al., 2005) charactered with high levels of congestion, pollution (particularly air and noise), traffic fatalities and injuries, and inequity. Ambient air pollution is of particular concern, in view of its widespread impacts on the urban population and long-term health implications. The link between traffic air pollution and health deterioration has been epidemiologically established, including elevated risks of cardiovascular disease (Folino et al., 2017), respiratory illnesses (OECD and Transport, 2014; Prüss-Üstün et al., 2016), asthma among children (Brauer et al., 2002), and life expectancy reduction (Brunekreef and Holgate, 2002; Hoek et al., 2002; Pope et al., 2009). These negative health effects are considered preventable. There has been ample focus on better environmental regulations to limit pollutants by less polluting vehicles. Alternative (and sustainable) transport and land use planning that reduce travel needs or shifting away from more polluting motorised modes to cleaner ones might be a more long lasting remedy with social benefits (Frank, 2000; Hickman and Banister, 2014).

In Vietnam, the 1986 *Doi Moi* economic reforms opened the once isolated and improvised country to the world – transforming itself into a vibrant export-oriented market economy. This has greatly improved livelihood but also bought forth severe air pollution, as in many other emerging economies in the region such as China (Poon et al., 2006) and India (Badami, 2005). Apart from industrial and power generation, powered two wheelers (PTW) being the dominant mode is also a major source of air pollutants in South East Asian nations (McGranahan and Murray, 2003), including Vietnam (Ho, 2017; Phung et al., 2016). Fig. 1 highlights the severity of air pollution in the region with Hanoi and Ho Chi Minh City (HCMC) both listed on top the chart.

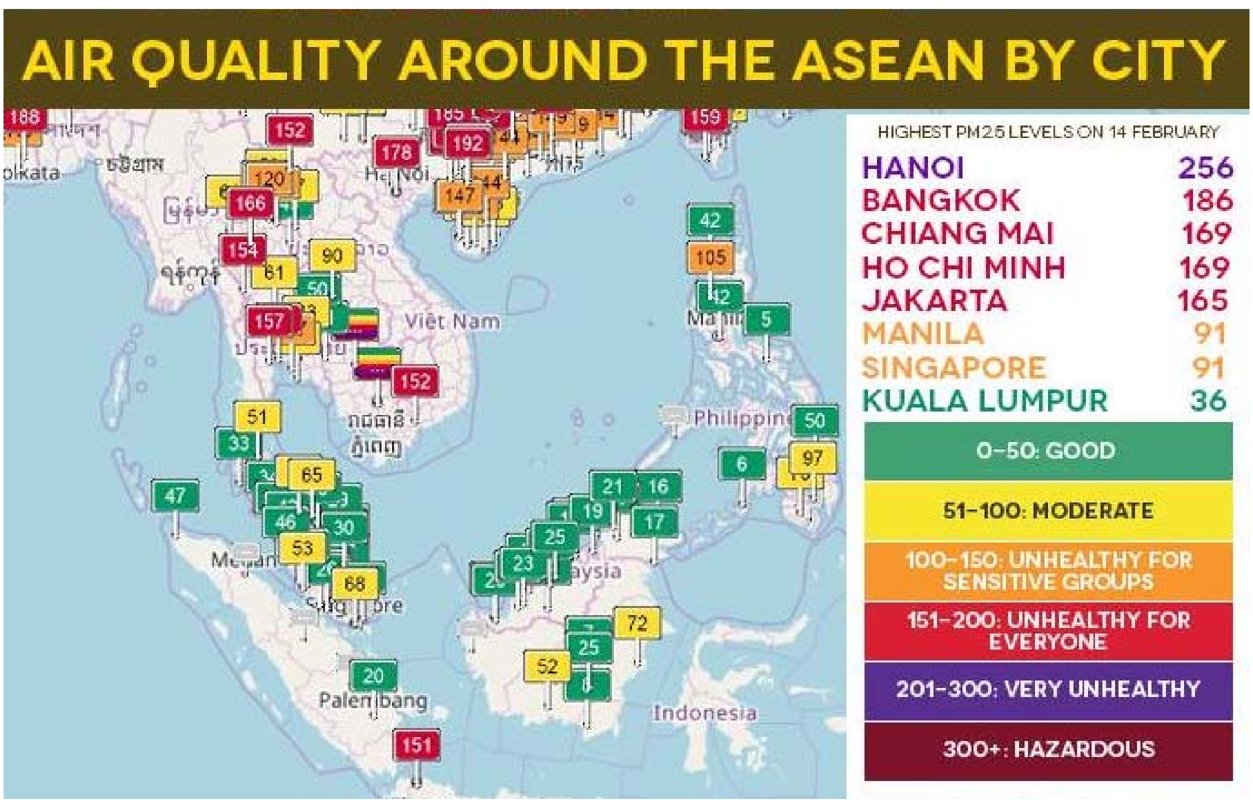

Fig. 1. Air quality index of ASEAN region on 15 February, 2018 (Source: LivingASEAN, with air quality index data from AQICN.org)

Once dominated by bicycles and pedestrians, personal motorised modes, in particular motorcycles and cars are becoming essential for Vietnamese life, and also being seen as a status symbol (Truitt, 2008). Unless a Singapore or Hong Kong style car restraint and public transport first policies are in place, reverting the tide of motorisation in these "traffic-saturated cities" (Barter, 2000) appears difficult. While grand public transport plans were devised and commenced back in the 2000s, with two metro systems now under construction in Hanoi (the capital) and HCMC (the largest city), progress is hampered by significant delays due to unfavourable weather and worksite accidents. Hanoi Metro was scheduled to be operational in April 2019 but is delayed yet again. Meanwhile the HCMC Metro is pushed later until 2020. Until then, the congestion and air pollution situation of both cities would remain stark.

Measuring pollution has been a mainstay of environmental and pollution studies, with a large volume of literature looked at atmospheric dispersal patterns, accounting for emission inventories and the health impacts (Han and Naeher, 2006). There is also a growing recognition of studies looking at public perception of air pollution. The reasons could be summarised as the following: (1) Not all forms of air pollution are visible, there is an actual and perception gap which affects the effectiveness of risk communication and adaptive measures (Smallbone, 2012). (2) Social impacts arising from air pollution are fundamentally an issue of perception, such as effects on property values (Chasco and Le Gallo, 2015) or mental health (e.g. depression) (Claeson et al., 2013). (3) Concerns about air pollution may be a benefit or hindrance to sustainable transport policy depending on how its effect or causes are being perceived (Henry and Gordon, 2003; Sun et al., 2016). Understanding how the public perceive air pollution could be instrumental in garnering support for better environmental, transport and land use policy to reduce emissions, which could then reduce the associated health impacts.

Active travel modes are often considered less attractive (or even dangerous) in heavily polluted cities due to the perception greater exposure to pollutants (Cole-Hunter et al., 2015). While some argue the physical activity benefits outweighs this risk (Cepeda et al., 2017), there is limited incentives for individual to reduce personal pollution until the ambient air quality becomes visible or starting to affect health due to "tragedy of commons" as clean air can be considered as a shared public good. Milan's successful congestion pricing scheme which was driven by widespread concern of air pollution, which aroused awareness and enticed support for more effective pollution reducing transport, environmental and land use policies (Mattioli et al., 2012).

Based on these reasons, this paper examine the perceptions of traffic air pollution with a specific attention on socio-demographic and travel patterns of a fast growing metropolis of a developing country – HCMC (also known as Saigon). HCMC is the largest and the most economically dynamic city of Vietnam, experiencing rapid inward migration, population growth and urban expansion (Nguyen et al., 2016). The factors that are associated with the perception of air pollution during daily commute are also explored. This type of research is novel in Vietnam as previous studies have been largely focused on objectively measured air pollution levels and impacts (Ho, 2017; Luong et al., 2017; Phung et al., 2016). In a wider context, air pollution studies considering perception and travel pattern simultaneously is not common. The findings may inform transport policy makers in Vietnam or similar cities about how the public perceive traffic-related air pollution - including exposure effects, air quality, environmental concern, and government information sources. Geographic, socio-demographic data and travel preferences (e.g. usual mode) can also be compared with perceptions, which can be used to gauge the level of public support for the solutions, such as implementing restraint of polluting modes, improving public transport or enforcing more stringent emissions standards.

This paper is organised in the following structure: Literature review is first conducted to outline the concept of risk perception in prior research. This is followed by the methodology outlining the context of the study area, the survey process and the key variables considered. The results are then presented in the form of descriptive statistics and quantitative modelling outputs. Discussion of these findings is provided for, which also establishes the links between previous literature and suggests some key policy implications. The limitations and future research opportunities are also suggested. This paper ends with a concluding remark which summarises the key findings and contributions.

2. Literature Review

2.1. Risk society, perception and communication

Modern risk perception studies originated in the 1940s in human geography fields that examined response to hazards and how flood risks were coped with (Kellens et al., 2013). A key impetus of these studies was to understand how human perceive risks, and how risks can be communicated to reduce loss in lives and property. The frameworks developed were then expanded to many other forms of risks. As a result of global industrialisation and improved standard of living (Starr, 1969), risk is seen as embedded as part of modern living, creating the notion of "risk society" (Beck, 1992) - risks are scientifically assessed, accepted when it is negligible, but also feared (and prepare for) in event of disasters. Air pollution is a risk that is, unlike floods, considered not immediate and direct in nature. It is atmospheric, global and interconnected – producing wide-ranging and long-term health impacts (Maturo and Moretti, 2018). This demands a more holistic type of research, which encompasses the domain of sociology, and in particularly, perceptive research. Traditionally air pollution studies focused on objective measures, such as quantity of pollutants and effects. Many monitoring and modelling studies have been conducted – these often include research on emissions inventory, environmental dispersal, interaction with atmospheric conditions, and health impacts (Jerrett et al., 2004). Many of these works are not dissimilar to other hazards studies, such as floods or climate change. While these studies are important in advancing scientific understanding of hazards, public involvement has been rather limited (Bickerstaff, 2004). Risk-managing authorities usually take a public education, or a one-way approach to disseminate scientific information and knowledge. However, "the concept of "risk" means different things to different people" (Slovic, 2000, p. 223), and to ultimately solve the problem of pollution requires the society to reduce the overall level of pollutants (Bickerstaff and Walker, 1999; Sun et al., 2016). Thus, a growing attention of research is on how environmental impacts or hazards are perceived, how willing the public is to reduce their impact by adopting less polluting lifestyles or invest in more environmentally stringent inventories. Survey tools to gauge perceived environmental risk has also been developed, which includes a range of pollution issues (air, water, solid waste, noise) (Weber et al., 2000) or health impacts (Dixon et al., 2009). There were also attempts to develop a global standardised scale for air quality perception (Deguen et al., 2012). However, some of these are generic in nature and are not focusing on traffic-related pollution.

2.2. Perception studies of air pollution and transport

As reviewed by Oltra and Sala (2014), air pollution risk perception research begun with basic measures of the level of awareness in the 1950s to 1960s (Crowe, 1968; Schusky, 1966). These were then expanded to incorporate comparisons with actual pollution measurements that identify the causes of perception forming (Lercher et al., 1995). More recent studies turned into a better focus on how perception relates public participation and activism (Elliott et al., 1999; Gould, 1993), with a greater focus on "citizen science" that empowers the public to reveal information (and their perceptions) to air pollution scientists and also decision makers. Neighbourhood and community factors were also linked – the idea of "neighbourhood halo" effect, where communities amplify or reduce their perceptions of air pollution severity based on the level of attractiveness of the area, is developed (Bickerstaff and Walker, 2001). Even if measured with the same air pollution measurements, industrial areas are often perceived as having greater levels of air pollution than the "greener" countryside. Elements of social inequity and environmental justice were also incorporated - air pollution exposure and impacts are usually spatially and socially correlated with greater social-economic disadvantage (Li et al., 2018; Lucas et al., 2016; Mitchell and Dorling, 2003; Pearce et al., 2006).

Perception studies often consider wide range of air pollution sources (industrial, transport, agricultural, natural), at the same time. Specific perception studies regarding transport or traffic air pollution were not as common but are slowly emerging. Early traffic pollution studies of these kind also consider traffic noise effects – or "hearing is feeling" air pollution (Hollingworth, 1982). More recent studies made use of advanced spatial analysis to further confirm neighbourhood halo or stigma effects (Gatersleben and Uzzell, 2000; Kim et al., 2012; King, 2015), and attempted to establish the perceptive links of air pollution to specific health impacts (e.g. cardiovascular disease), physical activity and also the uptake of active modes (Anowar et al., 2017; Apparicio et al., 2016; Badland and Schofield, 2005;

Badland and Duncan, 2009; Cepeda et al., 2017). Studies also looked at solutions, such as the effectiveness of public information campaign for promoting sustainable modes (Henry and Gordon, 2003). Most studies used psychometric surveys and quantitative analysis, yet qualitative approaches are also found to be able to exact in-depth personal feelings, concerns and experiences (Day, 2006; Johnson, 2012; Xu et al., 2017) which are useful in settings with higher levels of illiteracy (e.g.: slums in Sub-Saharan Africa) (Ngo et al., 2017). Recently, perceptions expressed in the cyberspace and online were also studied by computer text-mining techniques (Guo and Li, 2018).

Since the 2010s, perception studies in emerging economies with severe air pollution are also growing, in particular, China, with varying focus on health effects (Lan et al., 2016; Wang et al., 2015), neighbourhood halo effects (Li et al., 2014), tourism impacts (Becken et al., 2017; Zhang et al., 2015), public knowledge and information (Guo and Li, 2018; Qian et al., 2016; Zhao et al., 2018), and wider policy such as willingness to pay for pollution mitigation (Liu et al., 2016; Sun et al., 2016). We are not aware of other studies of air pollution perceptions and travel conducted in Vietnam to date. This is a key motivation for this study.

3. Methodology

3.1. Study area and perception survey

We considered a number of approaches from the relevant literature, but our approach is mostly based on Badland and Duncan's (2009) study in Brisbane with a number of local adaptations and improvements. Between March and April 2018, a household survey was conducted in HCMC covering 24 urban districts. This study is part of an on-going wider transport study (Final sample size ~2500). For this stage, a total of 222 samples with no missing values of the air pollution questions were obtained. Sampling was conducted in highly urbanised areas (with over 80% continuously built area coverage). The southernmost district of Can Gio at the coastline of HCMC is not included in the survey area. Samples were selected randomly on a list of addresses of households. Only those who were over 17 years old, regularly commutes to work or education were the intended target population. Fig. 2 maps the context of the study area. District 1 is where the city centre and municipal government is located. While the sample size of each district is rather small (approximately 10 each), and may not be fully representative, our study is more focused on how different the respondents are perceiving air pollution and travel, adjusted by district level geography and personal socio-economic differences.

Population density at district level in 2016 were obtained from the HCMC Statistical Office. District level land use coverage of HCMC Metropolitan Region of 2010 was sourced from World Bank's Platform for Urban Management and Analysis (PUMA) database (World Bank, 2013). The survey data provides socio-demographic, travel characteristics and psychosocial metrics of air pollution perceptions regarding their commute. The survey consists of a number of 1-5 point Likert scale statement questions, ranging from strongly agreed (1) to strongly disagreed (5). The following subsection describes these variables in detail.

3.2. Dependent Variables – Perceived effects of exposure to air pollution during commute

Three dependent variables are based on questions regarding the perceived effects of exposure to traffic air pollution during commute (to work or school) - *E1: Exposure to air pollution during commute negatively affects my health*; *E2: Exposure to air pollution during commute is a major barrier for me to undertake active travel*; and *E3: Exposure to air pollution during commute increases my risk of cardiovascular disease*. E1 gauges the general concern of health impacts from air pollution during commute. E2 elicits whether air pollution is preventing the respondent to undertake active travel, which outdoor physical activity level is associated with personal health benefits. E3 asked for a specific, but less well-known health impact of air pollution. In perception studies, perceived air pollution impacts are usually reported as experience of serious medical symptoms (bronchitis, asthma or eczema) or psychosomatic discomfort (headaches, fatigue, eye/nasal irritation, and effects on general mood/wellbeing) (Elliott et al., 1999; Gatersleben and Uzzell, 2000; Howel et al., 2003; Lercher et al., 1995). However, there are significant associations between higher levels of pollutants (NO_2 and PM_{10}) and cardiorespiratory hospitalisations in HCMC (Phung et al., 2016). Similar health effects were examined in a global meta-analysis of low to middle-income countries (Newell et al., 2017). The perceived association of cardiovascular disease could be related to the respondent's knowledge about the health impacts of air pollution and the actual/perceived severity of pollution.

3.3. Influencing variables

The selection of influencing variables is based on a number of prior studies (Badland and Duncan, 2009; Oltra and Sala, 2014). Socio-demographics variables are often used in most perception studies as they strongly relate to the lifestyle and exposure risk to pollution. Variables included in this study are gender, age, education level, income, and marital status. There are slightly more females (n=120, 54.1%) than males (n=102, 45.9%) in our sample. Sampling also captured more younger, more educated segment of the population, partially reflecting their higher willingness to participate. Travel characteristics are also captured in the question about the most often used mode of the respondents. Our sample included a higher percentage using active travel and/or public transport (n=77, 34.7%), whereas car (n=64, 28.8%), with motorcycle users are less represented (n=36, 16.2%). The last large scale comprehensive household travel survey was conducted nearly a decade ago by ALMEC Corp., a Japanese foreign aid agency (2004). Circumstance may have greatly changed as motorisation rates have soared. Vehicle ownership was 222.4 motorcycles per 1000 persons and 20.2 cars per 1000 persons in 1996. In 2016, these figures skyrocketed to 847.8 motorcycles per 1000 persons and 81.3 cars per 1000 persons. Vietnam is classified as a traffic saturated city (Barter, 2000), with exceptionally high motorcycle use but car ownership remains low by global standards (Bakker et al., 2017).

A range of psychometric variables are used to measure the perception of air pollution and are based from prior studies as well. These include the perceived main traffic source of air pollution by modes pollution (Gatersleben and Uzzell, 2000; Hollingworth, 1982), local settings such as proximity to busy roads (Elliott et al., 1999), awareness to pollution (self-rated air quality), response to air pollution during commute (changing route when conducting active/non-active travel and travel time (Badland and Duncan, 2009)) , environmental concern (Stern, 2000), self-relevancy of own travel that is causing pollution (Zhou et al., 2016), emotion (annoyance felt from air pollution) (Oltra and Sala, 2018), self-rated health (Kim et al., 2012; Pantavou et al., 2017) and government air pollution information adequacy and reliability (Bickerstaff, 2004; Smallbone, 2012). Real-time and detailed information of HCMC's air pollution are not disseminated by the authorities - only periodical summary data are released. The only real-time data available in HCMC are collected by the US embassy's rooftop sensors. Limited accessibility and reliability of air pollution information might affect perception of air pollution is also a research issue.

3.4. Statistical analysis

The district level geography and individual survey data allows the analysis of characteristics associated with perceived exposure to air pollution during commuting travel. These are compared with the entire sample and those with positive response to the dependent variables (E1, E2 and E3). Likert scale variables are dichotomously collapsed into binary values of 'yes' (strongly agreed + agreed) and 'no' (neutral, disagree and strongly disagree). Non-parametric statistical comparison between these variables were conducted by Mann-Whitney U-test for binary influencing variables (Gender, psychometric variables) and by Kruskall–Wallis (one-way ANOVA) test for ordinal or continuous variables (Population density, land use cover, age, income, mode choice and perceived mode that is a main contributor to traffic air pollution). The dependent variables are tested against the influencing variables with a binary logistic model. The adjusted odds ratio is shown only as crude odds ratios are not realistic. We have also tested the crude odds ratios and report for key association changes.

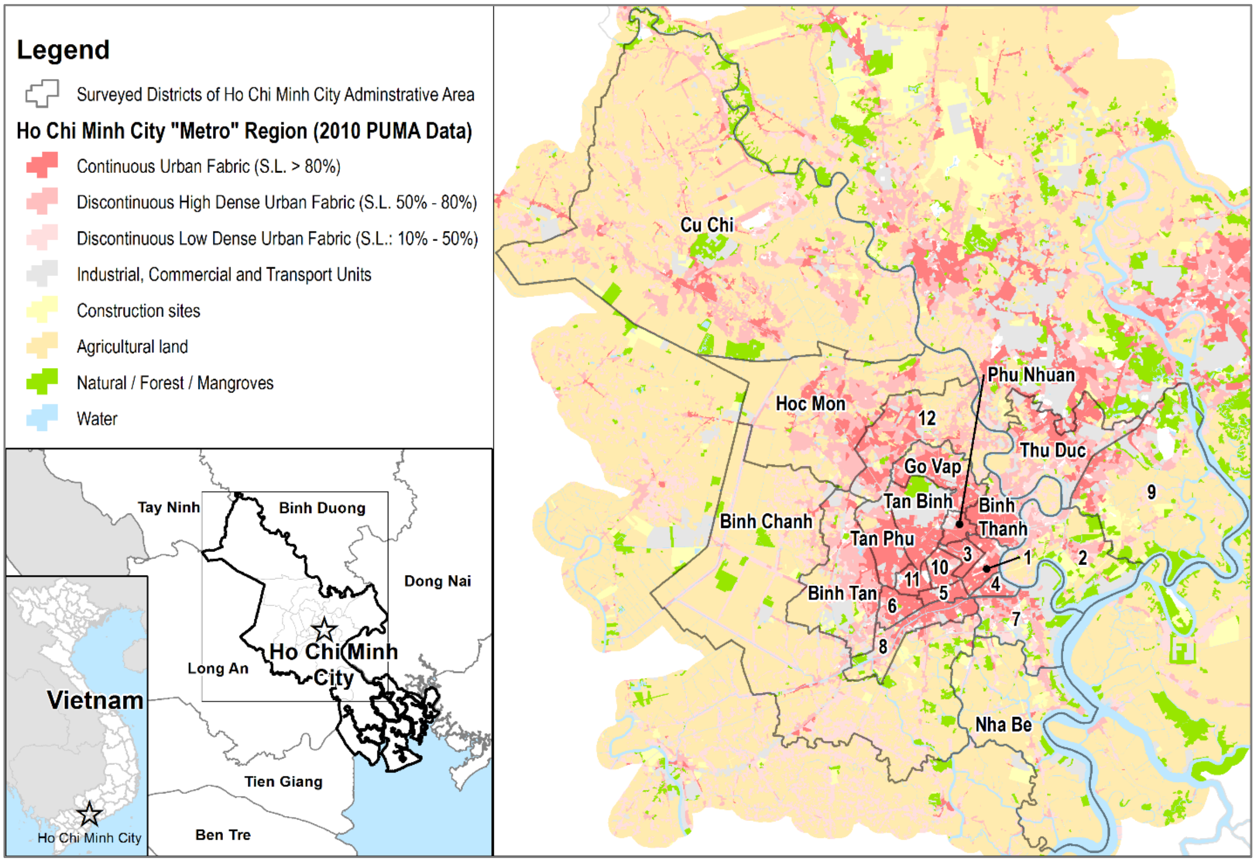

Fig. 2. The Metropolitan Region of Ho Chi Minh City, showing the major land use within and its surrounding areas

4. Results and discussion

Table 1 shows the descriptive statistics of mean and summary values of the influencing variables and the results of non-parametric tests. Table 2 shows the binary logistic modelling results with adjusted odds ratios (OR). While not all the variables are significant in binary modelling, we are also interested to show the direction of effect and the use the non-significant variables as controlling factors. The binary models are showing an acceptable model fit – the Pseudo R_2 (McFadden) of the dependent variables are E1=0.34, E2=0.33 and E3=0.41 respectively.

For district level geographical variables, there are statistically significant associations with the dependent variables but undiscernible odds ratio differences (OR=0.99 for E1, E2 and E3). A study in Essen, Germany shown urban green areas were found to be associated better actual air quality (Kuttler and Strassburger, 1999). However, the presence of urban parks does not improve the exposure impact perceptions in HCMC, with higher odds ratios for those reported greater health and travel impacts (E1=1.19, E2=1.16, E3=1.18). Objective measure of higher natural land use cover is associated with less perceived impacts (E1=0.8, E2=0.81, E3=0.77) at very high statistical significance (p-value=0.001). While this might imply these areas have less dense urban development and less traffic, qualitative findings in London (Day, 2007) have reported personal accounts about the presence of greenery improves air quality perceptions. Regarding "neighbourhood halo" effects, the district percentage of industrial, commercial and transport land use cover exerts a slight negative effect on the degree of responses stating exposure to air pollution in commutes is a major barrier of active travel (E2) (OR=1.04). The same association pattern but without statistical significance is found in health effects (E1 and E3). This variable is similar to the response "living close to busy roads", which is highly statistically significant for association with perceived risks of heart disease (E3) and with a stronger magnitude of effect (OR=4.49).

For socio-demographic variables, gender does not exert clear difference in descriptive statistics for the whole sample and those agreeing to E1, E2 and E3 exposure questions. When this is adjusted with all other influencing variables in binary logistic modelling, females are found to be slightly more likely to report perceived negative health and is statistically significant for citing traffic air pollution is a barrier to active travel (OR=2.26). This confirms with the findings of a previous cyclist perception study in Brisbane, Australia (Cole-Hunter et al., 2015). Older ages are also showing statistically significant higher odds ratios for E1 (Aged 35-49 OR=2.5, Aged over 50 OR=6.74) and E2 (Aged over 50 OR=3.39). This contrasts with the similar studies by Badland and Duncan (2009) and Brody et al. (2004) reporting no strong, or mixed effects caused by the difference of age (Howel et al., 2003). Perhaps air pollution is more serious in urban Vietnam, or different age groups have different perceptions. This might be of interest in future studies. Income effects are mixed and generally not significant, except for E3 with lower odd ratios. Those with moderate or higher incomes tends not to view air pollution in travel is causing heart issues. Marital status is significant for married respondents with higher association with E3 (OR=4.3).

Usual mode does not have statistically significant associations with perceived impacts of exposure. However, a general trend is that respondents who reported usual travel by private motorised modes (car, taxi) have higher odds of perceived exposure impacts than active or public transport. A global study looked at actual dosage of pollutants suggests motorised mode passengers are more exposed to traffic air pollution than active modes (Cepeda et al., 2017). For air pollution perception variables measured in psychometrics, those who perceive cars or trucks are the main source of air pollution tends to have higher odds ratio with dependent variables. Of particular attention is those who indicate truck as the main source have a very high odds ratio (8.34) to E3 (exposure is air pollution is causing heart disease) and this is statistically significant. A number of respondents reported public transport as main source of traffic air pollutants as buses in HCMC mostly run on diesel, and possibly with older Euro emission standards. Even so, this variable has a lower odds ratio than 1 which implies the association is less than other motorised modes. Self-rated air quality is largely reported as poor (64.9% of all samples, with E1=74.6%, 69.7% and 70.6%). However, the adjusted odds ratio of this variable less than 1. The crude odds ratio (running the model with only one influencing variable) of this variable is however higher than 1 (OR: E1=2.43, E2=1.59 and E3=1.79). This implies other influencing variables have moderated the self-reported air quality response. A possible explanation is the widespread perception of poor air quality in HCMC. This is not resulting in statistically significant effects on perceived exposure impacts when considering all the variables. Similarly, emotional annoyance is closely associated with air pollution in prior studies (Lercher et al., 1995), however, for our research, annoyance from traffic air pollution is only more strongly associated with E1 (OR=2.4, p-value 0.08), and with lower statistical significance and odds ratios for E2 and E3.We did not measure annoyance in more specific ways, such as visible dust, soot, dirt, or unpleasant odour (Claeson et al., 2013; Forsberg et al., 1997).

Some respondents also expressed concern about the environment, and they are more likely, and highly statistically significant to the perceived impacts from travel air pollution (odds ratios: E1=3.44, E2=3.96, E3=6.56). In paralleling hazards perception research, flood victims were found to be more likely to be concerned about climate change (Whitmarsh, 2008). Environmental concern should be viewed in conjunction with a similar variable about self-awareness or relevance of causing traffic-related pollution, which has an odds ratio over 1, and is particularly strong for E3 (OR=10.22). For response to air pollution, responding by changing routes resulted in low odds ratios, although the variable of non-active travel route changes is statistically significant. Responding by changing travel time to avoid traffic and its air pollution resulted in odds ratios of over 1 for the exposure (dependent) variables. Meanwhile, we found self-rated health is a statistically significant variable with fairly high odds ratios (E1=2.96, E2=4.31, E3=3.73) and this is largely consistent with prior research (Kim et al., 2012; Pantavou et al., 2017). Finally, for variables regarding air pollution information, just over a half respondents reported being able to access to air pollution information (54.5%) and high percentages reported the information is unreliable (59.5%). These two information variables have some effects towards the perceived impacts of exposure with over 1 odds ratios, however, it is not statistically significant.

Table 1: Descriptive statistics and non-parametric tests of the surveyed dataset (AP means air pollution)

	All Respondents		E1: Commuting exposure to AP negatively affects my health			E2: Commuting exposure to AP is a major barrier for active travel			E3: Commuting exposure to AP causes cardiovascular disease		
	All Respondents		Agree		p-value	Agree		p-value	Agree		p-value
	mean	%	mean	%		mean	%		mean	%	
District geography											
Population density (in thousands)	23.092		23.444		0.643	23.769		0.326	23.925		0.232
District Land use cover %											
Industrial, Commercial and Transport	17.7		18.2		0.099	18.6		0.111	17.0		0.933
Urban Park	2.3		2.8		0.087	2.6		0.233	2.6		0.526
Natural / Forest / Mangroves	3.0		2.6		0.242	2.7		0.306	2.5		0.007
	All Respondents		Agree		p-value	Agree		p-value	Agree		p-value
	n	%	n	%		n	%		n	%	
Total sample	222		114			119			126		
Socio-demographic											
Gender					0.867			0.930			0.977
Male	102	45.9	53	46.5		55	46.2		58	46.0	
Female	120	54.1	61	53.5		64	53.8		68	54.0	
Age group					0.001			0.003			0.073
17-35 years old	102	45.9	37	32.5		45	37.8		49	38.9	
35-49 years old	82	36.9	50	43.9		47	39.5		56	44.4	
50 years old and over	38	17.1	27	23.7		27	22.7		21	16.7	
Educational level					0.886			0.206			0.170
High school	87	39.2	43	37.7		39	32.8		46	36.5	
College / University	94	42.3	42	36.8		52	43.7		52	41.3	
Postgraduate	25	11.3	18	15.8		17	14.3		19	15.1	
Other	16	7.2	11	9.6		11	9.2		9	7.1	
Income (1 million VND ~ 4 USD)					0.098			0.279			0.006
Under 20 million VND per month	45	20.3	28	24.6		22	18.5		34	27.0	
10 to 20 million VND per month	128	57.7	64	56.1		78	65.5		69	54.8	
Over 20 million VND per month	49	22.1	22	19.3		19	16.0		23	18.3	
Marital status					0.601			0.017			0.050
Single	103	46.4	50	43.9		45	37.8		49	38.9	
Married	83	37.4	44	38.6		53	44.5		57	45.2	
Divorced / Separated / Widowed	36	16.2	20	17.5		21	17.6		20	15.9	
Usual mode					0.857			0.008			0.513
Motorcycle	36	16.2	22	19.3		20	16.8		25	19.8	
Car	64	28.8	33	28.9		39	32.8		33	26.2	
Taxi	45	20.3	20	17.5		29	24.4		25	19.8	
Active and/or public transport	77	34.7	39	34.2		31	26.1		43	34.1	
Psychometrics of air pollution (AP) perception											
Perceived of main source of AP					0.277			0.003			0.042
Motorcycle	110	49.5	58	50.9		65	54.6		61	48.4	
Car	26	11.7	21	18.4		19	16.0		21	16.7	
Truck	19	8.6	5	4.4		10	8.4		11	8.7	
Public Transport (Bus / Train)	67	30.2	30	26.3		25	21.0		33	26.2	
Living close to busy roads					0.001			0.001			0.001
No	93	41.9	35	30.7		37	31.1		32	25.4	
Yes	129	58.1	79	69.3		82	68.9		94	74.6	
Awareness: Self-rated air quality					0.002			0.102			0.040
Not Poor	78	35.1	29	25.4		36	30.3		37	29.4	
Poor	144	64.9	85	74.6		83	69.7		89	70.6	
Respond by changing route - non-active travel					0.001			0.001			0.007
No	95	42.8	37	32.5		36	30.3		44	34.9	
Yes	127	57.2	77	67.5		83	69.7		82	65.1	
Respond by changing route - active travel					0.001			0.284			0.001
No	78	35.1	25	21.9		38	31.9		32	25.4	
Yes	144	64.9	89	78.1		81	68.1		94	74.6	
Respond by changing time of travel					0.001			0.004			0.001
No	119	53.6	47	41.2		53	44.5		53	42.1	
Yes	103	46.4	67	58.8		66	55.5		73	57.9	
Concern for environment					0.001			0.001			0.001
No	101	45.5	33	28.9		38	31.9		41	32.5	
Yes	121	54.5	81	71.1		81	68.1		85	67.5	
Self-relevance: My motorised travel causing AP					0.001			0.182			0.001
No	95	42.8	37	32.5		46	38.7		36	28.6	
Yes	127	57.2	77	67.5		73	61.3		90	71.4	
Emotion - annoyed by AP					0.001			0.001			0.001
No	71	32.0	16	14.0		26	21.8		26	20.6	
Yes	151	68.0	98	86.0		93	78.2		100	79.4	
Health - Poor self-rated health					0.001			0.001			0.001
No	136	61.3	49	43.0		53	44.5		60	47.6	
Yes	86	38.7	65	57.0		66	55.5		66	52.4	
Info. about AP from government accessible					0.001			0.098			0.002
No	101	45.5	37	32.5		48	40.3		46	36.5	
Yes	121	54.5	77	67.5		71	59.7		80	63.5	
Info. about AP from government unreliable					0.001			0.012			0.006
No	90	40.5	31	27.2		39	32.8		41	32.5	
Yes	132	59.5	83	72.8		80	67.2		85	67.5	

Table 2: Binary logistic model of perceived effects of exposure to air pollution (AP) when commuting

	E1: Commuting exposure to AP negatively affects my health			E2: Commuting exposure to AP is a major barrier for active travel			E3: Commuting exposure to AP causes cardiovascular disease		
	OR[a]	95% CI	p-value	OR[a]	95% CI	p-value	OR[a]	95% CI	p-value
District geography									
Population density	0.99	0.99-0.99	0.04*	0.99	0.99-1.01	0.15	0.99	0.99-0.99	0.04*
District Land use cover %									
Industrial, Commercial and Transport	1.03	0.99-1.08	0.12	1.04	1.01-1.09	0.04*	1.02	0.97-1.07	0.40
Urban Park	1.19	1.02-1.38	0.03*	1.16	1.01-1.34	0.05*	1.18	1.01-1.39	0.04*
Natural / Forest / Mangroves	0.80	0.68-0.94	0.01**	0.81	0.69-0.96	0.01**	0.77	0.65-0.91	0.01**
Socio-demographic									
Gender									
Male	1.00	Referent		1.00	Referent		1.00	Referent	
Female	1.34	0.59-3.01	0.48	2.26	0.99-5.18	0.05*	1.15	0.49-2.71	0.76
Age group									
17-35 years old	1.00	Referent		1.00	Referent		1.00	Referent	
35-49 years old	2.50	1.07-5.84	0.03*	1.30	0.55-3.1	0.55	2.60	0.98-6.89	0.06
50 years old and over	6.74	2.04-22.24	0.01**	3.39	1.03-11.19	0.05*	1.41	0.42-4.77	0.58
Educational level									
High school	1.00	Referent		1.00	Referent		1.00	Referent	
College / University	0.74	0.31-1.76	0.49	2.13	0.88-5.13	0.09	1.92	0.75-4.94	0.18
Postgraduate	0.81	0.19-3.49	0.78	0.93	0.19-4.43	0.92	1.24	0.25-6.09	0.79
Other	2.68	0.6-11.98	0.20	6.93	1.31-36.65	0.02*	2.04	0.43-9.63	0.37
Income (1 million VND ~ 4 USD)									
Under 20 million VND per month	1.00	Referent		1.00	Referent		1.00	Referent	
10 to 20 million VND per month	0.41	0.15-1.13	0.08	1.65	0.63-4.31	0.31	0.09	0.02-0.33	0.01**
Over 20 million VND per month	0.54	0.16-1.87	0.33	0.47	0.14-1.65	0.24	0.08	0.02-0.36	0.01**
Marital status									
Single	1.00	Referent		1.00	Referent		1.00	Referent	
Married	0.94	0.38-2.31	0.90	2.51	0.99-6.34	0.05*	4.30	1.61-11.48	0.01**
Divorced / Separated / Widowed	1.25	0.35-4.43	0.73	2.09	0.57-7.72	0.27	1.45	0.38-5.54	0.59
Usual mode									
Motorcycle	1.00	Referent		1.00	Referent		1.00	Referent	
Car	1.57	0.41-6.04	0.51	2.74	0.74-10.1	0.13	0.31	0.06-1.52	0.15
Taxi	1.45	0.37-5.73	0.59	3.45	0.84-14.12	0.09	0.38	0.07-1.97	0.25
Active and/or public transport	0.86	0.25-2.97	0.82	0.43	0.12-1.51	0.19	0.32	0.07-1.43	0.14
Psychometrics of air pollution (AP) perception									
Perceived of main source of AP									
Motorcycle	1.00	Referent		1.00	Referent		1.00	Referent	
Car	3.20	0.78-13.18	0.11	2.03	0.53-7.79	0.30	2.93	0.66-13	0.16
Truck	1.76	0.37-8.52	0.48	1.25	0.29-5.42	0.77	8.34	1.65-42.13	0.01**
Public Transport (Bus / Train)	0.92	0.36-2.31	0.85	0.37	0.15-0.94	0.04*	0.75	0.27-2.04	0.57
Living close to busy roads									
No	1.00	Referent		1.00	Referent		1.00	Referent	
Yes	1.19	0.48-2.96	0.70	1.12	0.46-2.68	0.81	4.49	1.61-12.52	0.01**
Awareness: Self-rated air quality									
Not Poor	1.00	Referent		1.00	Referent		1.00	Referent	
Poor	0.89	0.31-2.55	0.83	0.68	0.24-1.92	0.47	0.73	0.22-2.47	0.61
Respond by changing route - non-active travel									
No	1.00	Referent		1.00	Referent		1.00	Referent	
Yes	0.45	0.16-1.25	0.13	0.51	0.18-1.45	0.21	0.23	0.07-0.7	0.01**
Respond by changing route - active travel									
No	1.00	Referent		1.00	Referent		1.00	Referent	
Yes	1.27	0.45-3.55	0.65	0.55	0.2-1.54	0.25	1.06	0.34-3.26	0.92
Respond by changing time of travel									
No	1.00	Referent		1.00	Referent		1.00	Referent	
Yes	1.52	0.62-3.7	0.36	1.88	0.76-4.67	0.17	1.35	0.52-3.51	0.54
General concern for environment									
No	1.00	Referent		1.00	Referent		1.00	Referent	
Yes	3.44	1.42-8.3	0.01**	3.96	1.59-9.9	0.01**	6.56	2.33-18.5	0.01**
Self-relevance: My motorised travel causing AP									
No	1.00	Referent		1.00	Referent		1.00	Referent	
Yes	1.73	0.62-4.8	0.29	2.02	0.75-5.48	0.17	10.22	3.15-33.16	0.01**
Emotion - annoyed by AP									
No	1.00	Referent		1.00	Referent		1.00	Referent	
Yes	2.40	0.92-6.31	0.08	1.15	0.42-3.17	0.78	0.81	0.27-2.44	0.71
Health - Poor self-rated health									
No	1.00	Referent		1.00	Referent		1.00	Referent	
Yes	2.96	1.24-7.06	0.02*	4.31	1.7-10.9	0.01**	3.73	1.3-10.72	0.01**
Info. about AP from government accessible									
No	1.00	Referent		1.00	Referent		1.00	Referent	
Yes	1.31	0.5-3.47	0.58	1.11	0.42-2.92	0.83	0.74	0.24-2.26	0.60
Info. about AP from government unreliable									
No	1.00	Referent		1.00	Referent		1.00	Referent	
Yes	1.80	0.75-4.27	0.19	1.19	0.48-2.92	0.71	0.83	0.32-2.2	0.72
LR chi2 (31df)	104.87			100.91			125.29		
Probability > chi2	0.001			0.001			0.001		
Pseudo R2 (McFadden)	0.341			0.329			0.413		

Key: CI = confidence interval; OR = odds ratio.

[a] Odds ratios mutually adjusted by all other variables in the table.

p –values: * p<0.05; ** p<0.01

5. Methodological considerations and future research

While a majority of our findings are in line with existing air pollution-health risk evidence (Oltra and Sala, 2018; Saksena, 2011), our results on active travel and route change differ to a similar study by Badland and Duncan (2009). A possible reason due to different local settings – air pollution levels are much more serious in HCMC and also the way of travel, or mobility culture, is vastly dissimilar (Kuhnimhof and Wulfhorst, 2013). It could be interesting to conduct a comparable surveys in other cities to ascertain whether similar patterns can be found.

The findings of this research may help to provide the authorities of HCMC and possibly beyond with better understanding of public perception of air pollution. Respondents with varying geographical and socio-demographic backgrounds produced different responses to the exposure questions. This can help devise better targeted policy on air pollution abatement. HCMC's residents are generally concerned about poor air quality. Those with higher levels of environmental concern are also associated with greater perceived impacts from exposure, and seeing it as a barrier to active travel, especially for car or motorcycle users. This presents a challenge for sustainable transport policy in HCMC -less polluting active travel are being stifled by motorised modes that contribute to deteriorating air quality. Fleet electrification is a possible solution (Weiss et al., 2015), as demonstrated by trials of electric scooters or vehicles, but this is costly for a developing country. Electrification may help address air pollution, but only when it is powered by cleaner energy sources. Currently about 56% of power is sourced from fossil fuels (gas or coal), with clean energy (dominated by hydro) accounting for 43% (German Society for International Cooperation (GIZ), 2016).

There are several methodological limitations that can be addressed in future studies. Firstly, while binary linear modelling is simple and effective, it does not show the relationship between variables. To address this, structural equation modelling (SEM) could be adopted for our data for future attempts (Guo and Li, 2018; Li et al., 2014). Currently this work also only looked at perceptions in a general sense only. Air pollution impacts are widespread and takes long lead time of accumulated dose to cause actual harm. It is also involving complex urban environmental-human health interactions (Sarkar and Webster, 2017). To unpack these, objective measures of air quality, pollution levels and health effects are needed, which is not considered currently due to lack widely accessible in Vietnam. This restricts the ability for researchers to conduct "actual versus perception" studies conducted by Nikolopoulou et al. (2011) We call for government authorities in Vietnam to consider releasing more timely and accurate air pollution data. Health impacts research would require a more detailed research design and possibly expertise in health studies and hospital admission data which can be challenging for researcher without medical or health background or connections. Our approach could also be enriched by more qualitative and personal accounts as seen in prior studies (Guo and Li, 2018; Ngo et al., 2017; Tvinnereim et al., 2017; Xu et al., 2017).

While measuring perceptions by Likert scales is a proven and tested approach, respondents may have personal views or unique "storylines about air pollution. These can only be captured in open-end questions. Apart from interviews, a useful framework could be the Q method that allows systematic and efficient sorting of large volumes of subjective comments (Sala et al., 2015). Further analysis should also consider looking neighbourhood or place effects in greater detail using GIS-based spatial analysis (Brody et al., 2004; Elliott et al., 1999). The notion of environmental justice (Pearce et al., 2006) and the relationship between air pollution and social deprivation (Bailey et al., 2018) also warrant further research in HCMC. Another useful measure of perception could be willingness to pay (WTP), which is increasingly adopted in transport research. Previous studies have looked at WTP to for government air pollution reduction programs (Liu et al., 2016; Sun et al., 2016; Tokimatsu et al., 2016), or avoiding health risks (Istamto et al., 2014). Similarly, choice experiments could also be done (Apparicio et al., 2016). For instance, a latent demand choice model could be developed to link the perception analysis to actual travel behaviour. In this way the travel behaviour of travellers in HCMC could then be analysed under the influence of attitudes and perceptions on the choice set generation process.

6. Concluding remarks

Our study examined the perceived health and travel impacts of reported exposure to air pollution during commuting. This is generally associated with significantly higher odds with the variables of busy traffic, industrial/commercial/transport land use, old age (50 years older), environmental concern and poor self-rated health. Being female, using private motorised modes (car or motorcycle), and annoyance caused by air pollution were associated with elevated perceived exposure impacts as well. Income, education, self-rated air quality and access to government air pollution information were found to have mixed associations to the dependent variables. The inference made by this modest-sized sample and lessons learnt from the research limitations could help inform future air pollution studies and transport/land use policy in Vietnam or other areas also with severe air pollution problems. This study nonetheless added the body of knowledge with a Global South and emerging economy viewpoint of air pollution perception research, as studies from South-East Asian traffic-saturated cities remains limited and sparse. With some of the findings are contrasting to similar studies in developed cities, we call for more research to further understand these differences.

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