

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

Abraham Leung^{*a}, Thi Phuong Linh Le^b

^a*Cities Research Institute, Griffith University, Brisbane, Australia*

^b*RMIT University Vietnam, Ho Chi Minh City, Vietnam*

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.

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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) characterised 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

^{*} Corresponding author. Tel.: +61 07 37357003
E-mail address: abraham.leung@griffith.edu.au

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.

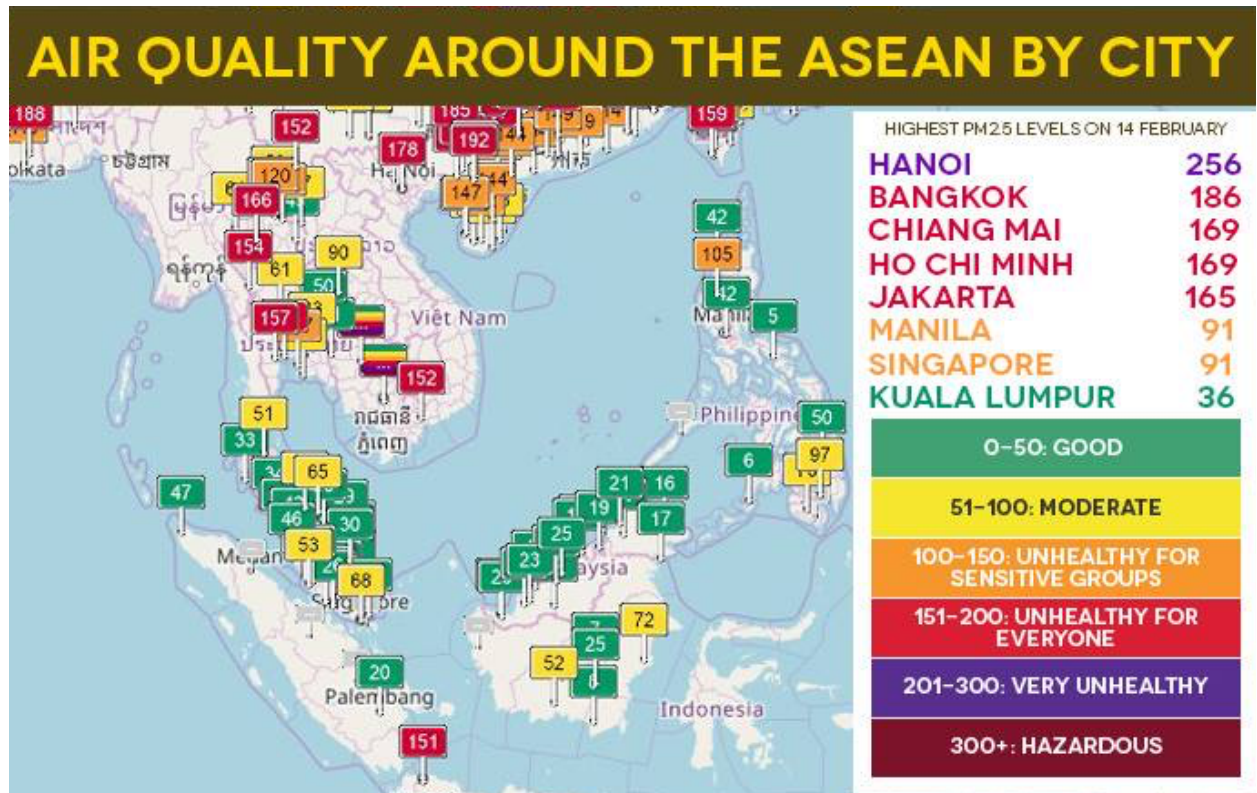


Fig. 1. Air quality index of ASEAN region on 15 February, 2018 (Source: LivingASEAN, with air quality index data from AQICN.org)

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 particular, 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 (NO₂ and PM₁₀) 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 Kruskal-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.

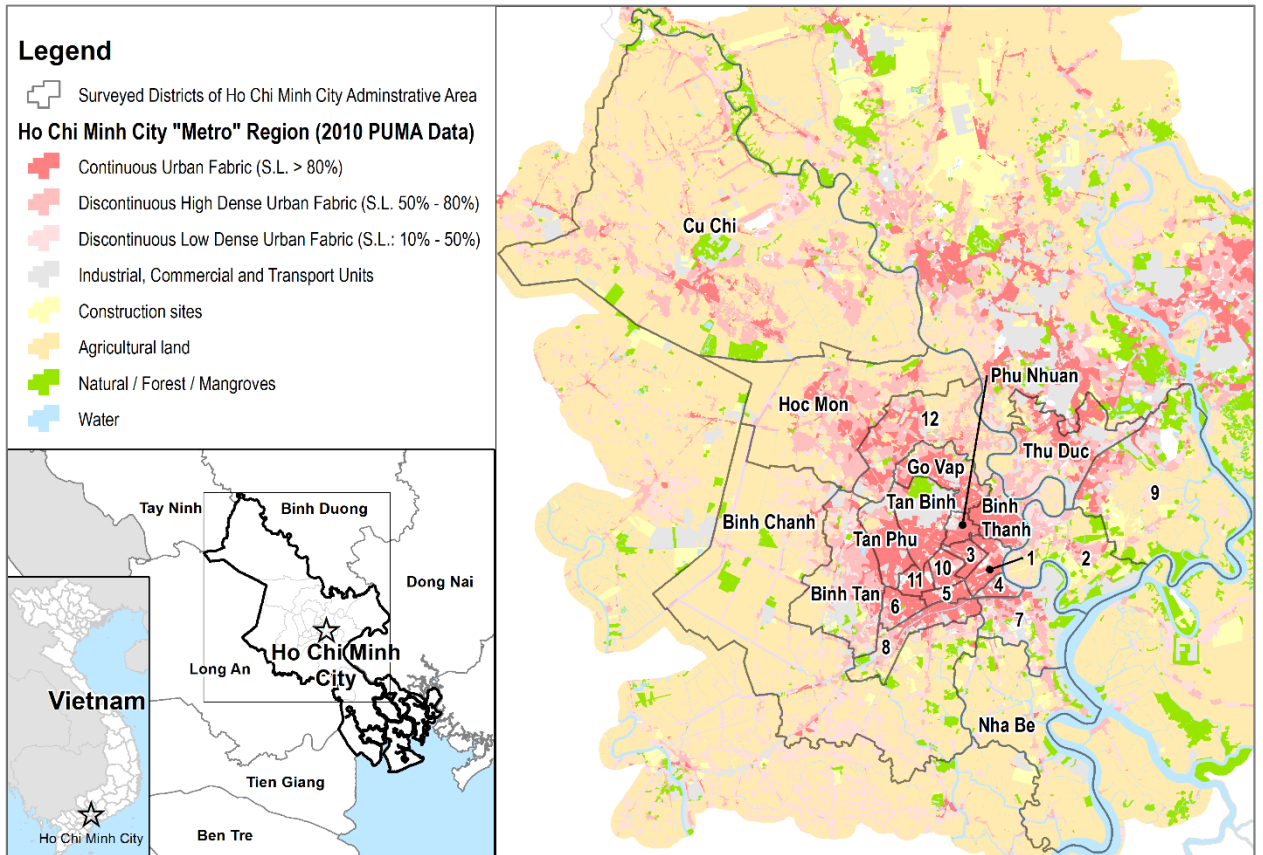


Fig. 2. The Metropolitan Region of Ho Chi Minh City, showing the major land use within and its surrounding areas

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 indiscernible 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 ($p\text{-value}=0.001$). 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 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 |
| Psychometrics of air pollution (AP) perception | | | | | | | | | |
| 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.

^aOdds 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 Wulforth, 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.

References

- ALMEC Corp., 2004. The study on urban transport master plan and feasibility study in Ho Chi Minh metropolitan area (HOU TRANS): final report ; Vol. 2. - Masterplan study. Japan International Cooperation Agency : ALMEC Corp.
- Anowar, S., Eluru, N., Hatzopoulou, M., 2017. Quantifying the value of a clean ride: How far would you bicycle to avoid exposure to traffic-related air pollution? *Transportation Research Part A: Policy and Practice* 105, 66–78. <https://doi.org/10.1016/j.tra.2017.08.017>
- Apparicio, P., Carrier, M., Gelb, J., Séguin, A.-M., Kingham, S., 2016. Cyclists’ exposure to air pollution and road traffic noise in central city neighbourhoods of Montreal. *Journal of Transport Geography* 57, 63–69. <https://doi.org/10.1016/j.jtrangeo.2016.09.014>
- Badami, M.G., 2005. Transport and Urban Air Pollution in India. *Environmental Management* 36, 195–204. <https://doi.org/10.1007/s00267-004-0106-x>
- Badland, H., Schofield, G., 2005. Transport, urban design, and physical activity: an evidence-based update. *Transportation Research Part D: Transport and Environment* 10, 177–196. <https://doi.org/10.1016/j.trd.2004.12.001>
- Badland, H.M., Duncan, M.J., 2009. Perceptions of air pollution during the work-related commute by adults in

- Queensland, Australia. *Atmospheric Environment* 43, 5791–5795. <https://doi.org/10.1016/j.atmosenv.2009.07.050>
- Bailey, N., Dong, G., Minton, J., Pryce, G., 2018. Reconsidering the Relationship between Air Pollution and Deprivation. *International Journal of Environmental Research and Public Health* 15, 629. <https://doi.org/10.3390/ijerph15040629>
- Bakker, S., Dematera Contreras, K., Kappiantari, M., Tuan, N., Guillen, M., Gunthawong, G., Zuidgeest, M., Liefferink, D., van Maarseveen, M., 2017. Low-Carbon Transport Policy in Four ASEAN Countries: Developments in Indonesia, the Philippines, Thailand and Vietnam. *Sustainability* 9, 1217. <https://doi.org/10.3390/su9071217>
- Barter, P.A., 2000. Urban Transport in Asia: Problems and Prospects for High-Density Cities. *Asia-Pacific Development Monitor* 2, 33–66.
- Beck, U., 1992. *Risk society: towards a new modernity, Theory, culture & society*. Sage Publications, London ; Newbury Park, Calif.
- Becken, S., Jin, X., Zhang, C., Gao, J., 2017. Urban air pollution in China: destination image and risk perceptions. *Journal of Sustainable Tourism* 25, 130–147. <https://doi.org/10.1080/09669582.2016.1177067>
- Bickerstaff, K., 2004. Risk perception research: socio-cultural perspectives on the public experience of air pollution. *Environment International* 30, 827–840. <https://doi.org/10.1016/j.envint.2003.12.001>
- Bickerstaff, K., Walker, G., 2001. Public understandings of air pollution: the ‘localisation’ of environmental risk. *Global Environmental Change* 11, 133–145. [https://doi.org/10.1016/S0959-3780\(00\)00063-7](https://doi.org/10.1016/S0959-3780(00)00063-7)
- Bickerstaff, K., Walker, G., 1999. Clearing the smog? Public responses to air-quality information. *Local Environment* 4, 279–294. <https://doi.org/10.1080/13549839908725600>
- Brauer, M., Hoek, G., Van Vliet, P., Meliefste, K., Fischer, P.H., Wijga, A., Koopman, L.P., Neijens, H.J., Gerritsen, J., Kerkhof, M., Heinrich, J., Bellander, T., Brunekreef, B., 2002. Air Pollution from Traffic and the Development of Respiratory Infections and Asthmatic and Allergic Symptoms in Children. *American Journal of Respiratory and Critical Care Medicine* 166, 1092–1098. <https://doi.org/10.1164/rccm.200108-007OC>
- Brody, S.D., Peck, B.M., Highfield, W.E., 2004. Examining Localized Patterns of Air Quality Perception in Texas: A Spatial and Statistical Analysis. *Risk Analysis* 24, 1561–1574. <https://doi.org/10.1111/j.0272-4332.2004.00550.x>
- Brunekreef, B., Holgate, S.T., 2002. Air pollution and health. *The Lancet* 360, 1233–1242. [https://doi.org/10.1016/S0140-6736\(02\)11274-8](https://doi.org/10.1016/S0140-6736(02)11274-8)
- Cepeda, M., Schoufour, J., Freak-Poli, R., Koolhaas, C.M., Dhana, K., Bramer, W.M., Franco, O.H., 2017. Levels of ambient air pollution according to mode of transport: a systematic review. *The Lancet Public Health* 2, e23–e34. [https://doi.org/10.1016/S2468-2667\(16\)30021-4](https://doi.org/10.1016/S2468-2667(16)30021-4)
- Chasco, C., Le Gallo, J., 2015. Heterogeneity in Perceptions of Noise and Air Pollution: A Spatial Quantile Approach on the City of Madrid. *Spatial Economic Analysis* 10, 317–343. <https://doi.org/10.1080/17421772.2015.1062127>
- Claeson, A.-S., Lidén, E., Nordin, M., Nordin, S., 2013. The role of perceived pollution and health risk perception in annoyance and health symptoms: a population-based study of odorous air pollution. *International Archives of Occupational and Environmental Health* 86, 367–374. <https://doi.org/10.1007/s00420-012-0770-8>
- Cole-Hunter, T., Morawska, L., Solomon, C., 2015. Bicycle Commuting and Exposure to Air Pollution: A Questionnaire-Based Investigation of Perceptions, Symptoms, and Risk Management Strategies. *Journal of Physical Activity and Health* 12, 490–499. <https://doi.org/10.1123/jpah.2013-0122>
- Crowe, M.J., 1968. Toward a “Definitional Model” Of Public Perceptions Of Air Pollution. *Journal of the Air Pollution Control Association* 18, 154–157. <https://doi.org/10.1080/00022470.1968.10469106>
- Day, R., 2007. Place and the experience of air quality. *Health & Place* 13, 249–260. <https://doi.org/10.1016/j.healthplace.2006.01.002>
- Day, R.J., 2006. Traffic-related air pollution and perceived health risk: Lay assessment of an everyday hazard. *Health, Risk & Society* 8, 305–322. <https://doi.org/10.1080/13698570600871869>
- Deguen, S., Ségala, C., Pédrone, G., Mesbah, M., 2012. A New Air Quality Perception Scale for Global Assessment of Air Pollution Health Effects: Global Assessment of Air Pollution Health Effects. *Risk Analysis* 32, 2043–2054. <https://doi.org/10.1111/j.1539-6924.2012.01862.x>
- Dixon, J.K., Hendrickson, K.C., Ercolano, E., Quackenbush, R., Dixon, J.P., 2009. The Environmental Health Engagement Profile: What People Think and Do About Environmental Health. *Public Health Nursing* 26,

- 460–473. <https://doi.org/10.1111/j.1525-1446.2009.00804.x>
- Elliott, S.J., Cole, D.C., Krueger, P., Voorberg, N., Wakefield, S., 1999. The Power of Perception: Health Risk Attributed to Air Pollution in an Urban Industrial Neighbourhood. *Risk Analysis* 19, 621–634. <https://doi.org/10.1111/j.1539-6924.1999.tb00433.x>
- Folino, F., Buja, G., Zanutto, G., Marras, E., Allocca, G., Vaccari, D., Gasparini, G., Bertaglia, E., Zoppo, F., Calzolari, V., Suh, R.N., Ignatiuk, B., Lanera, C., Benassi, A., Gregori, D., Iliceto, S., 2017. Association between air pollution and ventricular arrhythmias in high-risk patients (ARIA study): a multicentre longitudinal study. *The Lancet Planetary Health* 1, e58–e64. [https://doi.org/10.1016/S2542-5196\(17\)30020-7](https://doi.org/10.1016/S2542-5196(17)30020-7)
- Forsberg, B., Stjernberg, N., Wall, S., 1997. People Can Detect Poor Air Quality Well below Guideline Concentrations: A Prevalence Study of Annoyance Reactions and Air Pollution from Traffic. *Occupational and Environmental Medicine* 54, 44–48.
- Frank, L.D., 2000. Land Use and Transportation Interaction: Implications on Public Health and Quality of Life. *Journal of Planning Education and Research* 20, 6–22. <https://doi.org/10.1177/073945600128992564>
- Gatersleben, B., Uzzell, D., 2000. The risk perception of transport-generated air pollution. *IATSS Research* 24, 30–38. [https://doi.org/10.1016/S0386-1112\(14\)60015-7](https://doi.org/10.1016/S0386-1112(14)60015-7)
- German Society for International Cooperation (GIZ), 2016. MOIT/GIZ Energy Support Programme Together for a Better Energy Future - Power Sector in Vietnam [WWW Document]. URL <http://gizenergy.org.vn/en/knowledge-resources/power-sector-vietnam>
- Gould, K.A., 1993. Pollution and perception: Social visibility and local environmental mobilization. *Qualitative Sociology* 16, 157–178. <https://doi.org/10.1007/BF00989748>
- Guo, Y., Li, Y., 2018. Online amplification of air pollution risk perception: the moderating role of affect in information. *Information, Communication & Society* 21, 80–93. <https://doi.org/10.1080/1369118X.2016.1261170>
- Han, X., Naeher, L.P., 2006. A review of traffic-related air pollution exposure assessment studies in the developing world. *Environment International* 32, 106–120. <https://doi.org/10.1016/j.envint.2005.05.020>
- Henry, G.T., Gordon, C.S., 2003. Driving less for better air: Impacts of a public information campaign. *Journal of Policy Analysis and Management* 22, 45–63. <https://doi.org/10.1002/pam.10095>
- Hickman, R., Banister, D., 2014. Transport, climate change and the city, Routledge advances in climate change research. Routledge, Taylor & Francis Group, London ; New York.
- Ho, B.Q., 2017. Modeling PM 10 in Ho Chi Minh City, Vietnam and evaluation of its impact on human health. *Sustainable Environment Research* 27, 95–102. <https://doi.org/10.1016/j.serj.2017.01.001>
- Hoek, G., Brunekreef, B., Goldbohm, S., Fischer, P., van den Brandt, P.A., 2002. Association between mortality and indicators of traffic-related air pollution in the Netherlands: a cohort study. *The Lancet* 360, 1203–1209. [https://doi.org/10.1016/S0140-6736\(02\)11280-3](https://doi.org/10.1016/S0140-6736(02)11280-3)
- Hollingworth, G.H., 1982. Community perception of environmental problems generated by road traffic, in: Proceedings of the 11th ARRB Conference. Presented at the Eleventh ARRB Conference, Australian Road Research Board, Melbourne, Australia.
- Howel, D., Moffatt, S., Bush, J., Dunn, C.E., Prince, H., 2003. Public views on the links between air pollution and health in Northeast England. *Environmental Research* 91, 163–171. [https://doi.org/10.1016/S0013-9351\(02\)00037-3](https://doi.org/10.1016/S0013-9351(02)00037-3)
- Istamto, T., Houthuijs, D., Lebret, E., 2014. Willingness to pay to avoid health risks from road-traffic-related air pollution and noise across five countries. *Science of The Total Environment* 497–498, 420–429. <https://doi.org/10.1016/j.scitotenv.2014.07.110>
- Jerrett, M., Arain, A., Kanaroglou, P., Beckerman, B., Potoglou, D., Sahsuvaroglu, T., Morrison, J., Giovis, C., 2004. A review and evaluation of intraurban air pollution exposure models. *Journal Of Exposure Analysis And Environmental Epidemiology* 15, 185.
- Johnson, B.B., 2012. Experience with Urban Air Pollution in Paterson, New Jersey and Implications for Air Pollution Communication: Experience with Urban Air Pollution in Paterson, New Jersey. *Risk Analysis* 32, 39–53. <https://doi.org/10.1111/j.1539-6924.2011.01669.x>
- Kellens, W., Terpstra, T., De Maeyer, P., 2013. Perception and Communication of Flood Risks: A Systematic Review of Empirical Research. *Risk Analysis* 33, 24–49. <https://doi.org/10.1111/j.1539-6924.2012.01844.x>
- Kim, M., Yi, O., Kim, H., 2012. The role of differences in individual and community attributes in perceived air quality.

- Science of The Total Environment 425, 20–26. <https://doi.org/10.1016/j.scitotenv.2012.03.016>
- King, K.E., 2015. Chicago residents' perceptions of air quality: objective pollution, the built environment, and neighborhood stigma theory. *Population and Environment* 37, 1–21. <https://doi.org/10.1007/s11111-014-0228-x>
- Kuhnimhof, T., Wulforst, G., 2013. The Reader's Guide to Mobility Culture, in: Institute for Mobility Research (Ed.), *Megacity Mobility Culture*. Springer Berlin Heidelberg, Berlin, Heidelberg, pp. 55–64. https://doi.org/10.1007/978-3-642-34735-1_3
- Kuttler, W., Strassburger, A., 1999. Air quality measurements in urban green areas – a case study. *Atmospheric Environment* 33, 4101–4108. [https://doi.org/10.1016/S1352-2310\(99\)00151-X](https://doi.org/10.1016/S1352-2310(99)00151-X)
- Lan, G., Yuan, Z., Maddock, J.E., Cook, A., Chu, Y., Pan, B., Tu, H., Fan, S., Liao, X., Lu, Y., 2016. Public perception of air pollution and health effects in Nanchang, China. *Air Quality, Atmosphere & Health* 9, 951–959. <https://doi.org/10.1007/s11869-016-0397-0>
- Lercher, P., Schmitzberger, R., Kofler, W., 1995. Perceived traffic air pollution, associated behavior and health in an alpine area. *Science of The Total Environment* 169, 71–74. [https://doi.org/10.1016/0048-9697\(95\)04634-D](https://doi.org/10.1016/0048-9697(95)04634-D)
- Li, V.O., Han, Y., Lam, J.C., Zhu, Y., Bacon-Shone, J., 2018. Air pollution and environmental injustice: Are the socially deprived exposed to more PM 2.5 pollution in Hong Kong? *Environmental Science & Policy* 80, 53–61. <https://doi.org/10.1016/j.envsci.2017.10.014>
- Li, Z., Folmer, H., Xue, J., 2014. To what extent does air pollution affect happiness? The case of the Jinchuan mining area, China. *Ecological Economics* 99, 88–99. <https://doi.org/10.1016/j.ecolecon.2013.12.014>
- Liu, X., Wu, Y., Hu, Y., Liu, D., Zhang, J., Chen, C., Yuan, Z., Lu, Y., 2016. Government employees' perception of urban air pollution and willingness to pay for improved quality: a cross-sectional survey study in Nanchang, China. *Environmental Science and Pollution Research* 23, 22183–22189. <https://doi.org/10.1007/s11356-016-7204-1>
- Lucas, K., Mattioli, G., Verlinghieri, E., Guzman, A., 2016. Transport poverty and its adverse social consequences, in: *Proceedings of the Institution of Civil Engineers - Transport*. Thomas Telford (ICE Publishing).
- Luong, L.M.T., Phung, D., Sly, P.D., Morawska, L., Thai, P.K., 2017. The association between particulate air pollution and respiratory admissions among young children in Hanoi, Vietnam. *Science of The Total Environment* 578, 249–255. <https://doi.org/10.1016/j.scitotenv.2016.08.012>
- Mattioli, G., Boffi, M., Colleoni, M., 2012. Milan's pollution charge: sustainable transport and the politics of evidence. Presented at the Berlin Conference 2012 on the Human Dimensions of Global Environmental Change – “Evidence for Sustainable Development,” Berlin, Germany.
- Maturo, A., Moretti, V., 2018. Sociological Theories on Air Pollution: Between Environmental Justice and the Risk Society Approach, in: Capello, F., Gaddi, A.V. (Eds.), *Clinical Handbook of Air Pollution-Related Diseases*. Springer International Publishing, Cham, pp. 603–620. https://doi.org/10.1007/978-3-319-62731-1_32
- McGranahan, G., Murray, F. (Eds.), 2003. *Air pollution and health in rapidly developing countries*. Earthscan, London ; Sterling, VA.
- Mitchell, G., Dorling, D., 2003. An Environmental Justice Analysis of British Air Quality. *Environment and Planning A* 35, 909–929. <https://doi.org/10.1068/a35240>
- Newell, K., Kartsonaki, C., Lam, K.B.H., Kurmi, O.P., 2017. Cardiorespiratory health effects of particulate ambient air pollution exposure in low-income and middle-income countries: a systematic review and meta-analysis. *The Lancet Planetary Health* 1, e368–e380. [https://doi.org/10.1016/S2542-5196\(17\)30166-3](https://doi.org/10.1016/S2542-5196(17)30166-3)
- Ngo, N.S., Kokoyo, S., Klopp, J., 2017. Why participation matters for air quality studies: risk perceptions, understandings of air pollution and mobilization in a poor neighborhood in Nairobi, Kenya. *Public Health* 142, 177–185. <https://doi.org/10.1016/j.puhe.2015.07.014>
- Nguyen, T.B., Samsura, D.A.A., van der Krabben, E., Le, A.-D., 2016. Saigon-Ho Chi Minh City. *Cities* 50, 16–27. <https://doi.org/10.1016/j.cities.2015.08.007>
- Nikolopoulou, M., Kleissl, J., Linden, P.F., Lykoudis, S., 2011. Pedestrians' perception of environmental stimuli through field surveys: Focus on particulate pollution. *Science of The Total Environment* 409, 2493–2502. <https://doi.org/10.1016/j.scitotenv.2011.02.002>
- OECD, Transport, R., 2014. *The Cost of Air Pollution: Health Impacts of Road Transport*. OECD Publishing.
- Oltra, C., Sala, R., 2018. Perception of risk from air pollution and reported behaviors: a cross-sectional survey study in four cities. *Journal of Risk Research* 21, 869–884. <https://doi.org/10.1080/13669877.2016.1264446>
- Oltra, C., Sala, R., 2014. A Review of the Social Research on Public Perception and Engagement Practices in Urban

Air Pollution. Department of the Environment (Spain).

- Pantavou, K., Lykoudis, S., Psiloglou, B., 2017. Air quality perception of pedestrians in an urban outdoor Mediterranean environment: A field survey approach. *Science of The Total Environment* 574, 663–670. <https://doi.org/10.1016/j.scitotenv.2016.09.090>
- Pearce, J., Kingham, S., Zawar-Reza, P., 2006. Every Breath You Take? Environmental Justice and Air Pollution in Christchurch, New Zealand. *Environment and Planning A* 38, 919–938. <https://doi.org/10.1068/a37446>
- Phung, D., Hien, T.T., Linh, H.N., Luong, L.M.T., Morawska, L., Chu, C., Binh, N.D., Thai, P.K., 2016. Air pollution and risk of respiratory and cardiovascular hospitalizations in the most populous city in Vietnam. *Science of The Total Environment* 557–558, 322–330. <https://doi.org/10.1016/j.scitotenv.2016.03.070>
- Pojani, D., Stead, D., 2016. The urban transport crisis in emerging economies. Springer Science+Business Media, New York, NY.
- Poon, J., Casas, I., He, C., 2006. The Impact of Energy, Transport, and Trade on Air Pollution in China. *Eurasian Geography and Economics* 47, 568–584. <https://doi.org/10.2747/1538-7216.47.5.568>
- Pope, C.A., Ezzati, M., Dockery, D.W., 2009. Fine-Particulate Air Pollution and Life Expectancy in the United States. *New England Journal of Medicine* 360, 376–386. <https://doi.org/10.1056/NEJMsa0805646>
- Prüss-Üstün, A., Wolf, J., Corvalán, C., Bos, R., Neira, M., 2016. Preventing disease through healthy environments: a global assessment of the burden of disease from environmental risks, Second edition. ed. World Health Organization, Geneva, Switzerland.
- Pucher, J., Korattyswaropam, N., Mittal, N., Ittyerah, N., 2005. Urban transport crisis in India. *Transport Policy* 12, 185–198. <https://doi.org/10.1016/j.tranpol.2005.02.008>
- Qian, X., Xu, G., Li, L., Shen, Y., He, T., Liang, Y., Yang, Z., Zhou, W.W., Xu, J., 2016. Knowledge and perceptions of air pollution in Ningbo, China. *BMC Public Health* 16. <https://doi.org/10.1186/s12889-016-3788-0>
- Saksena, S., 2011. Public Perceptions of Urban Air Pollution Risks. *Risk, Hazards & Crisis in Public Policy* 2, 19–37. <https://doi.org/10.2202/1944-4079.1075>
- Sala, R., Oltra, C., Gonçalves, L., 2015. Attitudes towards urban air pollution: a Q methodology study / Actitudes frente a la contaminación atmosférica urbana: un estudio basado en el método Q. *Psychology* 6, 359–385. <https://doi.org/10.1080/21711976.2015.1041293>
- Sarkar, C., Webster, C., 2017. Urban environments and human health: current trends and future directions. *Current Opinion in Environmental Sustainability* 25, 33–44. <https://doi.org/10.1016/j.cosust.2017.06.001>
- Schusky, J., 1966. Public Awareness and Concern with Air Pollution in the St. Louis Metropolitan Area. *Journal of the Air Pollution Control Association* 16, 72–76. <https://doi.org/10.1080/00022470.1966.10468444>
- Slovic, P., 2000. The perception of risk, Risk, society, and policy series. Earthscan Publications, London ; Sterling, VA.
- Smallbone, K., 2012. Individuals' interpretation of air quality information: customer insight and awareness study. University of Brighton, Brighton, UK.
- Starr, C., 1969. Social Benefit versus Technological Risk. *Science* 165, 1232–1238. <https://doi.org/10.1126/science.165.3899.1232>
- Stern, P.C., 2000. New Environmental Theories: Toward a Coherent Theory of Environmentally Significant Behavior. *Journal of Social Issues* 56, 407–424. <https://doi.org/10.1111/0022-4537.00175>
- Sun, C., Yuan, X., Yao, X., 2016. Social acceptance towards the air pollution in China: Evidence from public's willingness to pay for smog mitigation. *Energy Policy* 92, 313–324. <https://doi.org/10.1016/j.enpol.2016.02.025>
- Tokimatsu, K., Aicha, M., Yoshida, K., Nishio, M., Endo, E., Sakagami, M., Murakami, K., Itsubo, N., 2016. Measuring marginal willingness to pay using conjoint analysis and developing benefit transfer functions in various Asian cities. *International Journal of Sustainable Development & World Ecology* 23, 541–552. <https://doi.org/10.1080/13504509.2016.1168326>
- Truitt, A., 2008. On the back of a motorbike: Middle-class mobility in Ho Chi Minh City, Vietnam. *American Ethnologist* 35, 3–19. <https://doi.org/10.1111/j.1548-1425.2008.00002.x>
- Tvinnereim, E., Liu, X., Jamelske, E.M., 2017. Public perceptions of air pollution and climate change: different manifestations, similar causes, and concerns. *Climatic Change* 140, 399–412. <https://doi.org/10.1007/s10584-016-1871-2>
- Wang, R., Yang, Y., Chen, R., Kan, H., Wu, J., Wang, K., Maddock, J., Lu, Y., 2015. Knowledge, Attitudes, and Practices (KAP) of the Relationship between Air Pollution and Children's Respiratory Health in Shanghai,

- China. *International Journal of Environmental Research and Public Health* 12, 1834–1848. <https://doi.org/10.3390/ijerph120201834>
- Weber, J.M., Hair, J.F., Fowler, C.R., 2000. Developing a Measure of Perceived Environmental Risk. *The Journal of Environmental Education* 32, 28–35. <https://doi.org/10.1080/00958960009598669>
- Weiss, M., Dekker, P., Moro, A., Scholz, H., Patel, M.K., 2015. On the electrification of road transportation – A review of the environmental, economic, and social performance of electric two-wheelers. *Transportation Research Part D: Transport and Environment* 41, 348–366. <https://doi.org/10.1016/j.trd.2015.09.007>
- Whitmarsh, L., 2008. Are flood victims more concerned about climate change than other people? The role of direct experience in risk perception and behavioural response. *Journal of Risk Research* 11, 351–374. <https://doi.org/10.1080/13669870701552235>
- World Bank, 2013. PUMA land use dataset for Ho Chi Minh City [WWW Document]. URL <https://puma.worldbank.org/intro/index.php/downloads>
- Xu, J., Chi, C.S.F., Zhu, K., 2017. Concern or apathy: the attitude of the public toward urban air pollution. *Journal of Risk Research* 20, 482–498. <https://doi.org/10.1080/13669877.2015.1071869>
- Zhang, A., Zhong, L., Xu, Y., Wang, H., Dang, L., 2015. Tourists' Perception of Haze Pollution and the Potential Impacts on Travel: Reshaping the Features of Tourism Seasonality in Beijing, China. *Sustainability* 7, 2397–2414. <https://doi.org/10.3390/su7032397>
- Zhao, H., Wang, F., Niu, C., Wang, H., Zhang, X., 2018. Red warning for air pollution in China: Exploring residents' perceptions of the first two red warnings in Beijing. *Environmental Research* 161, 540–545. <https://doi.org/10.1016/j.envres.2017.11.058>
- Zhou, Y., Song, Y., Tian, J., 2016. Risk perception of air pollution: An exploration of self-relevancy. *Human and Ecological Risk Assessment: An International Journal* 22, 1506–1518. <https://doi.org/10.1080/10807039.2016.1190635>