Improving Transport-related Health Impacts by Promoting Active Transport and Public Transport

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Abstract

Health is always an important aspect of every individual and every community to ensure a happy life, happy community, well-being, to increase productivity, and to save health care costs. For every individual and community, good health is considered one of their main goals and one of the vital inputs for sustainable development. In the first International Conference on Health Promotion, there was a statement that "Good Health is a major resource for social, economic and personal development and an important dimension of quality of life" (WHO,1986).

However, human health is a complex issue and is influenced by many sectors beyond the health sectors. Among these sectors, transport plays an essential role in both promoting and threatening health. Health benefits of transport include providing people with accessibility to employment, education, shops, recreation, social and family networks, health care services, a wide range of other services, and giving the opportunities for integrating physical activity into daily life through walking and cycling. However, transport also creates tremendous detrimental health effects directly through traffic accidents, air pollution, noise pollution, and stress. These adverse health effects of transport are becoming global issues. Additionally, transport generates other indirect health effects on the population through land consumption, community severance, and climate change, which are generally ignored when thinking about the health impacts of transport.

The negative health impacts of the transport system are highly related to private motorised transport, which are consequences of transport infrastructure and transport policies that focus on the movement of private motor vehicles. Despite the adverse health effects associated with private motorised vehicles, the number of individual motorised vehicles is still increasing as a result of the increase in travel demand. The travel demand is predicted to grow continuously due to economic development, population growth and urbanisation, particularly in urban areas where the current transport system has already experienced an imbalance between supply and demand. Consequently, the negative health impacts of transport will continue to increase and if no effective solution is implemented, the negative health effects of the transport system will become worse.

A number of actions have been implemented to mitigate the negative impacts of the transport system, such as mixed land use, control vehicle ownership, apply stricter emission standards, congestion charge, vehicle sharing, and parking control. However, the benefits of these actions are limited and largely offset by the growth in travel demand. Among solutions, the shifting from private motorised transport to active transport (walking and cycling) and public transport seems to bring health benefits for both, individual and community. This approach is presented as an obvious solution to improve health and wellbeing through increased physical activity, reduced air and noise pollution, decreased greenhouse gas emissions, increased social interaction, reduced land consumption, provided equal opportunity, livability and transport efficiency without the side-effect of pollution. As health awareness is increasing rapidly, promoting active transport and public transport as healthy transport modes may contribute to improve the image and increase the attractiveness of these transport modes. Therefore, the infrastructure supporting active transport and public transport, together with policies to promote

walking, cycling, and public transport use are crucial for transport systems and deserves ongoing attention.

This study aims to improve transport-related health impacts through promoting active transport and public transport. Firstly, the primary transport-related health impacts have been investigated. Four primary transport-related health impacts have selected for detailed investigation, including traffic accidents, health impacts of exposure to traffic-related air pollution, health impacts of exposure to traffic-related noise pollution, and transport-related physical activity. The cause-effect relationships have been developed for these four major transport-related health impacts showing the health impact pathway of transport from the source to the human. Factors influencing these health impacts have been comprehensively described. Secondly, the literature review on the association of transport mode use and its health impacts on its users and other road users as well as on the general population has been conducted. Thirdly, as a case study, the transport-related health impacts in Ho Chi Minh City have been investigated in more detail. The awareness of commuters, the general population, and city authorities about the health impacts of transport is also evaluated. Then, the health impact assessment has been reviewed, and a causal pathway of transport and health has been proposed. Based on that, a qualitative health impact assessment of increasing active transport and public transport in HCM has been conducted. Fifthly, a health-oriented transport policy has been discussed, and a goal and objective system of the health-oriented transport policy has been proposed. Then, the importance of active transport and public transport in a healthy transport system has been highlighted. Finally, five strategies to promote active transport and public transport have been proposed.

Kurzfassung

Gesundheit ist immer ein wichtiger Aspekt jedes Einzelnen und jeder Gemeinschaft, um ein glückliches Leben, eine glückliche Gemeinschaft und Wohlbefinden zu gewährleisten, die Produktivität zu steigern und Gesundheitskosten zu reduzieren. Für jedes Individuum und jede Gemeinschaft gilt eine gute Gesundheit als eines ihrer Hauptziele und als eine der wichtigsten Voraussetzungen für eine nachhaltige Entwicklung. Auf der ersten Internationalen Konferenz zur Gesundheitsförderung wurde festgestellt, dass "Gute Gesundheit eine wichtige Ressource für die soziale, wirtschaftliche und persönliche Entwicklung und eine wichtige Dimension der Lebensqualität ist" (WHO, 1986).

Die menschliche Gesundheit ist jedoch ein komplexes Thema und wird von vielen Sektoren jenseits des Gesundheitssektors beeinflusst. Unter diesen Sektoren spielt der Verkehr eine wesentliche Rolle, sowohl bei der Förderung als auch bei der Gefährdung der Gesundheit. Zu den gesundheitlichen Vorteilen des Verkehrs gehören die Erreichbarkeit von Arbeitsplätzen, Bildungseinrichtungen, Geschäften, Freizeiteinrichtungen, sozialen und familiären Netzwerken, Gesundheitsdiensten und einer Vielzahl anderer Dienstleistungen sowie die Möglichkeit, körperliche Aktivität durch zu Fuß Gehen und Radfahren in den Alltag zu integrieren. Allerdings verursacht der Verkehr auch enorme direkte gesundheitsschädliche Auswirkungen durch Verkehrsunfälle, Luftverschmutzung, Lärmbelästigung, und Stress. Diese gesundheitsschädlichen Auswirkungen des Verkehrs werden zu einem globalen Problem. Darüber hinaus erzeugt der Verkehr weitere indirekte gesundheitliche Auswirkungen auf die Bevölkerung durch Flächenverbrauch, Trennwirkung und Klimawandel, was bisher kaum beachtet wird, wenn es um die gesundheitlichen Auswirkungen des Verkehrs geht.

Die negativen gesundheitlichen Auswirkungen des Verkehrssystems hängen in hohem Maße mit dem motorisierten Individualverkehr zusammen. Sie sind Folgen der Verkehrsinfrastruktur und einer Verkehrspolitik, die sich auf die Nutzung von privaten Kraftfahrzeugen konzentriert. Trotz der negativen gesundheitlichen Auswirkungen, die mit dem motorisierten Individualverkehr verbunden sind, nimmt die Anzahl der motorisierten Individualfahrzeuge aufgrund der steigenden Verkehrsnachfrage weiter zu. Es wird prognostiziert, dass die Verkehrsnachfrage aufgrund der wirtschaftlichen Entwicklung, des Bevölkerungswachstums und der Verstädterung auch weiterhin kontinuierlich zunehmen wird, insbesondere in städtischen Gebieten, in denen das derzeitige Verkehrssystem bereits ein Ungleichgewicht zwischen Angebot und Nachfrage aufweist. Folglich werden die negativen gesundheitlichen Auswirkungen des Verkehrs weiter zunehmen, und wenn keine wirksame Lösung umgesetzt wird, werden sich die negativen gesundheitlichen Auswirkungen des Verkehrssystems noch verschlimmern.

Es wurde eine Reihe von Maßnahmen ergriffen, um die negativen Auswirkungen des Verkehrssystems abzumildern, z.B. gemischte Flächennutzung, Kontrolle des Fahrzeugbesitzes, Anwendung strengerer Emissionsstandards, Einführung der City-Maut, gemeinsame Nutzung von Fahrzeugen und Parkraummanagement. Der Nutzen dieser Maßnahmen ist jedoch begrenzt und wird größtenteils durch das Wachstum der

Verkehrsnachfrage kompensiert. Unter den Lösungen scheint die Verlagerung vom motorisierten Individualverkehr auf aktiven Verkehr (zu Fuß gehen und Radfahren) und öffentliche Verkehrsmittel gesundheitliche Vorteile für den Einzelnen und die Gemeinschaft zu bringen. Dieser Ansatz wird als offensichtliche Lösung zur Verbesserung der Gesundheit und des Wohlbefindens durch erhöhte körperliche Aktivität, verringerte Luft- und Lärmbelastung, verringerte Treibhausgasemissionen, erhöhte soziale Interaktion, verringerten Flächenverbrauch, Chancengleichheit, Lebensqualität und Transporteffizienz ohne den Nebeneffekt der Umweltverschmutzung dargestellt. Da das Gesundheitsbewusstsein schnell zunimmt, kann die Förderung von aktivem Verkehr und öffentlichen Verkehrsmitteln als gesunde Verkehrsmittel dazu beitragen, das Image dieser Verkehrsmittel zu verbessern und ihre Attraktivität zu erhöhen. Daher ist die Infrastruktur zur Unterstützung von aktivem Verkehr und öffentlichem Verkehr zusammen mit politischen Maßnahmen zur Förderung des zu Fuß Gehens, Radfahrens und der Nutzung öffentlicher Verkehrsmittel von entscheidender Bedeutung für die Verkehrssysteme und verdient ständige Aufmerksamkeit.

Diese Studie zielt darauf ab, verkehrsbedingte Gesundheitsauswirkungen durch die Förderung des aktiven Verkehrs und des öffentlichen Verkehrs zu verbessern. Zunächst wurden die primären verkehrsbedingten Gesundheitsauswirkungen untersucht. Vier primäre verkehrsbedingte Gesundheitsauswirkungen wurden für eine detaillierte Untersuchung ausgewählt, darunter Verkehrsunfälle, Gesundheitsauswirkungen durch verkehrsbedingte Luftverschmutzung, Gesundheitsauswirkungen durch verkehrsbedingte Lärmbelastung und verkehrsbedingte körperliche Aktivität. Die Ursache-Wirkungs-Beziehungen wurden für diese vier wichtigsten verkehrsbedingten Gesundheitsauswirkungen entwickelt, die den Pfad der Gesundheitsauswirkungen des Verkehrs von der Entstehung bis zum Menschen aufzeigen. Die Faktoren, die diese Gesundheitsauswirkungen beeinflussen, wurden umfassend beschrieben. Zweitens wurde eine Literaturanalyse zum Zusammenhang zwischen der Nutzung von Verkehrsmitteln und ihren gesundheitlichen Auswirkungen auf ihre Nutzer und andere Verkehrsteilnehmer sowie auf die allgemeine Bevölkerung durchgeführt. Drittens wurden als Fallstudie die verkehrsbedingten Gesundheitsauswirkungen in Ho-Chi-Minh-Stadt genauer untersucht. Das Bewusstsein gesundheitlicher Auswirkungen des Verkehrs bei Pendlern, der allgemeinen Bevölkerung und den städtischen Behörden wurde ebenfalls bewertet. Anschließend wurden Methoden zur Bewertung der gesundheitlichen Auswirkungen überprüft, und ein Kausalpfad zwischen Verkehr und Gesundheit wurde vorgeschlagen. Darauf aufbauend wurden die gesundheitlichen Auswirkungen einer Steigerung des aktiven Verkehrs und des öffentlichen Verkehrs in HCMC qualitativ abgeschätzt. Fünftens wurde eine gesundheitsorientierte Verkehrspolitik diskutiert und ein Zielsystem für eine gesundheitsorientierte Verkehrspolitik vorgeschlagen. Im nächsten Schritt wurde die Bedeutung von aktivem Verkehr und öffentlichem Verkehr in einem gesunden Verkehrssystem hervorgehoben. Abschließend wurden fünf Strategien zur Förderung von aktivem Verkehr und öffentlichem Verkehr vorgeschlagen.

Table of Contents

1 Introduction

The introduction gives a brief overview of this thesis by presenting research motivations, research goals and objectives, scope of study, applied methods, and structure of the study.

1.1 Background and Motivations

The section aims to provide the background information of the importance of health, health impacts of transport, association between private motorised transport and health, the potential approaches to address transport-related health impacts, and challenges as well as opportunities of active transport and public transport in terms of addressing transport-related health impacts. Then, the primary motivations of the study are presented.

- **Importance of health**

Health, as defined by the World Health Organization (WHO), is "a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity" (WHO constitution, 1948). Health is one of the most important aspects of every human life to ensure their happiness and well-being. It is also essential for every community as it contributes to economic development. The healthy population lives longer, is more productive, saves healthcare costs and society's welfare.

As the first International Conference on Health Promotion (organised in Ottawa, 1986) stated, "Good health is a major resource for social, economic and personal development and an important dimension of quality of life" (WHO,1986). Poor health may pose significantly adverse impacts on quality of life, reduce productivity, and increase healthcare costs. Therefore, for every individual and community, good health is considered one of their main goals and also one of the vital inputs to enable the achievement of the other goals. In addition, health awareness is increasing considerably over time for both individuals and communities, particularly when the income level is growing. For example, health has always been one of the essential values for Germans and often ranked top important values since 2009, presented in figure 1-1. According to the report about public spending on health from WHO, total health spending is increasing faster than the gross domestic product and increasing more rapidly in low and middle-income countries (Xu et al., 2018).

Health is a complex issue and is influenced by many sectors that go beyond health sectors. Agriculture, housing, industry, transport, and education are seriously affecting population health through environmental risks and conditions. Among these sectors, transport plays an important role in both promoting and threatening health.

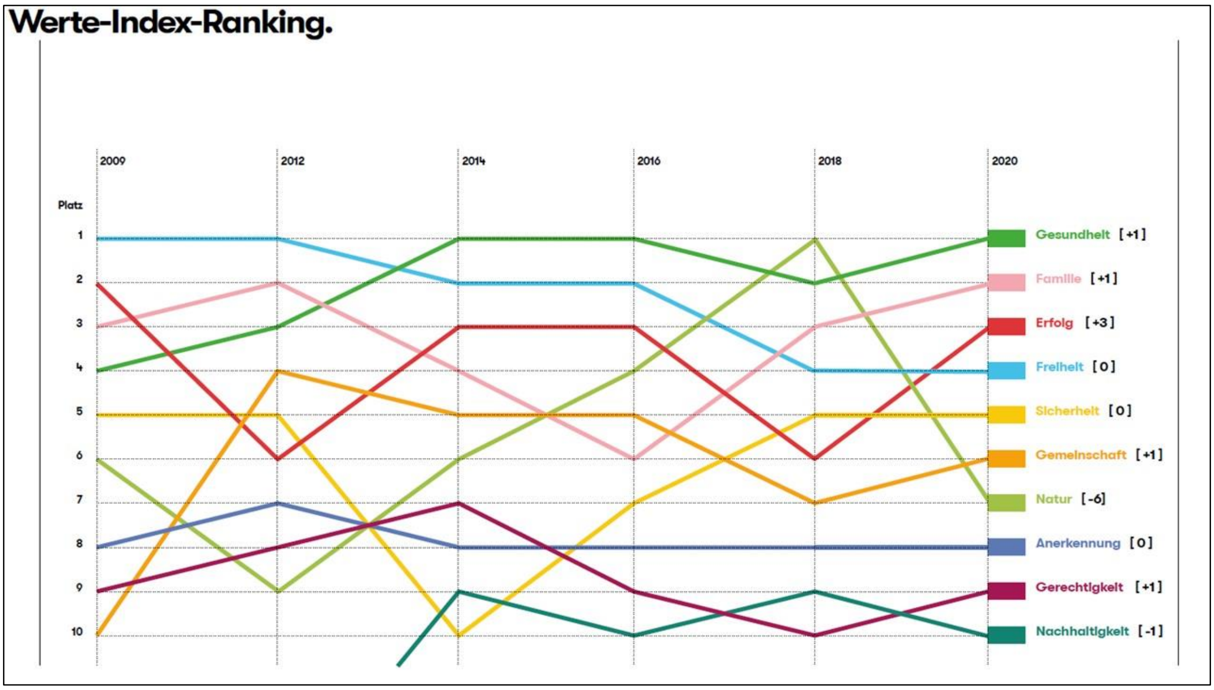

Figure 1-1: The most important values of the Germans (Source: Kantar GmbH, adapted from https://www.markenartikel-magazin.de/)

- **Health impacts of transport**

Transport is a fundamental component of every community. Besides enormous benefits for the development of the economy, society, culture, and human civilisation, it also has notable impacts on human health, both positively and negatively. The impacts of transport on human health (both physical health and mental health) and the environment are increasingly recognised by academics, practitioners, decision-makers, and citizens worldwide (Cavoli, Christie, Mindell, & Titheridge, 2015) (Sallis, 2016) (Khreis, May, & Nieuwenhuijsen, 2017a) (J. S. Mindell, 2017a).

Health benefits of transport include providing people with access to employment, education, shops, recreation, social and family networks, health care services, a wide range of other services, and giving the opportunities for integrating physical activity into daily life through walking and cycling. However, transport also creates tremendous detrimental health effects through traffic accidents, air pollution, noise pollution, stress, community severance, land consumption, and climate change. These adverse health effects of transport are becoming global issues.

The **road traffic accidents** only were responsible for 1.35 million deaths each year and caused up to 50 million injuries, ranked the eighth leading cause of death for people of all ages, and was the leading cause of death for children and young adults aged 5 to 29 years. More than 90% of road fatalities happened in low- and middle-income countries where 85% of the world's population live and which own 60% of the world's motor vehicles (WHO, 2018b).

Transport also is a superior contributor to **air pollution**, particularly in urban areas due to the high number of vehicles with combustion engines. The air pollution from vehicles caused 184,000 deaths globally, including 91,000 deaths from ischemic heart disease, 59,000 deaths from strokes, and 34,000 deaths from lower respiratory infections, chronic obstructive pulmonary disease, and lung cancer (Bhalla, Shotten, Cohen, Brauer, Shahraz, Burnett, Leach-Kemon, et al., 2014).

Similar to air pollution, transport is a major **source of noise** in urban areas, which has negative effects on health and well-being. Noise from road traffic alone is considered the second most harmful environmental stressor in Europe, just behind air pollution. Around 100 million people are exposed to road traffic noise, above 55 dB L_{den} in the EEA-33 member countries, and 32 million of these are living with a very high noise level, above 65 dB L_{den} (EEA, 2017a). The estimation from Fritschi et al. shows that at least 1 million healthy life years are lost every year due to exposure to traffic noise in the western European countries, including the EU Member States (Fritschi, Brown, Kim, Schwela, & Kephalopoulos, 2011).

Walking and cycling for commuting purposes are regarded as a possible way to integrate frequent physical activity into daily life and increase physical activity level. However, the current transport system, dominated by individual motor vehicles, is one of the underlying causes of **physical inactivity,** which is one of the leading risk factors for non-communicable diseases, such as cardiovascular diseases and diabetes, and harms mental health (Pérez et al., 2017) (De Nazelle et al., 2011).

Furthermore, transport generates other indirect health effects on the population through land consumption, climate change, and community severance, which are generally ignored when thinking about the health impacts of transport.

- **Private motorised transport and health**

The negative health impacts of the transport system are highly related to private motorised transport, which are consequences of transport infrastructure and transport policies that focus on the movement of private motor vehicles. Extensive literature has documented the disadvantageous health effects of automobile-oriented environments on health, such as traffic injuries, respiratory diseases, cardiovascular diseases, stress, and other health outcomes (Bhalla, Shotten, Cohen, Brauer, Shahraz, Burnett, Murray, et al., 2014) (Sallis, 2016). Despite the adverse health effects associated with private motorised vehicles, the number of individual motorised vehicles is still increasing as a result of the increase in travel demand. The travel demand is predicted to grow continuously due to economic development, population growth and urbanisation, particularly in urban areas where the current transport system has already experienced an imbalance between supply and demand. The rise in travel demand creates pressures to increase private motorised vehicles, energy consumption, transport infrastructure, land consumption, climate change, noise pollution, and air pollution. Transport is the one sector where the reduction in energy use and emission proves extremely difficult to achieve. Banister argued that the current situation is unsustainable, and transport must contribute fully to achieving carbon reduction targets (Banister, 2011). As a result, if no practical solution is implemented, the adverse health effects of the transport system will become worse.

- **Potential approaches to address transport-related health impacts**

A number of actions have been implemented to mitigate the negative impacts of the transport system, such as mixed land use, control vehicle ownership, apply stricter emission standards, congestion charge, vehicle sharing, and parking control. However, the benefits of these actions are likely small and offset by the growth in travel demand. It is currently expected that the development of transport technology and innovation, including electric vehicles and autonomous driving will highly contribute to solving urban transport problems and improving health. However, these solutions are still in the process, and their impacts on the transport system as well as on human health are uncertain. For example, electric vehicles or other alternative fuels may be better in terms of air and noise pollution reduction but do not affect other negative health impacts of transport such as safety and land consumption for parking. Moreover, this benefit is only effective if electricity comes from renewable energy sources. Additionally, electric vehicles could reduce the exhaust emission source, but they may emit more non-exhaust emission, such as particulate matter, due to it being heavier than petrol or diesel cars (Timmers & Achten, 2016). Regarding autonomous driving, it may provide accessibility to the non-driving population, such as children and the elderly. However, it may also increase travel demand, dependence on the automobile and reduce the level of physical activity.

Among solutions, the shifting from private motorised transport to active transport (walking and cycling) and public transport seems to bring better health benefits for both individual and community. There is a wide range of evidence that shifting from private motorised transport to active transport and public transport is presented as an obvious solution to improve health and wellbeing through increased physical activity, reduced air and noise pollution, decreased greenhouse gas emissions, increased social interaction, reduced land consumption, provided equal opportunity, livability and transport efficiency without the side-effect of pollution (Kleinert & Horton, 2016) (Stevenson et al., 2016b) (J. S. Mindell, 2017a) (Pérez et al., 2017) (Giles-Corti et al., 2016b) (Sallis et al., 2016a).

- **Challenges and opportunities for active transport and public transport**

As active transport and public transport play a key role in addressing health-related transport problems and other urban problems, these transport modes should be promoted to become the backbone of the transport system. The interventions that promote active transport and public transport have to make it safer, more attractive, affordable and desirable than motorised transport. However, the travel demand for active transport and public transport are still small and even reducing in many nations.

The importance of active transport and public transport is highly recognised in developed countries in terms of reducing greenhouse gas emission, improving the quality of the environment, and increasing residents' health and well-being. There are a number of projects at both regional and national levels to promote active transport in Europe, such as the PASTA project (Physical Activity through Sustainable Transport Approaches) and the 2020 National Cycling Plan in Germany. The public transport systems in developed countries are also well-developed, providing good accessibility for users. However, the transport modal share varies greatly among these countries. A study, which compared the transport mode choice between Germany and the USA, showed that Germany and the USA have the highest motorisation rates in the world; however, Germans walk, bike, and use public transport four-time higher than Americans do, 40% and 10%, respectively (Buehler, 2011). This could be explained by differences in policies and travel behaviours in these countries. Automobile dependence is still very high in many developed countries.

Developing countries are currently witnessing a rapid increase in the number of private motorised vehicles as a result of economic development. This trend is predicted to remain in the next coming decades. People tend to own a car when they could afford it. Realising this situation, many developing countries have started to invest in improving their public transport system, such as expanding public transport network, building mass transit system, and enhancing services. However, the transport modal share of public transport is still meagre and even decreasing. Active transport (walking and cycling) and public transport are considered unattractive and for lower socio-economic status people. In addition, active transport is generally ignored in transport planning. The facilities for pedestrians are usually low quality, while the facilities for cycling are missing (e.g., no bicycle lanes).

As health awareness is increasing rapidly, promoting active transport and public transport as healthy transport modes may contribute to improving the image and increasing the attractiveness of these transport modes. People who concern themselves with the health impacts of transport are generally in favour of discouraging private motor vehicles and supporting walking, cycling and public transport use (J. S. Mindell, 2017b). The practical evidence has shown that cities that prioritise active transport and public transport over motorised transport are achieving health, environmental sustainability, and economic development goals (Sallis et al., 2016a). Therefore, the infrastructure supporting active transport and public transport, together with policies to promote walking, cycling, and public transport use is crucial for transport systems and deserves ongoing attention.

There are two primary motivations for this study. Firstly, to raise the awareness of the general population as well as transport planners and decision-makers that their transport mode choice behaviours and their decisions strongly influence their individual health and community health. Secondly, providing knowledge for road users and transport planners and decision-makers to address transport-related health impacts that focuses on shifting towards and promoting active transport and public transport.

1.2 Goal and objectives

The overall goal of this study is to improve transport-related health impacts by promoting active transport and public transport. This goal is divided into five objectives as follows:

- Determine principal health impacts of transport
- Understand the transport mode use and its health impacts on users and the general population
- Identify the methods for a comprehensive assessment of the health impacts of transport
- Propose a health-oriented transport policy
- Develop effective strategies to promote active transport and public transport

1.3 Scope of the study

The study has determined all potential health impacts of transport. However, for detailed investigation and analysis, only four main issues have been selected, including the health impacts of traffic accidents, exposure to traffic-related air pollution, exposure to traffic-related noise pollution, and transport-related physical activity.

The transport mode use and its health impacts on users and the general population have reviewed. Transport modes selected for reviewing include individual motorised transport modes (cars and motorcycles), active transport (walking, cycling, pedelecs), public transport (buses, subways, trams). The health impacts of new types of vehicles such as electric cars, e-scooters, and shared-mobility are also investigated to some extent.

The majority of studies on the health impacts of transport have conducted in developed countries. However, in developing countries, these studies are still limited, while the magnitude of the problem is expected much greater. Ho Chi Minh City (HCM) has been selected for a detailed investigation of transport-related health impacts in this study to add further information into limited knowledge of the health impacts of transport in developing countries.

The study also aims to propose a transport-oriented policy presenting a goal and objective system that the transport system should achieve to promote population health. Depending on the local context, certain objectives could be selected and given priorities for implementation.

Promoting active transport and public transport to address the transport-related health impacts is the main objective of this study. This, however, could not be successfully achieved without the controlling of private motorised transport and improving the efficiency of the existing transport system. Therefore, the strategies to control private motorised transport and strategies to improve the efficiency of the transport system are also investigated in the study.

To form the strategies, common measures are selected based on the review across countries. The requirement for applications and the potential effects of measures have been discussed. The assessment of measures is not performed in this study due to time constraints; however, it is recommended for further research. Based on the existing situation of the urban transport system in Ho Chi Minh City (HCMC), specific measures and strategies for improving transport-related health impacts in the city have been proposed.

1.4 Methodology and structure of the study

The methodological approach and structure of this study are presented in figure 1-2.

Chapter 1 introduces the motivations, research goal and objectives, scope, and structure of the study.

Chapter 2 investigates the potential health impacts of transport through literature review. Four major transport-related health impacts are selected for detailed investigation, namely health impacts of traffic accidents, exposure to traffic-related air pollution, exposure to traffic-related noise pollution, and transport-related physical activity. The existing situation of these health impacts is presented. Then, a cause-effect relationship is developed for each of the health impacts.

The transport mode choice affects health in different ways, both positively and negatively. Thus, **Chapter 3** aims to investigate the association of transport mode use and its health impacts on both its users and other road users as well as on the general population. This chapter first introduces the transport modes in the urban transport system, including some new types of transport modes. Then, the impacts of transport mode use on health, comprising traffic accidents, exposure to traffic-related air pollution, exposure to traffic-related noise pollution, physical activity and other health effects will be reviewed and compared.

Chapter 4 examines the existing situation of transport-related health impacts in Ho Chi Minh City through reviewing the available documents and conducting surveys. The awareness of commuters, the general population, and public authorities on the health impacts of transport is then evaluated.

Chapter 5 focuses on the health impact assessment methods. The chapter first introduces the health impact assessment in general. Then, health impact assessments in transport sectors are reviewed. A causal relationship between transport and health is proposed. The study then further conducts the health impact assessment of increasing active transport and public transport in HCM. Two surveys have been conducted, consisting of an interview survey and a measurement survey, aiming to understand the transport mode use and its health impacts on users.

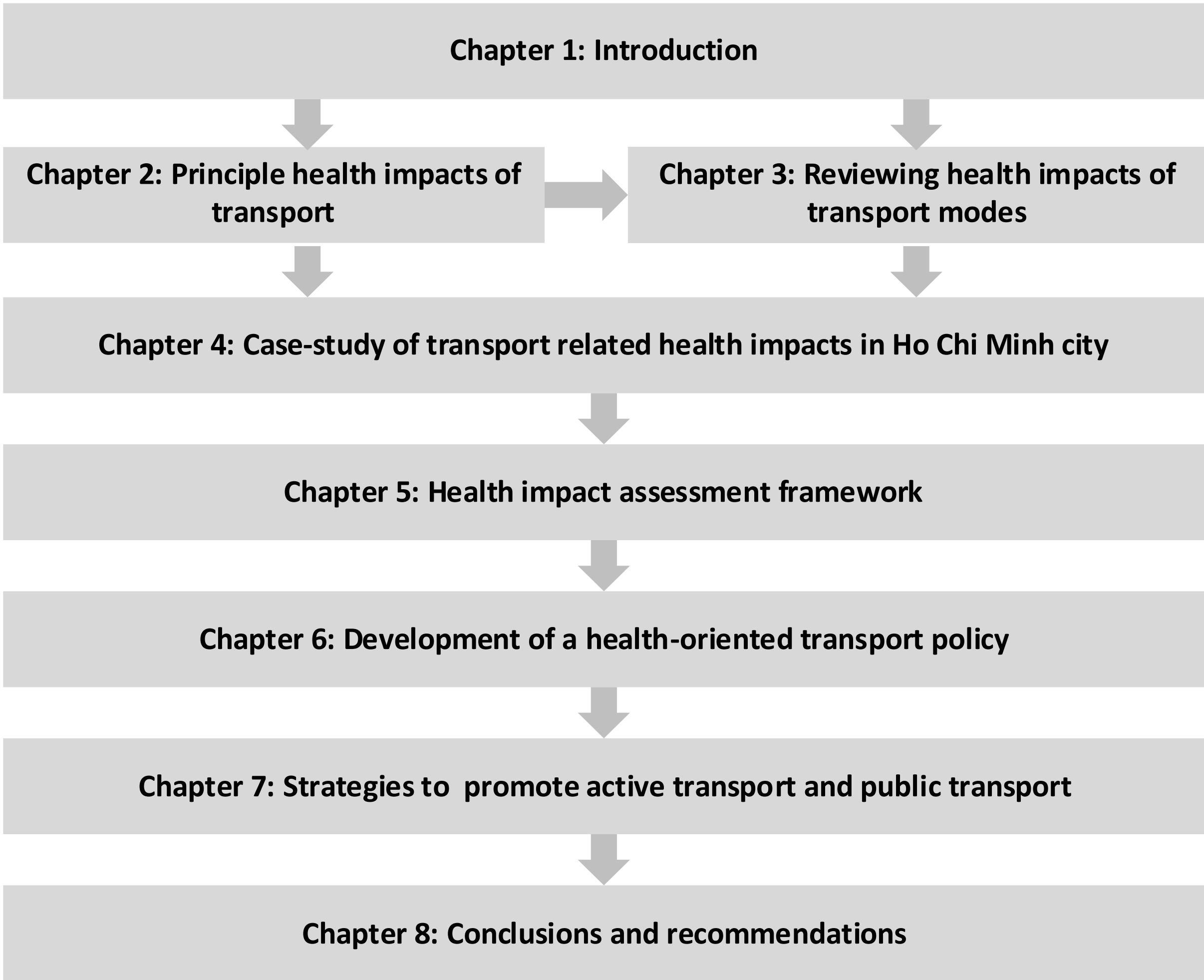

Figure 1-2: Structure of the study (Source: Author)

Chapter 6 develops a health-oriented transport policy that public authorities, transport planners, traffic engineers, the general population, and other stakeholders should aim to achieve to optimise the health effects of the transport system. In the beginning, the concept of a healthy-oriented transport policy is introduced, highlighting the importance of health and the role of the transport system in promoting health. Then, a goal system of a health-oriented transport system is proposed, which is mainly based on the results of chapters 2 and 3. The importance of active transport and public transport in improving health and addressing transport-related issues is discussed. Finally, a general recommendation for urban transport development in HCMC is presented.

Chapter 7 presents strategies to promote active transport and public transport. Basically, five strategies that consist of different measures are proposed to promote active transport and public transport. Then, applications and implementations of these strategies are recommended for HCMC.

In chapter 8, the conclusions and recommendations of the study are presented. Major research results are summarised. Then, the significance and limitations of the study are explained. Finally, the recommendations, as well as suggestions for further studies, are provided.

2 Principal Health Impacts of Transport

This chapter describes all possible health impacts of the transport system, including health impacts of traffic accidents, exposure to traffic-related air pollution, exposure to traffic-related noise pollution, transport related-physical activity, accessibility, stress, climate change, community severance, land consumption, and others. The detailed investigation has been conducted for four major health impacts, comprising traffic accidents, exposure to traffic-related air pollution, exposure to traffic-related noise pollution, and transport related-physical activity. For each of these health impacts, a cause-effect relationship is developed. This chapter aims to provide an overall view of the health impacts of transport and highlight the existing problems and causes, which could be the meaningful inputs for developing the interventions.

2.1 Traffic accidents

2.1.1 Existing situation

The road traffic accident is a well-known and earliest recognised health impacts of transport, which is associated with traffic fatalities, traffic injuries, and premature mortality (Khreis, May, & Nieuwenhuijsen, 2017b). The most tragic health consequence of a road traffic accident is the loss of human life, followed by heavy damage to health or disability (serious injuries), and slight injuries.

- **Fatalities due to road traffic accidents**

Based on the latest global status report on road safety from WHO (WHO, 2018b), the number of fatalities due to road traffic accidents and its distributions worldwide are summarised as below:

- The number of road traffic deaths remains unacceptably high and continues to increase, reaching 1.35 million deaths in 2016.
- The road traffic accident is the eighth leading cause of death for people of all ages and is the primary cause of death for children and young adults aged from 5 to 28 years.
- More than 90% of road fatalities happened in low-and middle-income countries where 85% of the world’s population live and which own 60% of the world’s motor vehicles.
- Countries in Africa and South-East Asia have the highest rates of road traffic fatalities, 26.6 and 20.7 deaths per 100,000 population, respectively. Countries in Europe and America have the lowest regional rates of 9.3 and 15.6 deaths per 100,000 population, respectively.
- More than half of global road traffic deaths are among vulnerable road users including pedestrians, cyclists, and motorcyclists.
- Africa has the highest percentage of pedestrian and cyclist fatalities with 44% of the deaths, while in South-East Asia and Western Pacific, most fatalities are among two- and three-wheeler users, 43% and 36% of all fatalities, respectively.

It is clear that road traffic accidents have tremendous health impacts globally, and low-and middle-income countries are suffering the highest health burden from road traffic deaths. However, when comparing the fatality rates for all road users, nearly everywhere, the risk of dying in a traffic accident is higher for vulnerable road users, including pedestrians, cyclists, and motorcyclists, than for car users. These road users are more vulnerable as a result of being less protected than car users, and it may also reflect the lack of infrastructure and facilities supporting these transport modes. In many countries, cyclists are travelling on the same roads with motorised vehicles, the crossing for pedestrians is unsafe, and sidewalks are often occupied for parking and other business purposes. Despite the high risks for vulnerable road users in these countries, many of them still could not afford or do not have access to safer vehicles. Some studies found that the people from low socio-economic status and less affluent areas tend to be died by road traffic injuries to a greater extent than others (P. Morency, Gauvin, Plante, Fournier, & Morency, 2012)(Borrell et al., 2005)(Sengoelge, Leithaus, Braubach, & Laflamme, 2019). The substantial burden of fatalities borne by these groups reflects the social inequity, as income and social status become social determinants of road traffic fatalities and injuries (Borowy, 2013).

Huge efforts have been implemented in cutting down the number of road traffic deaths at national and international levels. Globally, the rate of road traffic death relative to the size of the world's population has stabilised at around 18 deaths per 100,000 inhabitants and declined relative to the world's population of motor vehicles from 135 deaths per 100,000 vehicles in 2000 to 64 deaths per 100,000 vehicles in 2016, suggesting that there was a progress in mitigating the adverse health effects of increasing motorised transport (WHO, 2018b). However, the progress is distributed unequally across countries. The high-income countries have seen the most significant development, followed by middle-income countries, and there was no reduction in the number of road traffic fatalities in low-income countries. Currently, roads in Europe are the safest in the world, with less than 50 deaths per million population in 2017; remarkable progress has been made in Europe in the last two decades, the number of fatal accidents fell by 43% from 2001 to 2010, and by another 20% between 2010 and 2017 (European Commission, 2018).

Despite those enormous efforts, the road traffic deaths remain a global challenge, and the magnitude of the problem may become even greater because of data problems in road traffic fatalities. For example, there is still no general definition of road traffic death worldwide; the definitions vary across countries. The most common definition of a road traffic death is "any person killed immediately or dying within 30 days as a result of a road traffic accident" (European Commission, 2010). This definition is adopted by WHO and many European countries. However, in other countries, a road traffic death could be defined as one died within seven days of an accident or only died at the scene of the crash (WHO, 2018b). Underreporting is also a big problem in providing accurate statistics on road traffic deaths. For example, in Vietnam, there were 19,280 injuries, 8,417 fatalities caused by traffic accidents in 2016, based on the official data provided by the Vietnamese National Transport Safety Committee (NTSC) (United Nations, 2018). However, according to WHO's estimation, the number of road deaths in Vietnam was approximately three times higher than the reported number from NTSC, reaching 24,970 deaths (WHO, 2018b). The main reason for this difference is the differences in definitions of road traffic deaths and reporting problems. In Vietnam, there is still a lack of a clear definition of road traffic deaths. Deaths and injuries caused by traffic accidents were mainly counted right at the scenes. In addition, a large number of road traffic accidents were not reported to police due to the negotiations between road users, they negotiated to solve the problems without reporting to polices. Thus, these cases were not included in the traffic safety database.

- **Road traffic injuries**

As stated by (Peden et al., 2004) that "road traffic death toll represents only the "tip of the iceberg" of the total waste of human and societal resources from road traffic accidents". Traditionally, road safety performance has been measured by the reduction in the number of fatalities (European Commission, 2013). However, severe but non-fatal accidents also cause significant health effects on victims, and it is costly and problematic for society as well. Based on the estimation from WHO, between 20 million and 50 million people are injured or disabled each year in road traffic accidents. The main reason for the wide range of this estimation is underreporting issue.

The estimation from James showed that there were 54.2 million road injuries in 2017 (James et al., 2018). In Europe, around 135,000 people sustain serious road traffic injuries each year, which means that for every person killed in a traffic accident, five more suffer serious injuries; and the majority of seriously injured people are vulnerable road users (European Commission, 2018). Santacreu calculated the ratio between serious injuries and fatalities for 20 cities in the period of 2011-2015 and found that this ratio ranged from 2 to 42, and the mean value was 18 serious injuries per fatality (Santacreu, 2018b). Figure 2-1 presents the ratio between serious injuries and fatalities in those cities. Among different injuries, head injuries, spinal cord injuries, and injuries to the lower extremities are responsible for more than 90% of the serious injuries in EU countries (Wendy Weijermars et al., 2018). There is another estimation at the global scale that at least 30-45 people are being injured for every road traffic fatality (Jacobs, Thomas, & Astrop, 2000).

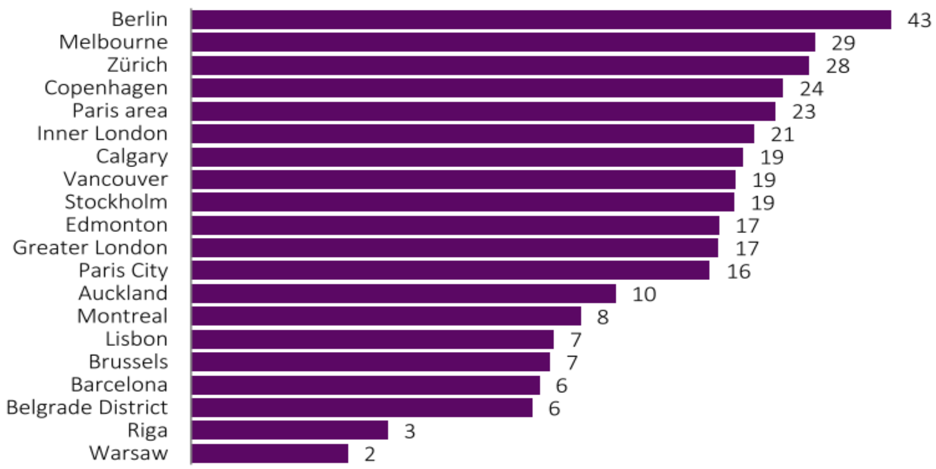

Figure 2-1: Ratio between MAIS3+ injuries and fatalities, 2011-2015 (Santacreu, 2018b)

Although road traffic injuries create huge effects on health, the ability to account or accurately estimate non-fatal injuries worldwide remains a challenge. It is predicted that the total number of seriously injured people in road traffic is substantially higher than current reports (European Commission, 2013). There are two main reasons for this. Firstly, there is no harmonised definition for injury severity. Secondly, a large number of injuries are underreported and misreported.

There are different methods to classify the injury severity; it could be classified based on the presence of hospital admission, the length of stay in the hospital, the types of injuries, the inability to work, the length of recovery, and injury severity scale (OECD/ITF, 2010). Thus, the current data of injury severity is not comparable across countries. A large proportion of non-fatal injuries are not reported at all, a study found that reporting was incomplete at all level of injury severity; around 70% of all serious injuries were actually reported and only 25% and 10% of slight injuries (treated as outpatient) and very slight injuries (treated outside hospitals) were officially reported, respectively (Elvik & Mysen, 1999). Furthermore, assessing injury severity requires clinical experience, while police in many countries who record official information on injuries generally do not have sufficient training to categorise injuries, leading to misreporting issues. The data is rarely checked later with hospital records (WHO, 2013a).

Recently, serious injuries have gained significant attention from EU countries, and most of the research papers on serious injuries are found in this region as well. Reducing the number of serious injuries is one of the strategic objectives set by the European Commission in 2010 in its road safety policy orientations for the period 2011-2020 (European Commission, 2010). In 2013, the High-Level Group on Road Safety representing all EU member States established a standard definition of serious injuries based on Maximum Abbreviated Injury Score (MAIS) (European Commission, 2013). The MAIS is a global accepted trauma scale used by medical professionals. The score ranges from 1 to 6, with levels from 3 to 6 defined as serious injuries.

In addition, the statistics and research on slight injuries caused by traffic accidents are largely missing. The health effects of these injuries on the victims remain unknown. However, these slight injuries often occur among pedestrians and cyclists. This may encourage them to shift to use cars or other transport modes that are safer for them. Consequently, the transport-related health impacts may never be addressed. Therefore, improving safety for pedestrians and cyclists should be prioritised in all countries.

- **Post-accident health impacts of road traffic accidents**

Road traffic injuries also lead to lifelong consequences for injured people (Andersson, Dahlback, & Allebeck, 1994) (Papadakaki et al., 2017) (Kenardy et al., 2017). For injured persons, the post-health effects of traffic accidents could be physical sequelae, psychological distress and various socio-economic consequences (Andersson et al., 1994).

Suffering from physical sequelae could be instability, weakness and restriction of movement in different parts of the body, hearing, and discomfort from scar or cartilage formations. The permanent disabilities resulted from road traffic accidents could deprive an individual of the ability to achieve even minor goals and result in the dependence on others for economic support and routine physical care (Peden et al., 2004). The most common psychological effects are stress, depression, posttraumatic stress disorder, and increasing anxiety when travelling. A one-year cohort study from three European countries (Greece, Germany, and Italy) about the psychological distress and physical disability in patients sustaining severe injuries in road traffic crashes showed that 20-25% of patients reported high levels of psychological distress one year after the accident, and more than 30% reported physical disability at the same time (Papadakaki et al., 2017). The psychological disorders were the most persistent consequences of traffic accidents; even relatively slight injuries could profoundly cause psychological effects (W. Weijermars et al., 2016).

The socio-economic effects on injured people could be changes in working condition, job losses, changing sport and leisure activities, and changing the current ways of life in many areas. Therefore, it is necessary to provide adequate medical treatment and psychological and social consulting for the rehabilitation of victims of traffic accidents.

A systematic review from (Rissanen, Berg, & Hasselberg, 2017) confirmed that the overall quality of life of the injured people due to traffic accidents significantly reduced, compared to the general population. Physical and psychological consequences are considerable for all levels of injury severity, but the levels of effect are different. People who are older, female, lower socio-economic status, diagnosed with post-traumatic stress disorder, with more severe injuries or injuries to the lower limbs are more vulnerable to loss of quality of life compared to other patient groups injured in road traffic crashes.

Both person who suffers disability due to a traffic accident and their family are forced to adjust their way of life(W. Weijermars et al., 2016). For example, the working capacity of an injured person's family members may be affected if they need to become carers. Earnings and productivity are thus doubly reduced. Consequently, there is a strong socio-economic burden on their families. The traffic accident also causes psychosocial impact not only on the victims but also on their family members. Road traffic crashes could create a strong burden on the family and friends of the injured persons, many of whom may experience adverse social, physical and psychological effects, in the short or long term (Peden et al., 2004) .

Apart from human suffering, serious injuries also have a significant impact on the whole society and the economic loss is substantial. Major costs related to serious road injuries include medical costs, production loss, and human costs. There is an estimation that costs per serious injury vary between 28,205 Eur and 975,074 Eur in European countries, and these costs vary between 0.04% and 2.7% of a country's Gross Domestic Product (GDP); the human cost (costs of pain, grief, sorrow and loss of quality of life) occupies the lion's share of the total cost (Schoeters, Wijnen, Carnis, & Weijermars, 2018).

- **Other health impacts of road traffic accidents**

Beyond the direct morbidity and mortality, road traffic accidents may create other potential health impacts linked to the perception of unsafety, which could result in reducing physical activities, such as reducing active travel and outdoor physical activities. A study reported that parents' concerns about unsafe streets were one of the reasons they drive their children to school (Granville, Laird, Barber, & Fiona Rait, 2002). The lack of physical activity is associated with a wide range of health effects, which will be mentioned in part 2.4

In conclusion, the health impacts of road traffic accidents still remain a global issue. The major health effects of road traffic accidents are fatalities and serious injuries, which may create long-term consequences for victims, their families, and the whole society. The magnitude of the problems is even higher than estimated due to the differences in definitions (deaths, serious injuries, etc.), underreport problems, and lack of reliability in the reporting process. The road traffic accident is a social equity issue; the economically disadvantaged groups and vulnerable road users are suffering the highest burden from road traffic accidents.

2.1.2Cause-effect relationships

To mitigate the health effects of road traffic accidents, it is essential to understand the causes of problems and its influencing factors. In this section, a cause-effect relationship between road traffic accidents and its health impacts is presented, which provides a conceptual framework for developing safety improvement strategies.

In the past, many studies have been conducted trying to explain why accidents happened, and various models have been developed aiming to describe road safety problems. Peden et al. defined that road traffic safety is a function of four components (Peden et al., 2004). The first is exposure, which is the amount of movement or travel within the transport system by different users or a given population density. The second is the probability of an accident, given a particular exposure. The third is the probability of injury or/and fatality, given an accident. The fourth element is the result of the accident. He identified that there are various risk factors causing traffic accidents. The following sections present more detail about these influencing factors.

- **Factors influencing the exposure to road traffic accidents**

Exposure to road traffic accidents usually refers to the amount of travel. The most appropriate indicator of exposure is the distance travelled by either vehicles or passengers because it reflects the actual exposure to risk and closer to the theoretical concept of exposure (Thomas et al., 2009). However, different transport modes travel at different speeds, while distance travelled does not reflect this. Therefore, the time spent in traffic is another exposure indicator suggested to use (Hakkert & Braimaister, 2002). In fact, the other exposure indicators are often used such as road network length, number of vehicles, driver population, and population, mainly because of the availability of these data and less requirement for complicated collection methods (George et al., 2005).

The travel need leads to exposing to the risk of involving in road traffic accidents. Thus, the factors influencing the travel demand also influence the level of exposure to road traffic accidents. Boltze classified the factors influencing the level of mobility into two groups, namely internal factors and external factors. These factors are presented in table 2-1.

Table 2-1: Factors influencing the exposure to road traffic accidents (Source: Lecture from Boltze, M. 2013)

Internal factors	External factors
▪ **Demographic factors**: age, gender, marital status, etc. ▪ **Socio-economic factors**: occupation, income, car ownership, etc. ▪ **Psychological factors**: motivations, learning and habituation effects, etc.	▪ **Settlement and spatial structure factors**: residential location, relation to central locations, provided services at the home residence, etc. ▪ **Transport infrastructure factors:** availability of public transport, accessibility of infrastructure supply, etc.

Different groups of people have different levels of exposure to road traffic accidents varying on influencing factors. For example, people aged between 25 and 44 are considered the most employable mobile population. Thus, their travel distance and their spending time on traffic are often higher than those from other groups. For example, the result of the National Household Travel Survey in the United States found that people aged between 25 and 34 had the highest daily vehicle mileage of travel with an average of 5.3 mileage, followed by people from 35 to 44 with 1.9 mileage (Mcguckin & Fucci, 2018). Factors related to land use, road network, and road infrastructure also strongly influence the degree of exposure. Good transport planning and land-use planning contribute to the reduction in the need to travel or in the travel distance.

- **Factors influencing road traffic accidents**

To identify the causes of the road traffic accident, the Haddon Matrix is adapted. This is a well-known framework developed by William Haddon, and this concept has been used for more than two decades in injury prevention research (Haddon, 1968) (Haddon, 1972). Haddon defined three phases of the time sequence of a crash event, including pre-crash, crash, and post-crash and three groups of factors involved in each of the three phases, comprising human, vehicles and equipment, and environment. Putting the phases and factors together creates the nine-cell Haddon's matrix (presented in table 2-2). This matrix makes it possible to recognise the common causes of road traffic accident and to develop interventions to reduce road traffic accidents. Regarding the health effects of road traffic accidents, the Haddon matrix is a comprehensive framework to describe the causes of problems. This matrix is useful to describe road traffic accidents in terms of causal and contributing factors and the time sequence of an accident.

In this thesis, the author extended the Haddon matrix, adding two groups of influencing factors, namely traffic flow factors and traffic regulation factors. These factors also contribute to road traffic accidents and it is difficult to integrate these factors into existing factors. The factors related to the environment are divided into two groups, road infrastructure factors and natural environmental factors. This could be useful for developing the interventions because factors related to road infrastructure could be modified, while factors related to the natural environment are unchangeable or difficult to change. Three phases of road traffic accidents, pre-crash, crash and post-crash, are the same as the Haddon Matrix.

Table 2-2: The Haddon Matrix (Haddon, 1972)

Phase	Factors		
	Human	**Vehicle and equipment**	**Environment**
Pre-Crash			
Crash			
Post-Crash			
Result			

The extended matrix is summarised as table 2-3. In each cell of the matrix, based on the literature review, the main influencing factors are listed. An accident could be the result of a single influencing factor, but usually it is the result of the combination of several factors. In the pre-crash phase, contributing factors are considered the causes to the accident occurrence, while those in the crash and post-crash are related to results of injuries.

In road traffic accidents, post-crash response is an instrumental factor to save human lives and to reduce the severity of injuries. A study in road traffic accidents showed that around 50% of deaths from road traffic collision occur within minutes at the scene or on the way to the hospital. For those who are taken to the hospital, some deaths occur between 1-4 hours after the accidents (15%), but the majority occur after 4 hours (35%) (ETSC, 1999). Another study found that death was potentially preventable in at least 39% of those who died from road traffic accidents before they arrived in the hospital (Hussain & Redmond, 1994). It is clear that the post-crash response is a crucial determinant of the chance and quality of survival after the road traffic accidents, a large proportion of fatalities could be avoided with the optimal post-impact response (European Commission, 2009).

Table 2-3: Factors contributing to road traffic accidents (Author extended based on Haddon matrix, 1972)

<table>
<tr><th rowspan="2">Phase</th><th colspan="6">Factors</th></tr>
<tr><th>Human</th><th>Vehicle</th><th>Road infrastructure</th><th>Traffic flow</th><th>Regulation</th><th>Natural environment</th></tr>
<tr><td>Pre-Crash</td><td>▪ Risky behaviours
▪ Physical impairments
▪ Psychological impairments
▪ Inexperience
▪ ………………</td><td>▪ Vehicle defects
▪ Maintenance conditions
▪ Operation conditions
▪ ………………….</td><td>▪ Road design and road layout
▪ Road defects
▪ Facilities for pedestrians and cyclists
▪ Road signs, road lightings
▪ Maintenance conditions
▪ ……………….</td><td>▪ Traffic flow components
▪ Traffic flow speed
▪ Traffic flow density
▪ Traffic volume
▪ …………….</td><td>▪ Traffic regulation
▪ Vehicle design regulation
▪ ……………..</td><td>▪ Weather conditions
▪ Topography
▪ Wildlife
▪ ……………..</td></tr>
<tr><td>Crash</td><td>▪ Use of protective devices
▪ Reactions during accidents
▪ …………….</td><td>▪ The functioning of protective devices
▪ Crash protective design
▪ …………….
▪</td><td>▪ Passive safety road equipment
▪ Forgiving infrastructure
▪ ………………..</td><td>▪ Traffic flow components
▪ Traffic flow speed
▪ Traffic flow density
▪ ……………...</td><td>▪ Vehicle maintenance regulation
▪ …………….</td><td>▪ Weather conditions
▪ Topography
▪ Wildlife
▪ ………………</td></tr>
<tr><td>Post-Crash</td><td>▪ First aid skills
▪ Provided treatments
▪ ………………</td><td>▪ Fire risk of crashed vehicles
▪ Assessing to accidents by rescue vehicles
▪ ……………….</td><td>▪ Road lane for rescue vehicles
▪ ………………..</td><td>▪ Traffic flow components
▪ Traffic flow speed
▪ Traffic flow density
▪ ……………….</td><td>▪ Regulation related to post-crash response, rescue services, and response time
▪ ……………..
▪</td><td>▪ Weather conditions
▪ Topography
▪ Wildlife
▪ ………………...</td></tr>
</table>

- **Human factors**

Human factors are responsible for a large number of road traffic accidents. A simplistic picture of accident causes was identified by Zein and Navin, presented in figure 2-2. The result was similar to those in the other studies. For example, (Wright & Baker, 1976) found that 64% of contributing factors were identified as human factors in a total of 123 contributing factors, and in 88% of the accident cases, at least one human factor were involved.

Pre-crash phases: Human factors in the pre-crash phase include all factors related to road users (pedestrians, cyclists, motorcyclists, and car drivers). Many studies were conducted to identify human-related factors that contribute to road traffic accidents (Petridou & Moustaki, 2001)(Wright & Baker, 1976)(Van Elslande & Fouquet, 2007)(Plankermann, 2013)(Rolison, Regev, Moutari, & Feeney, 2018). In general, these contributing factors could be grouped into six main groups: risky behaviours, physical impairments, psychological impairments, inexperience, lack of skills, and insufficient knowledge.

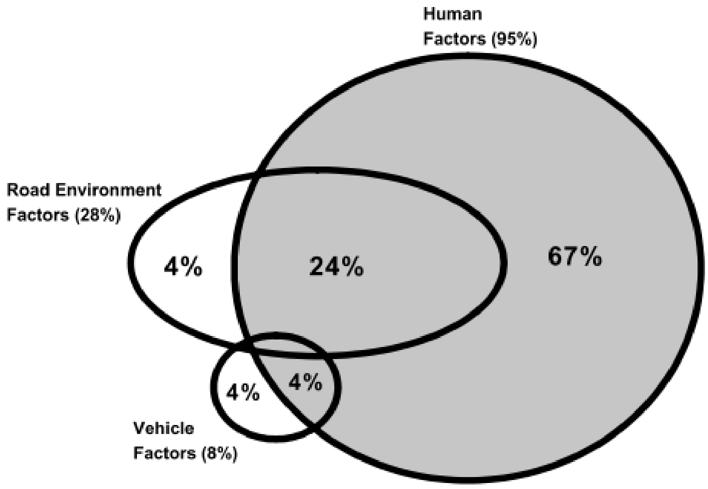

Figure 2-2: Simplistic representation of accident causes (Zein & Navin, 2003)

The most common risky behaviours in road traffic accidents are excess speed and inappropriate speed, drinking and driving, using drugs and driving, distraction and inattention while driving (e.g., using cell phone), carelessness, recklessness, and disobeying traffic rules. Speed has been identified as a key risk factor in road traffic accidents, influencing both the risk of a road accident as well as the severity of the injuries. Speeding was a contributing factor in 26% of total road traffic deaths in the United States in 2017 (NHTSA, 2017). Physical and psychological impairments, such as illness, disabilities, fatigues, drowsiness, stress, and inpatients, are also highly related to road traffic accidents. For example, a systematic review and mental analysis about sleepiness and the risk of road traffic accidents found that drowsy driving increases road accidents by 1.29 to 1.34 times higher than driving without sleepiness (Moradi, Nazari, & Rahmani, 2018). The factors related to inexperience (e.g., unfamiliar with roads and vehicles), lack of skills, and insufficient knowledge (e.g., lack of knowledge about road signs, traffic regulations) may lead to wrong adjustments of drivers that cause accidents as well. These factors have been found more common in the young population (Rolison et al., 2018).

Crash-phase: In terms of health effects during the accidents, using protective devices, such as seat-belts, helmets, child seats, and protective clothes, plays an essential role in reducing the probability of fatalities and severity of injuries. A systematic review of wearing helmets to prevent injury among motorcycle riders found that wearing motorcycle helmets reduced the risk of death by 42% and reduce the risk of head injury by 69% (B. Liu, Ivers, Norton, Blows, & Lo, 2007). If the accidents are unavoidable, the appropriate reactions of humans may also reduce the injury severity or the possibility of death.

Post-crash phase: After accidents, the types of help needed by victims vary with the severity of their injuries. Patients with minor injuries could usually treat themselves or seek the help of general practitioners and are not often hospitalised. However, in case of major injuries, the potential help provided to victims could be viewed as a chain consisting of different links that is presented in figure 2-3 (ETSC, 1999). There are many people involved in this phase, including injured persons, bystanders, prehospital providers, medical staff, doctors, psychologists, family members and friends of the victims. These people play different roles in the helping chain. For example, the skills of medical staff and health professionals could help to save lives and reduce the consequences of injuries, while psychologists and family members are more critical in the rehabilitation phase helping victims reintegrate into society.

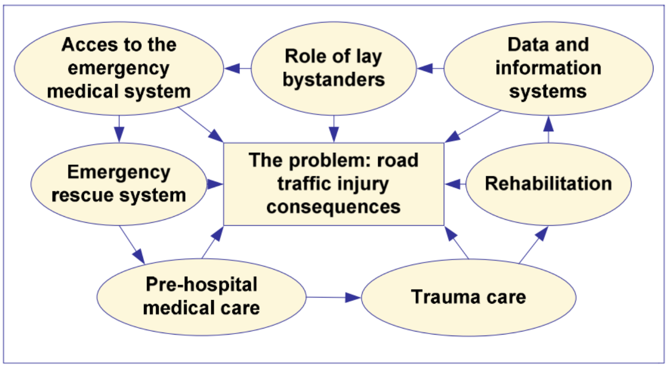

Figure 2-3: Post impact care - the chain of help (ETSC, 1999)

- **Vehicle factors**

Pre-crash phase: Vehicle factors have significant influence on road traffic accidents, it could contribute to crashes through vehicle defects. The defective vehicle parts, such as tires, brakes, and driving lights, could lead to serious accidents by affecting drivers' ability to maintain control over their vehicles. The other components of vehicles, such as turning lights and warning lights, do not work properly, leading to the misunderstanding of the other drivers may also cause accidents.

Crash phase: The functioning of protective equipment, such as airbag and seatbelts, during accidents considerably affects the possibility of survival and level of injury severity. For example, the estimation from the National Highway Traffic Safety Administration of the United States showed that from 1987, when airbags were first widely used in the production vehicle, through 2017, a total of more than 50,000 lives were saved (NHTSA, 2019).

Post-crash phase: Vehicle factors in this phase are related to both vehicles involved in the accidents and rescue vehicles (e.g. ambulance). For example, the risk of fire after the accidents due to poorly designed fuel tanks of crashed vehicles may prolong the rescue time of the rescue vehicles.

- **Road infrastructure factors**

Road infrastructure representing roadways, sidewalks, and traffic control systems may reduce the frequency and severity of road traffic accidents. It determines how road users perceive their environment and provide instructions for road users through road signs and traffic controls (Peden et al., 2004). The physical layout of the road and roadside environment should provide clear visual clues and signals to road users.

Pre-crash: Poor road design factors and road defects, such as improper curves/turns, inadequate road surface friction, improper traffic control devices and road signs, potholes, and uneven road surface, all may contribute to create road traffic accidents. In many developing countries, the facilities for pedestrians and cyclists are largely missing, and they have to share the same road spaces with other motorised vehicles, which increases the risks of involving in road traffic accidents among pedestrians and cyclists.

Crash phase: The passive safety road equipment, such as safety barriers and crash cushions, may reduce the consequences of road traffic accidents. It must be recognised that vehicles may also have collisions due to passive safety equipment. Therefore, it is vital to provide proper engineering designs for this equipment to ensure that the subsequent impact on safety objectives is significantly less severe than the resulting impact if the safety equipment is not in place (Thomson et al., 2005).

Post-crash phase: The availability of road lanes for rescue vehicles or ambulances may reduce the approaching time of these vehicles, contributing to mitigating the consequences of injuries.

- **Factors related to traffic flow**

The main factors related to traffic flow are traffic volume, traffic flow components, traffic flow speed, and traffic density. These factors affect all three phases of accidents. For example, the streets with mixed traffic flows where different types of vehicles use the same lanes may increase the possibility of accident occurrence. Or under congested traffic, the rescue time will be longer if an accident happens, which may affect the severity of injuries after the accident. A study about the relationship between traffic density, speed, and traffic safety on freeways found that the crash rate initially remains constant until a certain critical threshold combination of speed and density is reached (Kononov, Durso, Reeves, & Allery, 2012). The crash rate rises rapidly when this threshold is exceeded. The rise in crash rate may be explained by flow compressions without a notable reduction in speed; the headways are too small that drivers find it difficult or impossible to compensate for an error and avoid a crash.

- **Regulations**

Regulations including traffic regulations, vehicle design regulations, vehicle maintenance regulations, and regulations related to post-crash response are also associated with road traffic accidents. Traffic regulations related to speed limits, blood alcohol concentrations, wearing helmets, using seatbelts and mobile phone use are still incomplete and vary across countries. For example, currently, in Vietnam, there are no traffic regulations for using child-seat when children travel by car, resulting in many severe injuries for children if a car accident happens.

- **Natural environment factors**

Natural environment factors include weather factors and topography factors. These factors contribute to road traffic accidents as well. Weather conditions such as snow and rain may reduce road friction and impair the visibility of road users, which may result in accidents.

Overall, the cause-effect relationship between road traffic accidents and health is described in figure 2-4. Obviously, the health impacts of road traffic accidents are tremendous, which requires urgent actions to mitigate them. However, effective interventions could be successfully achieved when problems are clearly understood. First, the magnitude of the health impacts of road traffic accidents has to be adequately estimated by adapting harmonized definitions of road traffic deaths and injury severity. At the same time, the improvement in traffic safety report and integration of police data and hospital data on traffic accidents are needed to minimize underreporting and misreporting problems. In addition, further investigations of health impacts of both serious injuries and slight injuries are needed.

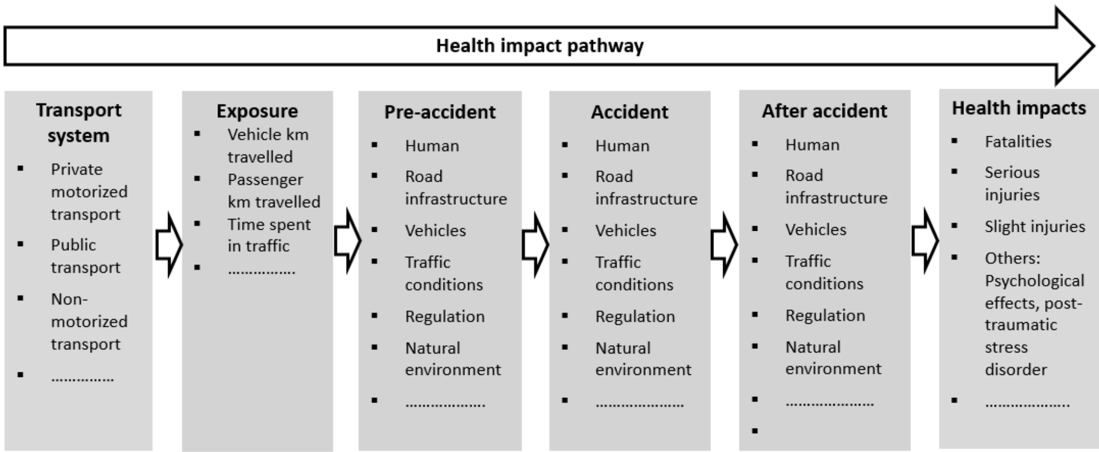

Figure 2-4: Cause-effect relationship between road traffic accidents and health (Source: Author)

2.2 Exposure to traffic-related air pollution

The health impacts of traffic-related air pollution (TRAP) are among the major concerns regarding the sustainability of the transport sector. Transport is a primary contributor to air pollution, particularly in urban areas with high numbers of motorised vehicles.

2.2.1Existing situation

- **Traffic-related air pollution (TRAP)**

Motor vehicles emit a wide range of air pollutants, including carbon dioxide (CO_2), carbon monoxide (CO) hydrocarbons (HC), nitrogen oxides (NO_x), particulate matter (PM), ultrafine particle (UFP), and substances known as mobile-source air toxics (MSATs), such as benzene, formaldehyde, acetaldehyde, 1,3-butadiene, and lead (where leaded gasoline is still in use). Each of these, together with secondary emission such as ozone, could negatively affect health (HEI, 2010). Particulate matter (PM), ozone (O_3), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2) are considered the most harmful to human health (WHO, 2005b). Among these pollutants, particulate matter (PM) has the greatest impact on human health. PM with a diameter less than 10 microns (PM_{10}) and less than 2.5 microns ($PM_{2.5}$) are small enough to penetrate deep into the thoracic region of the respiratory system (figure 2-5), that cause detrimental effects on the cardiovascular system and respiratory system, reduce lung function, increase the frequency of respiratory diseases, and reduce life expectancy (WHO, 2013b). The study from (Cohen et al., 2017) analysed the data from the global burden of disease, injuries, and risk factors in 2015 to estimate the burden of disease attributable to 79 risk factors, including ambient air pollution, in 195 countries from 1990 to 2015. The result showed that the long-term exposure to $PM_{2.5}$ caused 4.2 million deaths and 103.1 million lost years of healthy life in 2015, representing 7.6 % of total global mortality, making it the fifth-ranked global risk factors in 2015, and around 254,000 deaths were caused by exposure to ozone additionally (Cohen et al., 2017).

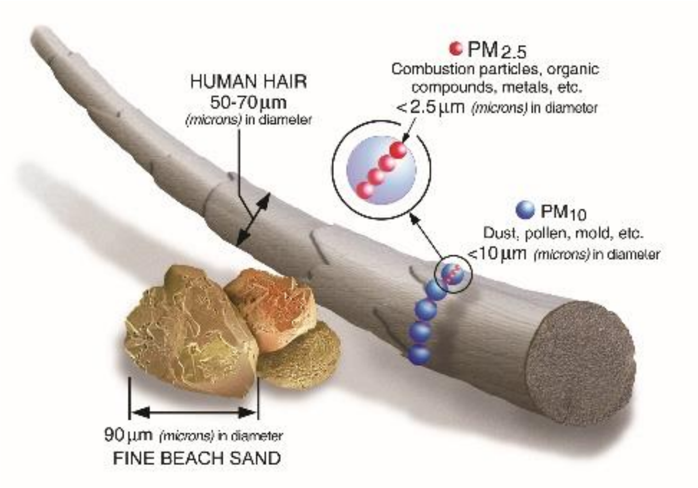

Figure 2-5: Size comparisons for PM particles (source: https://www.epa.gov/pm-pollution/particulate-matter-pm-basics)

- **Types of vehicle emissions**

Motor vehicles emit a wide range of air pollutants, and these pollutants could be divided into three groups: (1) Exhaust emissions as results of the combustion process, (2) Non-exhaust emissions produced from the mechanical abrasion and corrosion of vehicle parts such as vehicle's tyres, brakes, road wear, and road dust resuspension, which generates significant amount of PM, and (3) Evaporative emissions resulted of vapours escaping from vehicle's fuel system when vehicles are operated and parked. Evaporative emission is a significant source of volatile organic carbon (VOC), which reacts to nitrogen oxides (NO_x) and carbon monoxide (CO) under the presence of sunlight to form the ground-level ozone (O_3) (EEA, 2016a).

Exhaust emissions have been regulated widely and reduced significantly by implementing stricter vehicle emission regulations and innovative pollution control technologies worldwide. However, non-exhaust emissions currently are neglected and unregulated, and it may be a major source of TRAP when the emission controls from the combustion source become more effective. Recently, the non-exhaust emissions contribute up to 60 % and 42% of primary PM_{10} and $PM_{2.5}$ of the total road transport emissions of these pollutants in Europe, respectively (EEA, 2018b).

- **Contribution of road traffic to air pollution**

Figure 2-6 illustrates the contribution of regional transport, city area, and street traffic to air pollution concentration. The relative magnitude of the various contributions depends on the considered pollutants and the actual dispersion conditions (Hertel, 2009). Hertel explained that at a regional area, major air pollution comes from tall sources such as industries, power plants and other sources, which releases from tall chimneys because most of the pollution is transported out of the urban area before being dispersed down to the ground level. Thus, the contribution of these sources is very small to the local pollutant concentrations at ground level in urban areas. At a local area, the air pollutants emitted from traffic, local domestic heating, and low release high are major sources of the air pollution concentration and the busy roads are the hot spot areas in the urban environment. These air pollutants emit close to the areas where many people live and work. Thus, they contribute significantly to the level of air pollution concentration.

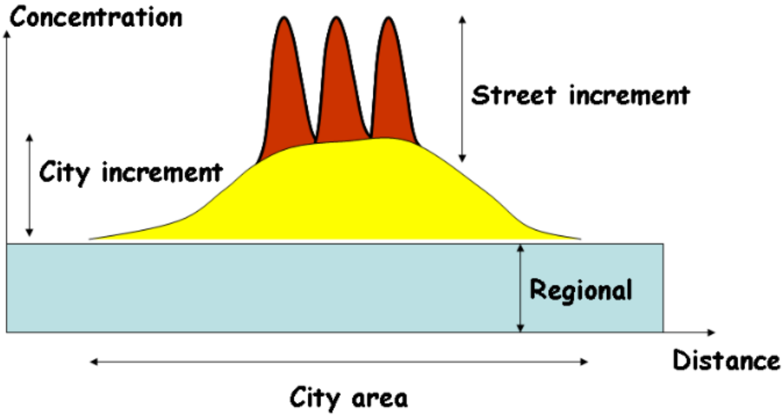

Figure 2-6: A schematic illustration of air pollutant contribution from regional transport, the city area, and the street traffic (Hertel, 2009)

Transport is the major contributor of PM, NO_x and O_3, and based on existing evidence, these pollutants are considered the most human-harmful air pollutants related to traffic. In Europe, the transport sector is responsible for more than 50% of total NO_x emission and contributes significantly to other air pollutants. Particularly, road transport continues to be a significant contributor to NO_x, PM_{10}, $PM_{2.5}$, which accounts for 29%, 8%, and 10% of the total emission, respectively (EEA, 2018b).

In Germany, for example, a huge number of air monitoring stations across the country have provided a good database of air quality. The data shows that the air pollution concentration of PM_{10}, $PM_{2.5}$, and NO_x at traffic stations is significantly high compared to that at background stations, meaning that traffic is a significant source of these air pollutants. In Germany, around 40% of nitrogen oxides (NO_x) caused by road traffic, and 91% of this comes from diesel cars (UBA, 2018).

Compared to cars, motorcycles are potentially a more sustainable means of transport since they need less space and emit less pollution than the car (Jittrapirom, Knoflacher, & Mailer, 2017). However, in Asian countries, motorcycles are the main sources of air pollution because of its dominance in the vehicle fleet and unregulated motorcycle emissions, low vehicle emission standards, the longevity of vehicles, and no mandatory inspection and maintenance programs for motorcycles.

Awareness of the health impacts of TRAP has grown, which has led to the introduction of regulation and innovative pollution control technologies throughout the world, such as applying stricter emission standards for new vehicles, cleaner fuels, and promoting electric vehicles. These approaches have made significant progress in reducing emissions from motorised vehicles and improving air quality, especially in developed countries. Although huge efforts have been implemented to reduce vehicle emissions, the benefits are offset by the increase in the number of the world's motorised vehicles and in travel demand as a result of economic development, urbanisation, and changes in land use. For example, road transport is still a major source of both greenhouse gases and air pollutants in Europe due to overall increases in passenger and freight demand (EEA, 2016a).

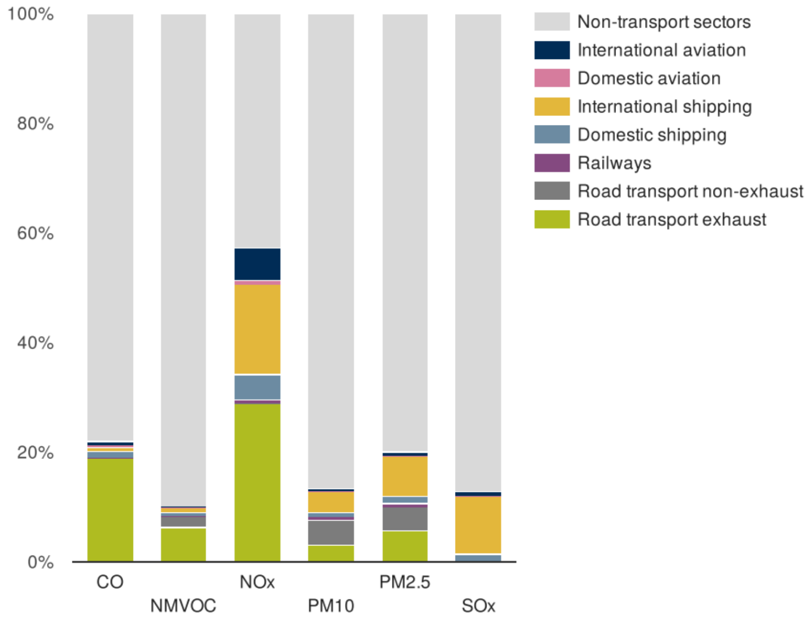

Figure 2-7: Contribution of the transport sector to total emissions of the main air pollutants in Europe (EEA, 2018)

- **Health impacts of exposure to TRAP**

It is difficult to precisely estimate the health impacts of specific pollutants because different air pollutants are mixed in the air, and people may be exposed to various air pollutants simultaneously. The air pollutants such as CO, NO_x found in motorised vehicles are also components of emissions from other sources such as industry, agriculture, and residential sources, making it difficult to differentiate contributions of these air pollutants from motor vehicles from those from other sources. However, pollutants emitted by vehicles generally occur in the areas where people live and work, such as cities and towns. Therefore, emissions from road transport may not be as large in absolute terms as those from other sources. The number of the population exposed to TRAP could be higher than that to other sources such as power plants, which often tend to be located in remote and less populated areas (EEA, 2016a). Possible health outcomes resulting from exposure to certain air pollutants are presented in figure 2-8.

Recently, the evidence from epidemiological studies on the health impacts of exposure to TRAP has increased significantly. Short-term and long-term exposure to TRAP both could cause harmful health effects. These air pollutants enter the human body through the respiratory system but have systemic impacts that could damage many other organs (Schraufnagel et al., 2019b).

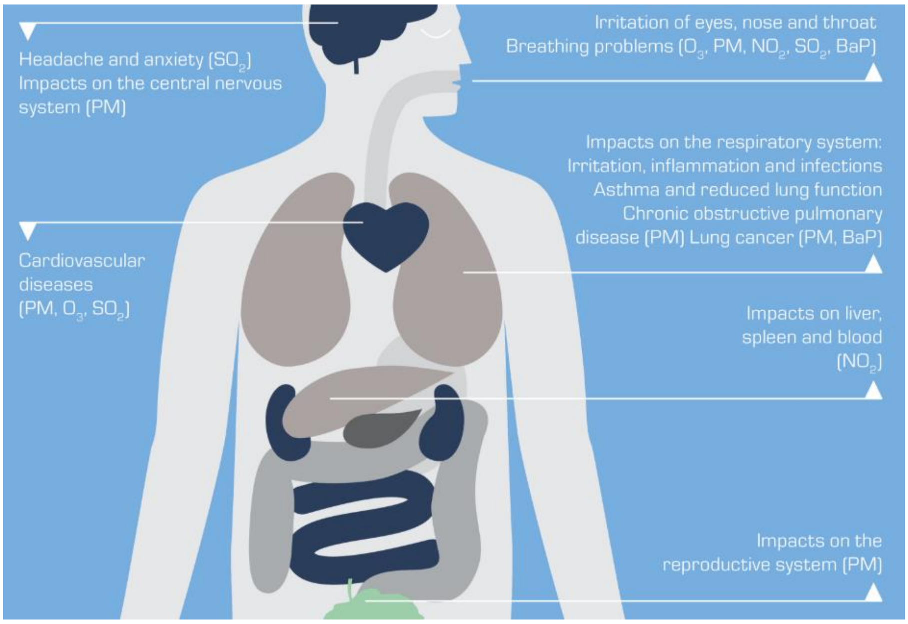

Figure 2-8: Health impacts of air pollutions (European Environmental Agency, 2014)

The major evidence indicates that exposure to TRAP increases the risk of mortality and morbidity, especially from the cardiopulmonary causes, and increases the risk of non-allergic respiratory symptoms and disease (WHO, 2005a) (HEI, 2010) (Schraufnagel et al., 2019a). Bhalla et al. estimated that exposure to air pollution from vehicles was responsible for 184,000 deaths globally, including 91,000 deaths from ischemic heart disease, 59,000 deaths from strokes, and 34,000 deaths from lower respiratory infections, chronic obstructive pulmonary disease, and lung cancer (Bhalla, Shotten, Cohen, Brauer, Shahraz, Burnett, Leach-Kemon, et al., 2014). Air pollution alone poses the single largest environmental risk factor in Europe today, and is responsible for more than 430,000 premature deaths, among various sources of air pollution in the urban area, road traffic is considered the main contributor (Ketzel, Kakosimos, Sørensen, & Jensen, 2018). Emissions from road transport were responsible for about one-fifth of mortality by outdoor $PM_{2.5}$ and O_3 in Germany, the United Kingdom and the United States, while globally, they account for 5% (Lelieveld, Evans, Fnais, Giannadaki, & Pozzer, 2015).

Exposure to TRAP also causes eye diseases and skin diseases. The eye diseases potentially related to exposure to air pollution are watery eyes, eye irritation, dry eyes, and redness. A study from South Korea found that the increase in ozone levels was associated with dry eye disease (Hwang et al., 2016). Another study reported that exposure to NO_2, O_3, PM_{10}, and SO_2 increased the chances of outpatient visits for nonspecific conjunctivitis (Chang, Yang, Chang, & Tsai, 2012). The TRAP that may cause skin problems are VOCs, NO_x, PM and O_3, exposure to these pollutants may contribute to skin ageing, acne, atopic dermatitis, psoriasis, and skin cancer (Drakaki, Dessinioti, & Antoniou, 2014)(Kim, Cho, & Park, 2016).

Recently, other health outcomes caused by exposure to TRAP such as reduced cognitive function, low birth weight, infant mortality, development symptoms of depression and anxiety, overweight in children, and preterm birth are investigated, but the results are not consistent and insufficient. Therefore, it requires further investigation (Li et al., 2017)(Clifford, Lang, Chen, Anstey, & Seaton, 2016)(Stieb, Chen, Eshoul, & Judek, 2012)(Shah & Balkhair, 2011) (de Bont et al., 2019).

In addition, high exposure to TRAP may result in other indirect health impacts through reducing the frequency of outdoor exercises or choosing not to use active transport (Geurs, Boon, & Wee, 2009). Other indirect effects may also come from climate change since road transport is one of the main contributors to greenhouse gas emission, influencing climate change, which consequences in severe extreme weather events and affects millions of people. More details of the health impacts of climate change will be presented in section 2.6.1.

Although air pollution affects people of all regions, ages and social groups, it distributes unequally across the population. The urban population is generally at a higher risk because they are exposed to a higher level of air pollution concentration than the rural population. The elderly, children, people with pre-existing health problems, and people who spent long time in traffic or near traffic are the most vulnerable to TRAP. So far, studies on the health impacts of TRAP are mostly conducted in developed countries, while in developing countries, where the problems are expected to be severer, studies about this topic are still limited.

2.2.2Cause-effect relationships

There is a process from vehicle emissions to health effects, which is presented in figure 2-9. Some harmful air pollutants are emitted directly from vehicles such as primary particulate matter (PM) and nitrogen oxides (NO_x). Other pollutants are formed in the atmosphere after emissions of precursor pollutants such as ozone (O_3) and secondary PM. Then, these pollutants are dispersed into the air, depending on the type of pollutants, weather conditions, surrounding environments, and street geometries. This results in the concentration of these pollutants in the air and subsequently affects people who are exposed to these air pollutants. Based on this process, a cause-effect framework of exposure to TRAP and its health impacts is developed in more detail and is presented in figure 2-10. The influencing factors vary with different steps in the framework, which will be presented in the next parts.

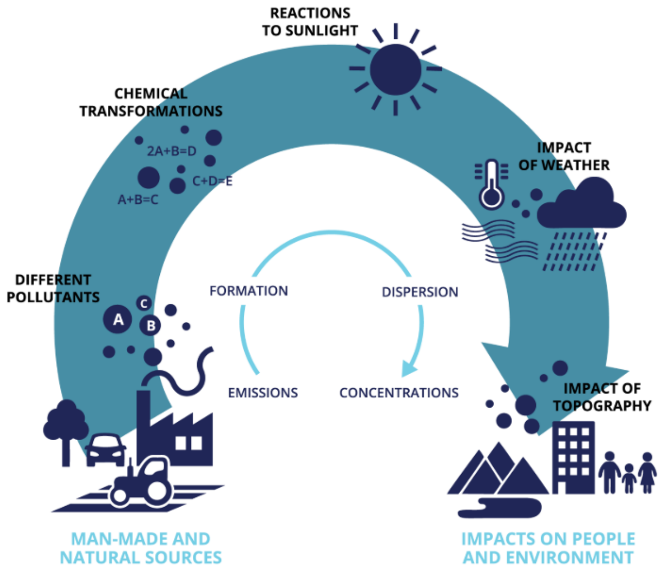

Figure 2-9: Air pollution: From emission to exposure (EEA, 2016a)

- **Factors influencing vehicle emissions:**

The factors that influence the level of vehicle emissions could be grouped into five main categories: vehicle factors, traffic conditions, driving behaviours, road conditions, and weather conditions. These factors affect differently the amount of vehicle emissions, which requires a comprehensive investigation.

- **Vehicle factors include** vehicle types, fuel used and fuel quality, operation and maintenance condition of the vehicle, vehicle age, vehicle kilometre travelled, vehicle size, loading factor/occupancy rate, wear parts (e.g., tires, brakes), engine lubricants used, emission standard, and emission control technology. These factors affect the amount of vehicle emissions differently. For instance, diesel vehicles are more fuel-efficient than gasoline vehicles. However, diesel vehicles emit higher levels of NO_x and PM than gasoline vehicles. Diesel cars are the main contributor to NO_x pollution in European countries. Although the stricter emission standards for new diesel vehicles are regulated, the NO_x emission under real driving condition is still significantly higher than the value measured on the chassis dynamometer when checking the exhaust emission limits (EEA, 2016a)(OECD/ITF, 2017).

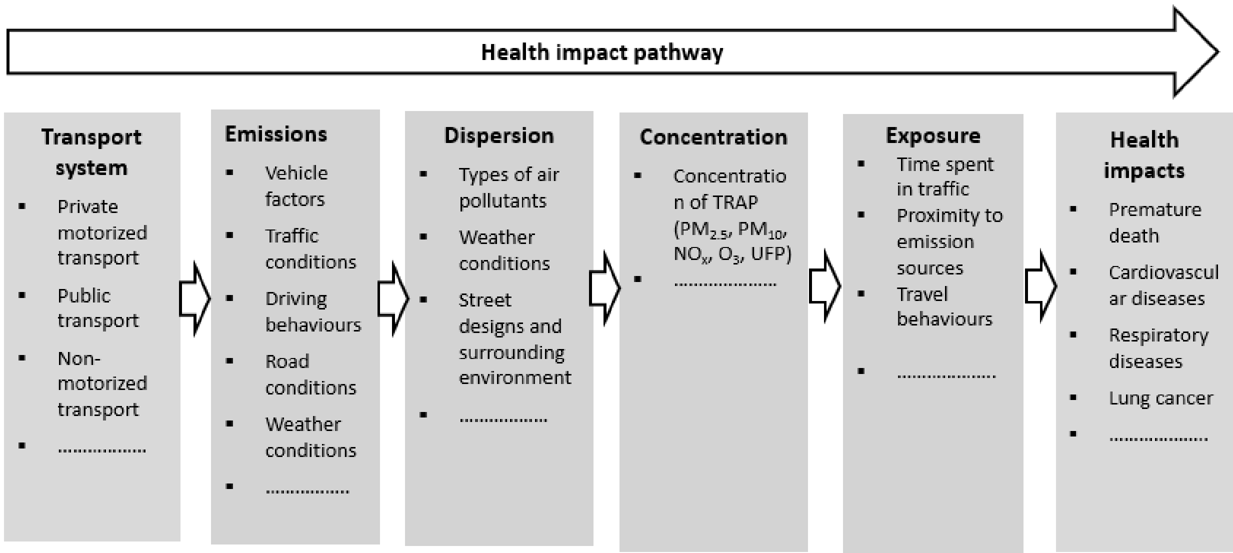

Figure 2-10: Cause-effect relationship between TRAP and health (Source: Author)

- **Traffic conditions** also play a major role in vehicle emissions. The major factors related to traffic conditions are traffic volume, average speed of traffic flow, level of service of the street (free-flow, saturated flow, congestion), traffic signal control, and speed limit. For example, vehicles that are running with the high frequency of accelerations and decelerations during congested and interrupted traffic conditions cause increased fuel consumption and pollutant emissions (Choudhary & Gokhale, 2016). Vlieger found that emissions from operating vehicles in peak hours were 20 to 45% higher than those in smooth-flowing traffic (Vlieger, 1997). Furthermore, under traffic congestions, road users usually spend longer travel time than in free-flow conditions, which results in increased exposure to air pollutions. Therefore, measures facilitating free-flow traffic pattern on urban roads could significantly reduce air pollutant concentrations in urban streets (Thaker & Gokhale, 2015).
- **Driving behaviours** influence vehicle emissions as well. A study reported that improving vehicle flow and reducing sudden and frequent acceleration could reduce annual vehicle emissions by up to 12% for CO2, 13% for CO and HC, and 24% for NOx as well as reduce fuel consumption (Rodríguez, Virguez, Rodríguez, & Behrentz, 2016).

Aggressive driving could increase fuel consumption by up to 24% (European Union, 2016).

- **Road conditions** such as road surface, road maintenance condition, road geometry, and pavement characteristic affect vehicle emission level of both exhaust emissions and non-exhaust emissions. Driving on rough surface roads may consume more fuel than driving on smooth surface roads, resulting in higher emissions. A straight road with less rough turnings, for example, may also reduce vehicle fuel consumption as vehicles are running at a constant speed.
- **The weather conditions** consisting of wind speed, wind direction, air temperature, snow, rain, and the presence of sunlight affect vehicle emissions as well. For example, using the heating system during cold weather or air-conditioning during hot weather increases vehicle emissions. In the summer, intense sunlight combined with high temperatures causes an increase in the formation of ground-level ozone.

- **Factors influencing the emission dispersion**

After being emitted from vehicles, some secondary pollutants are formed in the atmosphere. Then these pollutants are dispersed into the air, depending on the type of pollutants, weather conditions, and street designs and surrounding environments.

- **Type of air pollutants**, each type of air pollutants has its own characteristics in physical and chemical conditions, which influences its dispersion into the atmosphere. For example, tiny particles like ultrafine particle that is very light could easily and quickly disperse into the air after being produced from vehicles.
- **Weather conditions** such as wind speed, wind direction, temperature, rain, snow, and humidity strongly affect the dispersion of air pollutants. For instance, Hertel reported that the dilution of air pollutants generally increases with wind speeds. The highest level of air pollution concentration in urban areas occurs at low wind speeds (below 2m/s) (Hertel, 2009).
- **Street designs and surrounding environments** including road lane width, intersection designs, present of trees, building structure, building height impact the dispersion of air pollutants as well.

In urban areas, the street canyon is the worst type of street design in terms of air pollution dispersion. A street that is flanked by buildings on both sides is defined as a street canyon, which is illustrated in figure 2-11. In these streets, air pollutants are trapped and recirculated instead of being transported away from the streets (J. Khan et al., 2018).

In figure 2-11, the wind above the roof level is perpendicular to the street. Inside the street canyon, a vortex is created, and the wind direction at the street level is opposite to the wind direction above the roof level. The pollution concentrations could be up to 10 times higher on the leeward side compared to the windward side of the street (Berkowicz, Hertel, Larsen, Sørensen, & Nielsen, 1997). Another study reported that in street canyons, pollution concentration is higher in the centre of the street sections, as compared to cross-sections, closer to the junctions; and concentration found at 1.5 meters from the ground is higher than one at 2.5 meters height, which are of concern regarding pedestrian exposure to TRAP (Karra, Malki-Epshtein, & Neophytou, 2017).

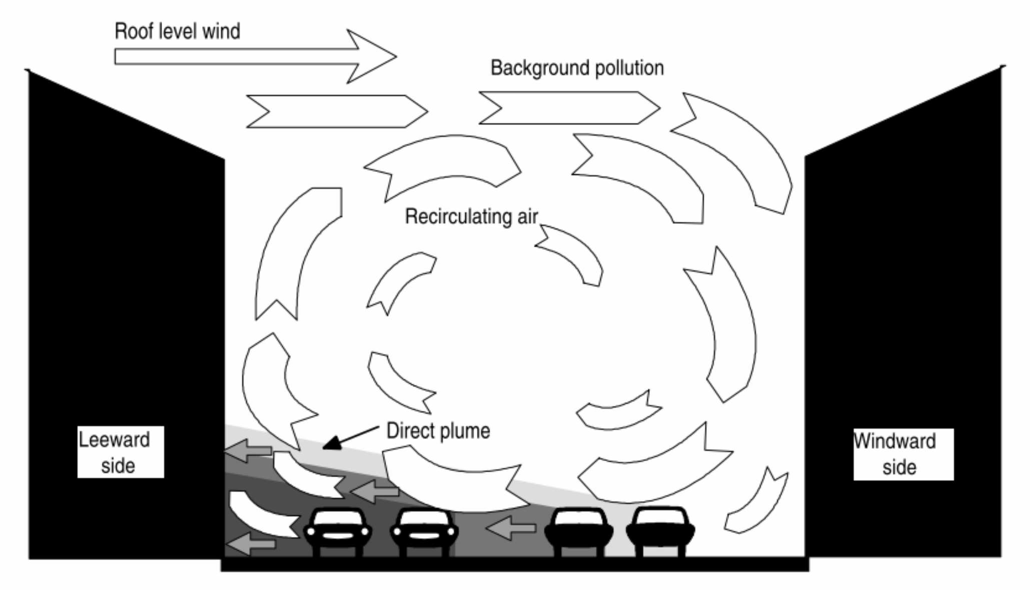

Figure 2-11: Schematic illustration of the flow and dispersion inside a street canyon (Berkowicz et al., 1997)

Fu et al. reported that the higher buildings prevent ventilation in street canyons resulting in a higher concentration of pollutants inside street canyons and lower pollution outside the canyons. They also found that the increase in building height from 20 meters to 40 meters has a small influence on pollution concentrations. However, the building height is over 40 meters; the pollutant concentrations increase significantly within street canyons. The level of pollutant concentrations could increase by about 52% if the building height increased from 20 to 60 meters. They also found that uneven building height along with a street significant influence pollutant dispersion. Street canyons are highly symmetric or highly asymmetric, the lower pollutant concentration at the pedestrian path (Fu et al., 2017).

- **Air pollution concentrations**

Air pollution concentration could be measured directly via air monitoring stations and mobile air measurement devices or indirectly via modelling. The level of concentrations varies across locations and time. For direct measuring air concentration level, the measurement devices and measuring methods strongly influence the accuracy of the data. In developed countries, most air monitoring stations have collected air quality data continuously and reported real-time air quality information, which is usually quite costly. In developing countries like Vietnam, air quality is still collected manually for a certain period of time (e.g., few hours per day, ten days per month) owing to limited finance. For accurately estimating the level of air concentrations via modelling, traffic data (e.g., characteristics of vehicle fleets, travel speeds, vehicle emission standards), weather data (e.g., wind speed, wind direction, temperature), urban factors (e.g., house structures, trees), and many others are required. This is consuming time and cost too.

In urban areas, air monitoring stations are often divided into two groups, including traffic air monitoring stations and background air monitoring stations. The traffic monitoring stations are often located close to major streets to measure emissions from traffic. Although it is difficult to differentiate the contribution of all emission sources accurately, data from traffic stations are often referred as the contribution of traffic to air pollution.

Table 2-4: Air quality standards of different regulations

Pollutants (unit µg/m^3)	Average exposure time	WHO AQG[1]	EU standards[2]	Vietnamese standard[3]
PM_{10}	24 hours	50	50	150
	Annual	20	40	50
$PM_{2.5}$	24 hours	25	-	50
	Annual	10	25	25
NO_2	1 hour	200	200	200
	24 hours	-		100
	Annual	40	40	40
SO_2	10 min	500		-
	1 hour	-	350	350
	24 hours	20	125	125
	Annual	-		50
O_3	1 hour	-	240	200
	8 hours	100	120	120
CO	1 hour	30000		30000
	8 hours	10000	10000	10000

Exposure to air pollutants is not always harmful to health if its concentration levels are low and under limited values. Table 2-4 presents limited values for several air pollutants, based on the World Health Organization air quality guideline (WHO AQG), EU air quality standards, and Vietnamese air quality standards. Usually, the air quality guidelines vary across countries depending on their development priorities and abilities to achieve objectives. To minimize the health impacts of exposure to air pollution, reducing air pollution concentration under the limited values in WHO AQG is strongly recommended.

In Europe, a large percentage of the urban population is still exposed to PM_{10}, $PM_{2.5}$, and O_3, above the WHO limited values, presented in figure 2-12. In Germany, for example, the number of populations exposed to PM_{10} has substantially reduced since 2007 according to EU air quality standards. However, there is still a high number of population exposed to $PM_{10,}$ exceeding WHO limited value, around 4.3 million people in 2015 (UBA, 2017).

[1] WHO air quality guidelines for particulate matter, ozone, nitrogen dioxide, and sulfur dioxide (2005)

[2] EU Ambient Air Quality Directives (Directive 2008/50/EC)

[3] National Technical Regulation on Ambient Air Quality (QCVN 05:2009/BTNMT)

Pollutant	EU reference value (ᵃ)	Exposure estimate (%)	WHO AQG (ᵃ)	Exposure estimate (%)
$PM_{2.5}$	Year (25)	6-8	Year (10)	74-85
PM_{10}	Day (50)	13-19	Year (20)	42-52
O_3	8-hour (120)	7-30	8-hour (100)	95-98
NO_2	Year (40)	7-8	Year (40)	7-8
BaP	Year (1)	20-24	Year (0.12) RL	85-90
SO_2	Day (125)	< 1	Day (20)	21-38

Key				
Key	< 5 %	5-50 %	50-75 %	> 75 %

Notes: (ᵃ) In µg/m³; except BaP, in ng/m³.

Figure 2-12: Percentage of the urban population in the EU-28 exposed to air pollutant concentrations, above EU and WHO limited values between 2014 and 2016 (EEA, 2018a)

- **Factors influencing the level of exposure to TRAP**

Human exposure is people's contact with a pollutant, which is a necessary condition for the occurrence of a health effect (WHO, 2005a). For example, air pollution concentration on major streets is usually high, and exposure to high air pollution concentration leads to many health consequences, but this only happens to people who travel or live close to these streets. People who do not travel or live in close proximity to these streets may not be affected. The number of exposed people, duration of contact, and concentration of the pollutants in the place where the contact takes place are often used to define the magnitude of the exposure and the extent of health effects in a population (HEI, 2010). Three main factors influencing the level of exposure to TRAP concertation of a person as well as the general population are time spent in traffic, proximity to traffic, and travel behaviours.

- **Time spent in traffic** strongly affects the level of air pollution exposure of an individual. For example, a person who spends long time travelling under high traffic volume is likely to be exposed to higher TRAP concentration than who spends less time travelling or travelling in the fewer traffic routes.
- **Proximity to vehicle emission sources** is defined as the distance to emission sources. A person who lives/works closer to major streets is exposed to higher air pollution concentration than a person who lives/works far away from major streets. Health effect institute (HEI) identified an exposure zone within a range of up to 300 to 500 meters from a highway or main road as the area most affected by traffic emissions (HEI, 2010).
- **Travel behaviours** such as transport mode use, time of commuting, and route selections also highly influence the level of exposure to TRAP concentration. Transport mode use affects the travel time or time spent in traffic of an individual. For instance, with the same travelled distance, cyclists often take a longer time than car users, increasing exposure to TRAP concentration among cyclists. As a result, the health impacts of exposure to air pollution on cyclists are much higher than car commuters. Or people who travel in peak hours are exposed to a higher level of air pollution than those who travel in the off-peak hours.

Overall, transport is the main source of air pollution in urban areas, which affects population health markedly. However, to precisely estimate the magnitude of the health impacts of exposure to TRAP remains a challenge as emission sources usually mix with each other and existing studies are limited to some main air pollutants only. In addition, the majority of studies on the health impacts of exposure to TRAP have been conducted in developed countries. In contrast, in developing countries, where the problems are expected to be more severe, studies about this topic are still limited. Further studies in developing countries are necessary.

2.3 Exposure to traffic-related noise pollution

2.3.1 Existing situation

- **Noise emission from road traffic**

Based on EU directive 2002/49/EC on the management of environmental noise defined environmental noise as “unwanted or harmful outdoor sound created by human activities, including noise from road, rail, airports and industrial sites”.

Noise is one of the major environmental issues affecting a large proportion of the population. In urban areas, traffic noise is a principal noise source. With continuing urbanization and increasing population, traffic noise is a growing problem. According to a report from European Environment Agency (EEA), noise from road traffic alone is the second most harmful environmental stressor in Europe that affects both physical and mental health of the population, just behind air pollution. Around 100 million people are exposed to road traffic noise above 55 dB, and 32 million of these people exposed to very high noise levels of above 65 dB, in the 33 member countries of the EEA (EEA, 2017b).

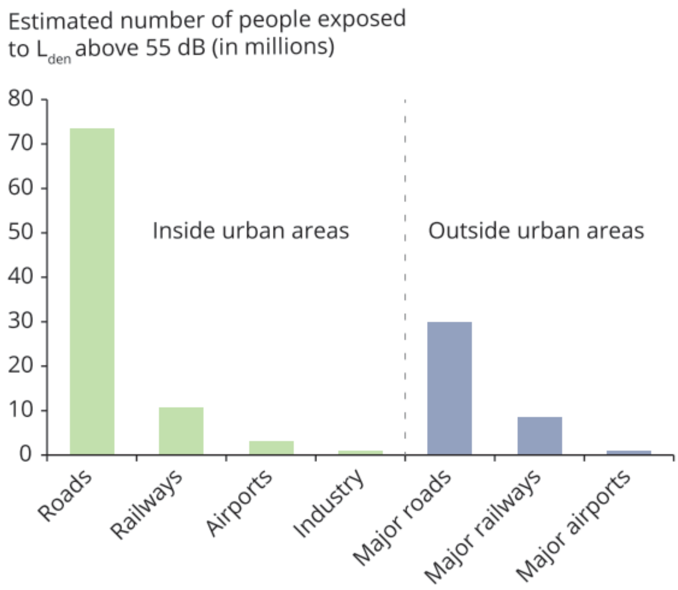

Figure 2-13: Number of people in the EEA-33 member countries exposed to noise levels of above 55 dB Lden, 2012 (EEA, 2017a)

- **Health effects of road traffic noise**

Many studies have investigated the health effects of environmental noise, and the results showed that exposure to persistent or high levels of noise causes a number of adverse health impacts, both directly and indirectly. Adverse health outcomes include cardiovascular disease, cognitive impairment, sleep disturbance, annoyance, mental health and well-being, hearing impairment and tinnitus, and adverse birth outcomes (Basner et al., 2014)(Fritschi et al., 2011) (WHO, 2009) (WHO, 2018a). In western European countries, it is estimated that Disability Adjusted life years (DALYs) lost from environmental noise were 61 000 years for ischaemic heart disease, 45 000 years for cognitive impairment of children, 903 000 years for sleep disturbance, 22 000 years for tinnitus and 654 000 years for annoyance. It means that at least 1 million healthy life years are lost every year due to exposure to ambient noise in European countries (Fritschi et al., 2011). Among these health effects, sleep disturbance and annoyance are the most common and well-known health effects caused by exposure to traffic noise. These effects are responsible for most of the burden of environmental noise in western Europe.

- **Sleep disturbance:** The WHO-Night Noise Guidelines in 2009 described the detailed relationship between noise and sleep (WHO, 2009). The report stated that sleep is a biological need, and disturbed sleep is linked with a number of health problems. The elderly, children, shift-workers, and people with pre-existing sleep disorders are the most affected. Noise could affect sleep by fragment sleep, difficulty in falling asleep, awakening during sleep, reducing sleep continuity, and reducing the quality of sleep and total sleep time. Sleep disturbance is associated with a range of adverse health effects such as changes in glucose metabolism and appetite regulation, impaired memory consolidation, and dysfunction of blood vessels and these are precursors for other diseases such as obesity, diabetes, high blood pressure, and probably also dementia (Zaharna & Guilleminault, 2010)(Cappuccio, D'Elia, Strazzullo, & Miller, 2010). The consequence of sleep disturbance could be seen immediately in the next day, for example, sleepiness, impaired cognitive performance, and that may increase the risk of errors and accidents.
- **Annoyance:** Annoyance is the second major health impact of exposure to environmental noise after sleep disturbance. A systematic review of environmental noise and annoyance reported a strong correlation between noise and annoyance (Guski, Schreckenberg, & Schuemer, 2017). Noise could interfere people's daily activities, feelings, thoughts, sleep, or rest and may cause negative responses, such as anger, displeasure, exhaustion, anxiety, distraction, and stress-symptoms (Öhrström, Skånberg, Svensson, & Gidlöf-Gunnarsson, 2006).
- Many studies have investigated associations of exposure to environmental noise and **cardiovascular diseases**. Exposure to environmental noise has found associated with hypertension, arteriosclerosis, and ischaemic heart disease; among these, hypertension is considered an important risk factor for other cardiovascular diseases such as stroke (WHO, 1999) (Babisch, 2014) (van Kempen, Casas, Pershagen, & Foraster, 2018)

  The noise reaction scheme presented in figure 2-14 explained that the impacts of noise exposure on the cardiovascular system could go through two ways, directly from the physiological stress reaction to the actual noise level, and indirectly from the psychological appraisal of noise through noise annoyance.

- **Mental health problems:** noise is considered an environmental stressor and could affect mental health in different ways. Exposure to noise could directly lead to an increase in stress hormones and cortisol, leading to the development of depression and anxiety disorders (Clark & Paunovic, 2018b). Indirectly, psychological stress responses due to sleep disturbance and annoyance may also create stress hormones, leading to different mental health problems. The high noise annoyance is linked with impaired mental health as well (Hammersen, Niemann, & Hoebel, 2016) . Another study found that exposure to road traffic noise increases the risk of depressive symptoms (Orban et al., 2016). Okokon et al. reported that exposure to high level of road traffic noise is associated with psychotropic medication use (Okokon et al., 2018).

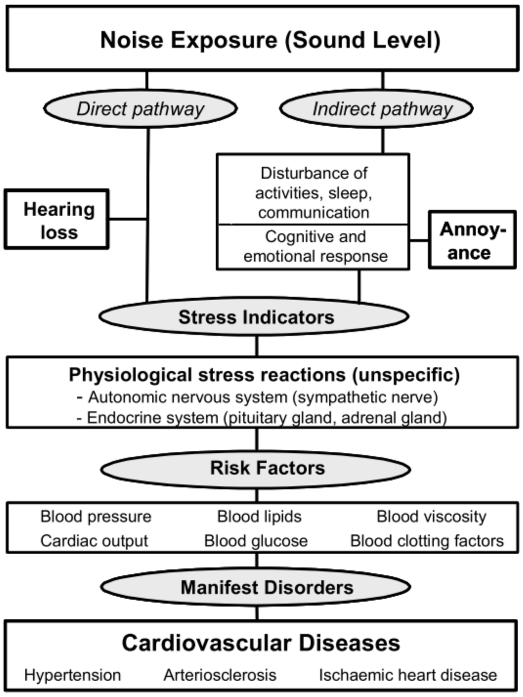

Figure 2-14: Noise effects reaction scheme (Babisch, 2014)

- **Cognitive impairment:** the extent to which noise impairs cognition, particularly in children, has been studied with experimental and epidemiological designs (Fritschi et al., 2011). Exposure to noise could potentially affect the ability of reading, short-term and long-term memory, the ability of attention, and executive functions (e.g. task flexibility, problem-solving) (Clark & Paunovic, 2018a). Children are the most vulnerable to noise, particularly the critical periods of learning at school could potentially affect the children's development and have a lifelong impact on educational attainment.
- **Other health outcomes:** There are several health outcomes that may be associated with the exposure to road traffic noise such as hearing impairment (Śliwińska-Kowalska & Zaborowski, 2017), adverse birth outcomes (Wallas et al., 2019) (Hohmann et al., 2013), diabetes (Ketzel et al., 2017)(Zare Sakhvidi, Zare Sakhvidi, Mehrparvar, Foraster, & Dadvand, 2018), obesity (Argalášová et al., 2017), reduced physical activity (Foraster et al., 2016), and mitigate leisure-time sports (Roswall et al., 2017). However, the number of available studies about these issues is still limited, and the results are not always consistent. Therefore, further studies are suggested.

2.3.2Cause-effect relationships

Generally, road traffic noise results from the combination of rolling noise, propulsion noise, and aerodynamic noise (Gloerfelt, 2009). Rolling noise is produced from the interaction between the vehicle’s tire and road surface. Propulsion noise is produced from engine, exhaust, gears, and air intake. Aerodynamic sound is generated by air movement in conjunction with contiguous rigid solid surfaces of vehicles. There is a large number of factors influencing the level of road traffic noise, but they could be classified into five main groups, including vehicle factors, road factors, traffic situation, driving behaviours, and weather factors.

- **Factors influencing the road traffic noise**
    - **Vehicle factors** include vehicle types, engine types, tire types, vehicle ages, vehicle mass, and vehicle maintenance and operation conditions, etc. Different vehicle types produce different noise levels. For example, an experimental study found that hybrid and electric vehicles emit significantly less noise in suburban and urban traffic (at least 10 dBA less) than petrol and diesel vehicles. However, noise from the interaction between tires and road surface remains the primary source of noise, particularly at high speeds (Ibarra, Ramírez-Mendoza, & López, 2017). The propulsion noise of vehicles comes from engines, transmission, exhaust, and suspension. Poor vehicle maintenance, such as those with incomplete exhaust systems, are noisier than well-maintained vehicles. Rolling noise is generated by contact between vehicle tires and the road surface; thus, types of vehicles' tires also influence the road traffic noise level.
    - **Traffic conditions** include traffic volume, traffic composition, average traffic flow speed, traffic congestion, and free-flow traffic. These factors affect the total noise emission from road traffic. For example, streets with high traffic volume are usually noisier than streets with less traffic volume. Thus, a reduction in traffic volume will lead to a decrease in traffic noise. Ellebjerg found that given the same speed, traffic composition, and driving patterns, reducing 20% of vehicles results in a 1 dB noise reduction (Ellebjerg, 2005). Heavy vehicles also generate more noise than passenger cars or motorcycles. Thus, the roads with a high share of heavy vehicles tend to be much noisier than streets with few of these vehicles. A comparison of different traffic flow conditions on urban road traffic noise showed that the decelerated traffic flow had the lowest noise level, compared to congestion, acceleration, and free flow, 6%, 14% and 12%, respectively (Maghrour Zefreh & Torok, 2018).

      Additionally, noise emissions from vehicles are profoundly affected by vehicle speed. Figure 2-15 presents the relationship between vehicle speeds and noise emission of a passenger car and a five-axles heavy truck (Kragh, 2011). The rolling noise is dominant when a vehicle is running at high speeds. Propulsion noise is dominant when a vehicle is running at lower speed, especially for heavy vehicles. Rolling noise dominates the others when a passenger car moves at above 40 km/h or when a heavy vehicle moves at above 70 km/h.

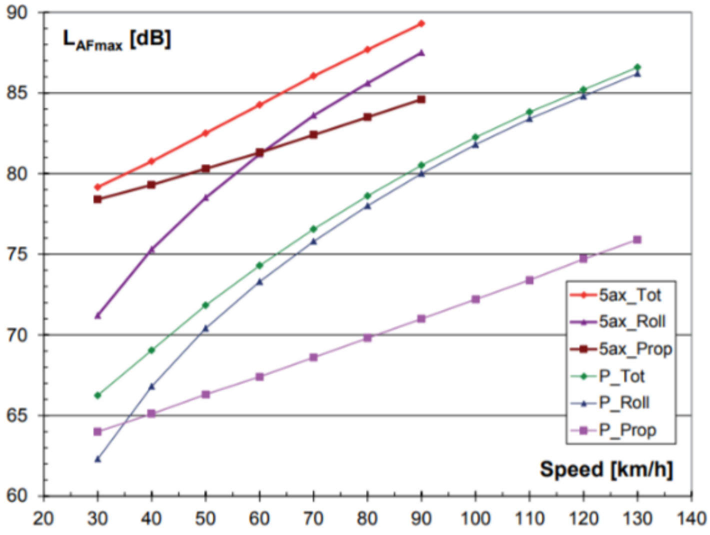

Figure 2-15: Rolling noise, propulsion noise, and total pass-by noise levels as a function of the vehicle speed for a passenger car and a 5-axle heavy truck (Kragh, 2011)

- **Road conditions** such as road surfaces, road maintenance conditions, road gradients, and road layouts play a significant contribution to the level of road traffic noise. Smooth and well-maintained road surfaces produce less noise than those with rough, damaged, and cracked surfaces. In addition, roadside surfaces with vegetated soil could absorb and moderate noise, while concrete or asphalt does not have any benefits in reducing noise (Jaecker-Cueppers, 2011). The road traffic noise level on roads with steep grades and sharp corners is often high, resulting from acceleration, braking, and gear changes from vehicles.
- **Driving behaviours** such as driving at high speeds, using vehicle's horns, or sudden braking or acceleration also affect road noise levels. In countries where road users often travel in mixed traffic flows, like Vietnam and India, using vehicle's horns is quite common. This is a significant contributor to road traffic noise, especially in peak hours (Phan, Yano, Phan, et al., 2010)(Konbattulwar, Velaga, Jain, & Sharmila, 2016).
- **Weather factors,** including temperature, humidity, wind speed, wind direction, rainy, and snow, also contribute to road traffic noise levels. For example, tire/road noise tends to increase when temperatures decrease due to the increased stiffness of the tread compound (Peeters & Blokland, 2007). Wind speed and wind direction highly affect the aerodynamic noise of vehicles.

- **Factors influencing the dispersion of road traffic noise**

Similar to air pollution, after being released, road traffic noise also dispersed into the air and affects people health. The major factors influencing the dispersion of road traffic noise are weather conditions and noise barriers.

- **Weather factors** such as wind speed, wind direction, and temperature play a role in dispersing noise. For example, downwind sites are usually less noisy than sites upwind direction (Jaecker-Cueppers, 2011).
- **A Noise barrier,** also known as a sound wall, noise wall, or sound barrier, is an exterior structure to reduce noise exposure. Noise barriers could reduce noise levels by 3-6 dB exposed by receivers (Boer & Schroten, 2007). Figure 2-16 shows the propagated

pathway from a mobile emitting source to a receiver. The sound propagation could be influenced by reflection with surfaces (e.g. ground surface, building facades, roof, barriers), diffraction from edges as from sound wall, scattering from the rough surface as irregular facades and atmospheric turbulence, refraction by temperature and wind gradients in the air, and attenuation of sound waves by air absorption (Hornikx, 2016).

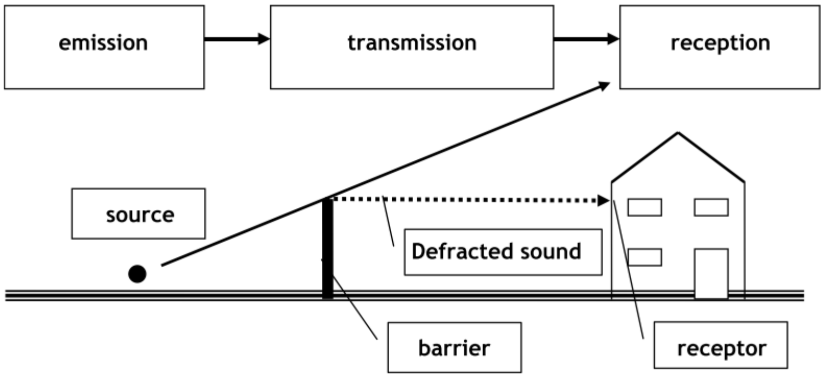

Figure 2-16: Emission, transmission, and reception of noise (Jaecker-Cueppers, 2011).

Surrounding environments such as building, vegetation, buffer zones, and noise insulation on buildings also affect the dispersion of noise pollution into the air and inside houses. Natural vegetation, for example, if high, wide, and dense enough, has been reported to reduce road traffic noise (Ow & Ghosh, 2017). Interestingly, Ow and Ghosh also suggested that a vegetative barrier is also likely an artificial barrier that influences people's psychological perceptions. This means that the noise reduction put forth by a vegetative barrier could be perceived as being larger than the actual noise reductions.

- **Noise indicators**

From scientific opinions, the best criterion for selecting a noise indicator is its ability to predict an effect. Various indicators may be suitable for different health end-points, and some indicators are more practical to use or easier to calculate than others**.** Therefore, different noise indicators could be chosen for different health endpoints. However, from the practical point of view, the chosen indicators should be easy to understand for the public, and indicators should be consistent with the existing practices in the legislation to allow quick and easy application and enforcement (WHO, 2009).

The most common noise indicators are L_{den} and L_{night}. Those indicators are generally reported by authorities and widely used for exposure assessment in health effect studies. However, other noise indicators such as L_{max} might be helpful to reflect particular noise situations. For example, shooting noise or noise emitted by trains, L_{max} could be used for setting noise limits to determine specific health effects (WHO, 2018a)**.** The LAeq, 24h (A-weighted equivalent sound pressure level over 24 hours) is also recommended for health effect studies (Lekaviciute, Kephalopoulos, Stansfeld, & Clark, 2013).

The definition of noise indicators was defined in the **Environmental Noise Directive 2002/49/EC.**

L_{den} is the A-weighted average sound pressure level, measured at the most exposed façade, outdoors over 24 hours, with a 10 dB penalty added to the average level in the night (11 pm to 7 am or 10 pm to 6 am), a 5 dB penalty added to the evening (19:00 – 23:00 or 18:00 – 22:00), and no penalty added to the day time period (7:00 – 19:00 or 6:00 – 18:00). The penalties aim to indicate people's extra sensitivity to noise during the evening and night.

L_{night} is an equivalent outdoor sound pressure level, measured at the most exposed façade, associated with a particular type of noise source during the night time (at least 8 hours).

- **Recommended threshold for noise indicators**

WHO has developed the night noise guideline for Europe (WHO, 2009). A systematic review of the evidence from epidemiological and experimental studies on the health impacts of exposure to environmental noise has conducted. The results showed that below 40 dB $L_{night,outside}$ produced no harmful health effects. However, adverse health effects are observed at the level above 40 dB $L_{night,outside}$, such as self-report sleep disturbance and insomnia. Above 55 dB, the adverse health effect increases significantly. Therefore, it was recommended that the population should not be exposed to night noise levels, above 40 dB of $L_{night,outside}$ during sleeping time. An interim target of 55 dB $L_{night,outside}$ is recommended for countries that the achievement of the target 40 dB is not feasible in the short-term.

Table 2-5: Guideline values for community noise in specific environments (WHO Guideline) (WHO, 1999) (Note: #1: As low as possible)

Specific environment	Critical health effect(s)	L_{Aeq} [dB(A)]
Outdoor living area	Serious annoyance, daytime and evening Moderate annoyance, daytime and evening	55 50
Dwelling, indoors Inside bedrooms	Speech intelligibility & moderate annoyance, daytime & evening Sleep disturbance, night-time	35 30
Outside bedrooms	Sleep disturbance, window open (outdoor values)	45
School class rooms & pre-schools, Indoors	Speech intelligibility, disturbance of information extraction, message communication	35
Pre-school bedrooms, indoor	Sleep disturbance	30
School, playground outdoor	Annoyance (external source)	55
Hospital, ward rooms, indoors	Sleep disturbance, night-time Sleep disturbance, daytime and evenings	30 30
Hospitals, treatment rooms, indoors	Interference with rest and recovery	#1
Industrial, Commercial shopping and traffic areas, indoors and Outdoors	Hearing impairment	70
Ceremonies, festivals and entertainment events	Hearing impairment (patrons:<5 times/year)	100
Public addresses, indoors and outdoors	Hearing impairment	85

Recently, the WHO Regional Office of Europe has developed new environmental noise guidelines for European Region. That provides an updated recommendation for protecting human health from exposure to environmental noise, generated from different sources (transport noise, wind turbine noise, leisure noise). Regarding road traffic noise, it is strongly recommended to reduce noise levels produced by road traffic to below 53 decibels (dB) L_{den}; a higher level is associated with adverse health effects). The road traffic noise levels during the night time should be below 45 dB L_{night} (as night-time road traffic noise above this level is associated with adverse effects on sleep) (WHO, 2018a).

In additions, there are several values for noise levels in specific environments. They are presented in table 2-5. However, these values are different across countries. For example, in Vietnam, the limited values for noise levels of L_{den} and L_{night} are 70 dB and 55 dB, respectively (QCVN 26:2010/BTNMT).

- **Factors influencing the exposure of road traffic noise:**

The health impacts of road traffic noise depend on the level of exposure. The level of exposure of an individual depends on the magnitude of exposed noise, distance to the noise sources, and duration of exposure (e.g., time spent in traffic). Additionally, people's exposure to road traffic noise is also strongly influenced by the propagation paths from sources to receivers and highly dependent on the disposition of receivers relative to sources (Brown & van Kamp, 2017). People who live near major roads should close windows to reduce the level of exposed noise. This could reduce at least 24 dB compared to outside noise (WHO, 2009).

Overall, a cause-effect relationship between road traffic noise and health is summarized in figure 2-17 below. Road traffic noise is a major source of noise pollution in cities, which affects human health adversely. Sleep disturbance, annoyance, cardiovascular diseases, and mental health impacts are among the most common health effects of exposure to road traffic noise.

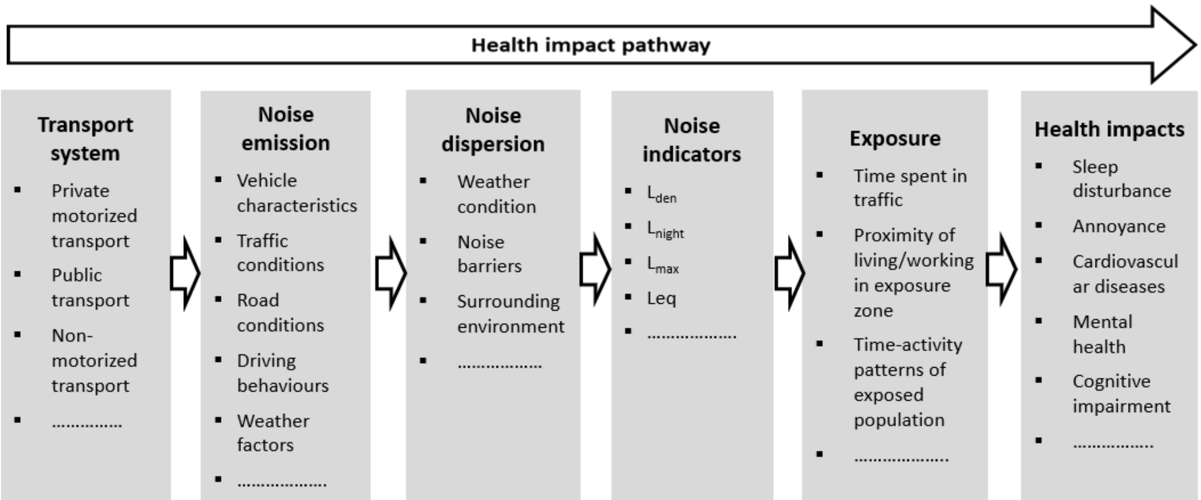

Figure 2-17: Cause-effect relationship between road traffic noise and health (Source: Author)

2.4 Transport-related Physical activity

Nowadays, physical inactivity and insufficient physical activity are among the most health challenges that affect health enormously. Daily lifestyle and behaviours such as eating habits, exercising, and sedentary lifestyles reduce the level of physical activities among populations considerably. This section reviews the association between physical inactivity and health, highlighting relations of transport, physical activity, and health.

2.4.1Existing situation

- **Health effects of physical inactivity**

Physical inactivity and insufficient physical activity are associated with the increase in the risk of many adverse health effects, including major non-communicable diseases such as coronary heart disease, type 2 diabetes, obesity, breast and colon cancers, and shortens life expectancy (WHO, 2011) (Lee et al., 2012). There was an estimation that physical inactivity was responsible for 13.4 million DALYs globally (Ding et al., 2016). Available data suggest that worldwide around 27.5% of the population do not meet the public health recommendations for physical activity, with a higher risk on women and older people (Guthold, Stevens, Riley, & Bull, 2018). Another study reported that worldwide, 31.1% of adults (15 years or older) are physically inactive, ranging from 17% in southeast Asia to 43% in America and the eastern Mediterranean. And around 80.3% of global adolescents (13 to 15 years old) are doing less than 60 minutes of physical activity of moderate to vigorous intensity per day, which is below WHO's recommendation for daily physical activity level among this age (Hallal et al., 2012). They also found that inactivity growths with age, higher in women than in men, and increased significantly in high-income countries. Figure 2-18 presented the distribution of physical inactivity in adults worldwide.

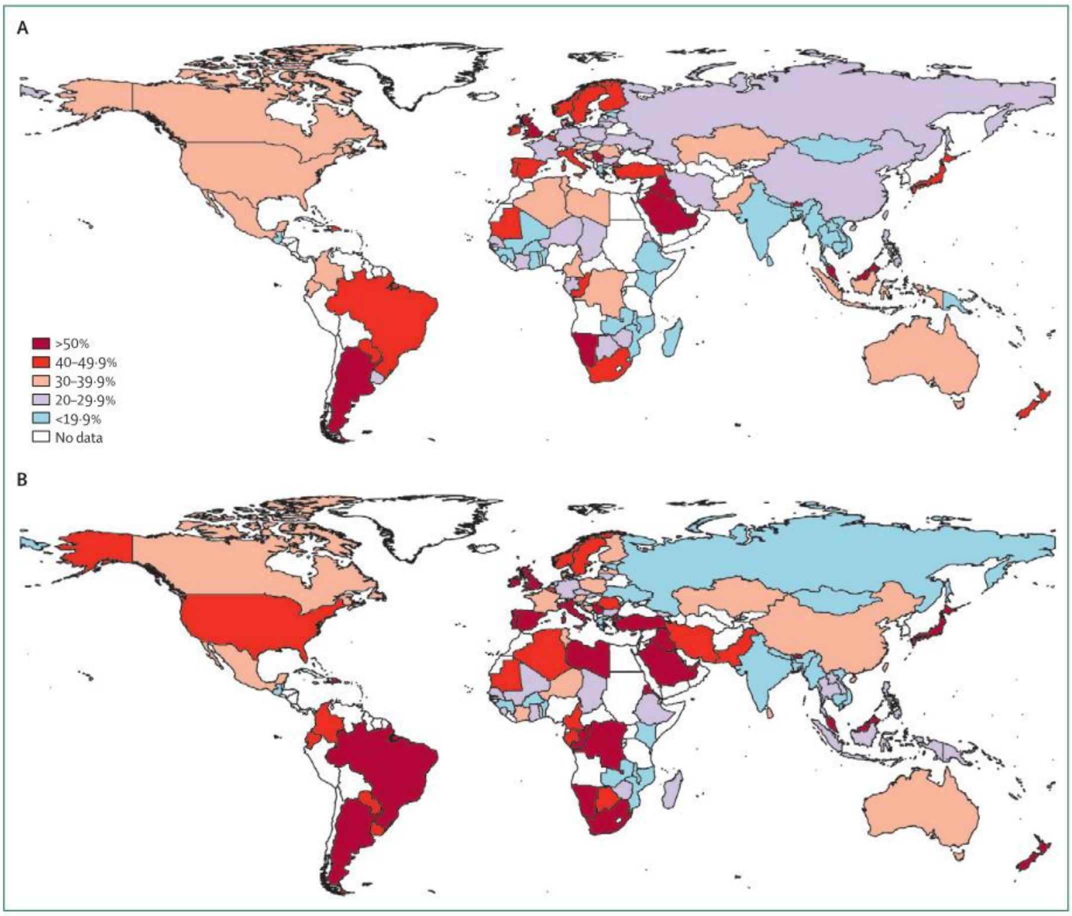

Figure 2-18: Global distribution of physical inactivity in adults (15 years or older) in men (A) and women (B) (Hallal et al., 2012)

In Europe, a survey on sport and physical activity was conducted in the 28 Member States of the European Union in 2013. The findings showed that 59% of EU citizens never or seldom did exercise or play sport. The highest percentage was seen in the older population, aged above 55. 71% and 70% of women and man never or seldom exercise or play sport, respectively. Although the European population is aware of the importance of physical activity to their health, lack of time is one of the main reasons why they could not do sport or exercise (European Commission, 2014).

The level of insufficient physical activity varied significantly across regions and income groups. The largest increase in insufficient physical activity has happened in high-income countries, while the largest decreases have occurred in East and Southeast Asia. This situation could be explained that in high-income countries, the shifting towards more sedentary occupations and individual motorised travel has caused a reduction in the level of physical activity. Whereas, in low-income nations, as work or transport still requires a large amount of physical activity. However, this situation is predicted to rapidly change in the future (Guthold et al., 2018).

- **Transport, physical activity, and health**

For decades, physical activity research has focused mainly on sports, leisure, and recreation activities. Although walking and cycling for transport have been a daily source of physical activity throughout human history, it has ignored in physical activity research until recently. This is a result of transport policies that have principally focused on the movement of motorised vehicles. The investment and policies promoting walking and cycling have been largely neglected (Sallis, 2016).

Those who spend a long travel time in cars may not have time for physical activities, which causes many adverse health effects, including overweight, obesity, and cardiovascular diseases. Some studies have found that people who use the car for daily commuting tended to gain more weight than those who did not commute by car (Sugiyama, Ding, & Owen, 2013a) (Sugiyama et al., 2016). A longitudinal study from Ellen Flint and colleagues investigated the change in commute mode and body-mass index(Flint, Webb, & Cummins, 2016a). In this study, active transports as walking and cycling were grouped with public transport and compared with car commuting. The study used body mass index (BMI) to examine the relationship between changes in commuting mode and changes in BMI over four years. The main results were that people who changed the commuting mode from active or public transport to car had a relative increase in BMI of 0.3 kg/m^2, and those who switched from car to active or public transport had a relative decrease in BMI of 0.3 kg/m^2. The study supported the argument that physical activity associated with the use of public transport, such as walking to and from transit stations, might play an essential role in preventing obesity. Policies that promote active travel to work, through encouraging walking, cycling, and public transport, could contribute to preventing obesity.

Promoting active transport (walking and cycling) and public transport is a potential way to improve physical activity since it could be easily integrated into people's busy schedules than other activities such as leisure-time exercise. Recently, walking and cycling are considered a promising method to contribute to overall physical activity, particularly in developed countries.

Most studies about the health impacts of active transport have originated predominantly from developed countries, including the United States, Australia, European countries, and New

Zealand. The findings showed that health benefits gained by increasing in PA levels through active transport exceed detrimental impacts of traffic incidents and exposure to air pollution (Mueller et al., 2015) (Götschi et al., 2015). A study conducted by Mueller et al. estimated the number of premature deaths that could be preventable under compliance with the international exposure recommendations for physical activities, air pollution, noise, heat, and access to green spaces in Barcelona, Spain (Mueller et al., 2017a). Nearly 20% of mortality could be avoided if international recommendations for doing physical activity, exposure to air pollution, noise and heat, and access to green space were met. The greatest portion of preventable deaths was attributable to the increase of PA, followed by reductions of exposure to air pollution, traffic noise, and heat.

- **Recommended levels of physical activity for health**

Recommendations on physical activity for health was proposed by WHO, based on the age of people. Children and young people aged 5–17 years old should accumulate at least 60 minutes of moderate- to vigorous-intensity physical activity daily. People from 18 to 64 years old should do at least 150 minutes of moderate-intensity aerobic physical activity throughout the week, or do at least 75 minutes of vigorous-intensity aerobic physical activity throughout the week, or an equivalent combination of moderate- and vigorous-intensity activity. And people from 65 years old and above should do at least 150 minutes of moderate-intensity aerobic physical activity throughout the week, or do at least 75 minutes of vigorous-intensity aerobic physical activity throughout the week, or an equivalent combination of moderate- and vigorous-intensity activity (WHO, 2010a).

The recommendations mentioned above are for the general population. However, the implementation should be adapted to individual health conditions and environmental conditions. For example, pregnant women, people with chronic health conditions, and people with disabilities should carefully select types of physical activities and level of physical activities that they could conduct. For these people, consulting with medical professionals and other related professionals is highly recommended. A person who changes from a sedentary lifestyle to an active lifestyle should gradually change their physical activity level that allows their body time to adapt to change. Environmental factors such as weather conditions, traffic, and locations for exercising should also be considered to ensure the safety and security for people.

Physical activity brings health benefits, but injuries and other adverse events sometimes happen, resulting in hesitation to be physically active in many people. For example, when people are doing too much physical activity, accidents or injuries may occur. However, scientific evidence strongly shows that physical activity could be safe for almost everyone, and its health benefits far outweigh the risks (The U.S. Department of Health and Human Services, 2018)

Based on the report of physical activity guidelines for Americans, some key definitions related to physical activity are presented as below (The U.S. Department of Health and Human Services, 2008)(The U.S. Department of Health and Human Services, 2018).

Physical activity is any bodily movement produced by the contraction of skeletal muscle that increases energy expenditure above a basal level.

Inactive is not getting any moderate- or vigorous-intensity physical activity beyond basic movement from daily life activities.

Insufficiently active is doing some moderate- or vigorous-intensity physical activity but less than 150 minutes of moderate-intensity physical activity a week or 75 minutes of vigorous-intensity physical activity or the equivalent combination. This level is less than the target range for meeting the key guidelines for adults.

Intensity refers to how much work is being performed or the magnitude of the effort required to perform an activity or exercise. Intensity could be expressed either in absolute or relative terms.

The absolute intensity of an activity is determined by the rate of work being performed and does not take into account the physiologic capacity of the individual. For aerobic activity, absolute intensity typically is expressed as the rate of energy expenditure (for example, millilitres per kilogram per minute of oxygen being consumed, kilocalories per minute, or METs) or, for some activities, simply as the speed of the activity (for example, walking at 3 miles an hour, jogging at 6 miles an hour), or physiologic response to the intensity (for example, heart rate). For resistance activity or exercise, intensity frequently is expressed as the amount of weight lifted or moved.

The relative intensity considers or adjusts for a person's exercise capacity. For aerobic exercise, the relative intensity is expressed as a percentage of a person's aerobic capacity (VO2max) or VO2 reserve, or as a percentage of a person's measured or estimated maximum heart rate (heart rate reserve). It also could be expressed as an index of how hard the person feels he or she is exercising (for example, a 0 to 10 scale).

The metabolic equivalent of the task (MET) is a unit commonly used to express the intensity of a physical activity. One MET is the rate of energy expenditure while sitting at rest, and is approximately 3.5 millilitres of oxygen consumed per kilogram of body weight per minute (mL/kg/min), representing the amount of oxygen used by the body at rest.

Moderate-intensity physical activity. On an absolute scale, physical activity is done at 3.0 to 5.9 times the intensity of rest. On a scale relative to an individual's personal capacity, moderate-intensity physical activity is usually a 5 or 6 on a scale of 0 to 10.

Vigorous-intensity physical activity. On an absolute scale, physical activity is done at 6.0 or more times the intensity of rest. On a scale relative to an individual's personal capacity, vigorous-intensity physical activity is usually a 7 or 8 on a scale of 0 to 10.

Accumulate. The concept of meeting a specific physical activity dose or goal by performing an activity in short bouts, then adding together the time spent during each of these bouts. For example, a goal of 30 minutes a day could be met by performing 3 bouts of 10 minutes each throughout the day.

Duration of an activity is the length of time in which an activity or exercise is performed and generally expressed in minutes.

Table 2-6: Examples of physical activity based on absolute intensity (The U.S. Department of Health and Human Services, 2018).

Moderate-intensity activities	Vigorous-Intensity Activities
▪ Walking briskly (2.5 miles per hour or faster) ▪ Recreational swimming ▪ Bicycling slower than 10 miles per hour on level terrain ▪ Tennis (doubles) ▪ Active forms of yoga (for example, Vinyasa or power yoga) ▪ Ballroom or line dancing ▪ General yard work and home repair work ▪ Exercise classes like water aerobics	▪ Jogging or running ▪ Tennis (singles) ▪ Vigorous dancing ▪ Bicycling faster than 10 miles per hour ▪ Jumping rope ▪ Heavy yard work (digging or shovelling, with heart rate increases) ▪ Hiking uphill or with a heavy backpack ▪ High-intensity interval training (HIIT) ▪ Exercise classes like vigorous step aerobics or kickboxing

- **Health benefits of physical activity:**

Regular physical activity provides many health benefits for participants. Overall, people of all ages could gain health benefits from physical activity. The major health benefits linked to physical activity is presented in table 2-7**.** Some benefits could be seen immediately, such as reduced feelings of anxiety, improved sleep quality, and reduced blood pressure. Other benefits such as increased muscle strength and increased cardiorespiratory fitness may need a longer time to be seen (The U.S. Department of Health and Human Services, 2018)

Table 2-7: Health benefits associated with regular physical activity (The U.S. Department of Health and Human Services, 2018)

<table>
<tr><th colspan="2">Children and Adolescents</th></tr>
<tr><td colspan="2">▪ Improved bone health (ages 3 through 17 years)
▪ Improved weight status (ages 3 through 17 years)
▪ Improved cardiorespiratory and muscular fitness (ages 6 through 17 years)
▪ Improved cardiometabolic health (ages 6 through 17 years)
▪ Improved cognition (ages 6 to 13 years)
▪ Reduced risk of depression (ages 6 to 13 years)</td></tr>
<tr><th colspan="2">Adults and Older Adults</th></tr>
<tr><td>▪ Lower risk of all-cause mortality
▪ Lower risk of cardiovascular disease mortality
▪ Lower risk of cardiovascular disease (including heart disease and stroke)
▪ Lower risk of hypertension
▪ Lower risk of type 2 diabetes
▪ Lower risk of adverse blood lipid profile</td><td>▪ Improved cognition
▪ Improved quality of life
▪ Reduced anxiety
▪ Reduced risk of depression
▪ Improved sleep
▪ Slowed or reduced weight gain
▪ Weight loss, particularly when combined with reduced calorie intake
▪ Prevention of weight regain following initial weight loss</td></tr>
</table>

▪ Lower risk of cancers of the bladder, breast, colon, endometrium, oesophagus, kidney, lung, and stomach ▪ Reduced risk of dementia (including Alzheimer's disease)	▪ Improved bone health ▪ Improved physical function ▪ Lower risk of falls (older adults) ▪ Lower risk of fall-related injuries (older adults)

2.4.2Cause-effect relationships

Physical activity generates immense health benefits, while physical inactivity and insufficient physical activity cause many adverse health effects. The physical activity generated during commuting or travelling for daily trips is considered a potential way to improve physical activity. However, the level of transport-related physical activity varies across countries. It is influenced by various factors that could be grouped into five main groups, infrastructures and policies, trip characteristics, cultural attitudes, weather and topography conditions, and surrounding environments.

Health effects of transport-related physical activity depend on the time spent on active travel, the intensity of physical activity, and the frequency of physical activity.

- **Transport infrastructures and policies**

A transport system could be designed as a facilitator or a barrier to encourage or discourage transport-related physical activity. A transport system that supports walking, cycling, and public transport could increase the level of transport-related physical activity by increasing the number of walking and cycling trips. A transport system that focuses on vehicles' movement results in increasing dependence on motorised vehicles and reducing walking and cycling trips. Providing convenient, safe, and connected walking and cycling network is the key to promoting active transport (ALR, 2016)(Panter, Heinen, Mackett, & Ogilvie, 2016). Major infrastructures for walking and cycling are cycling lanes, cycle paths, cycling parking, crossing, and sidewalks. Urban transport networks that are designed friendly for walking, cycling, and public transport, encourage more people to use these transport modes.

In addition, transport policies that limited private motorised transport uses (e.g., road pricing, parking restrictions, access restrictions) also facilitate commuting by active transport and public transport. These policies aim to make commuting by individual motorised vehicles more expensive and less convenient than active transport and public transport. Promotional activities such as user incentives, free travel by public transport, discount tickets, and free bicycle parking further increase active transport and public transport ridership. In addition, the health benefits of walking, cycling, and using public transport should be highlighted when promoting these transport modes.

- **Urban factors**

Urban factors include size, layout, land use, and urban density, which strongly affect the level of active transport and public transport usage. For example, the smaller the urban size is, the higher share of walking and cycling resulted from the short travel distance between home and destinations. The large cities may lead to longer travel distance as the separation between homes and destinations becomes large, encouraging people to use cars or public transport. Cities designed friendly for cycling, walking, and public transport are more likely to encourage people to travel by these transport modes. The diversity of land use in an area that allows people to easily walk or cycle to reach their daily destinations is strongly associated with cycling and walking in this area.

Further detailed information of interaction between transport mode use and urban factors could be referred to “Strategies for Integrated Transport and Urban Development in Asian Developing Countries” (Van, 2018). Although she focused mainly on Asian Developing Countries, the general interactions of transport mode use and urban factors are described in detail. Figure 2-19 shows the comprehensive interaction among urban factors, traffic management planning, and transport system developed by Van (2018).

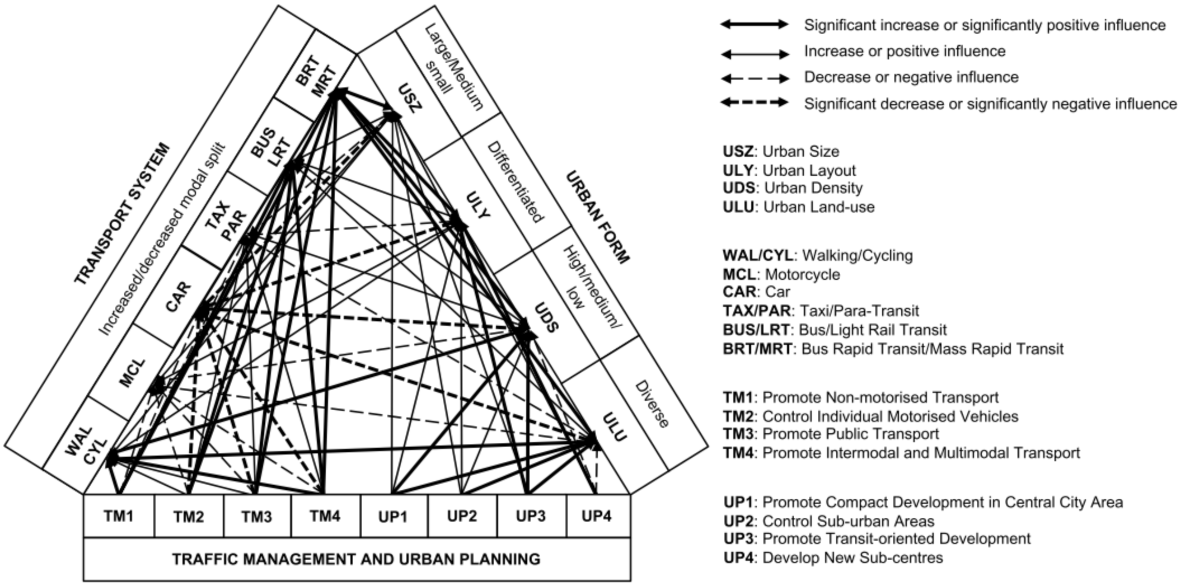

Figure 2-19: Comprehensive interactions among urban form, traffic management planning, and transport system (Van, 2018).

- **Traffic conditions**

Traffic conditions including traffic flow component, traffic flow speed, traffic volume, heavy vehicle, and speed limit affect walking and cycling significantly. For example, people may not cycle on streets with heavy traffic volume and the high share of heavy vehicles because of safety concern. Potential cyclists are more likely sensitive to traffic conditions than regular cyclists. If a person perceives that traffic conditions are not safe for cycling, they may not cycle. For example, Ghekiere et al. reported that parents are not letting their children cycle when they perceive traffic is not safe for them to cycle (Ghekiere et al., 2014).

Furthermore, exposure to high levels of air and noise pollution also discourage walking and cycling. Traffic conditions may affect cyclists’ travel behaviour as well. A study reported that cyclists cycled an average of 6.4% longer distances to avoid traffic impacts on accident risks and risk of exposure to high air and noise pollution (Gössling, Humpe, Litman, & Metzler, 2019). This, accidentally, brings further health benefits for cyclists due to increased physical activity level.

- **Attitudes and culture towards active transport and public transport**

People's attitudes and cultural factors affect transport-related physical activity. In developing countries, having a car is a means of showing its owner's social status, and people often tend to own a car when they could afford it. Using public transport, cycling, and walking are considered transport modes for the low social-economic population. In these countries, infrastructure for active travel is still largely missing, and public transport services are often at low quality. These conditions further reduce the uptake of active and public modes. To change people's perceptions towards active transport and public transport in these countries require significant improvements in providing a safe, convenient, affordable, and comprehensive network for these transport modes.

In developed countries, infrastructures for walking and cycling and the quality of public transport services are often much better than those in developing countries. But the ridership of these transport modes is still relatively low in many countries, strong car-dependent culture is one of the primary reasons for this situation. However, some countries such as Germany, Netherland, and Denmark have gained a significant increase in active and public transport ridership, resulting from a comprehensive approach limiting car uses and promoting cycling, walking, and public transport. The perception and attitudes of the population towards active and public transport in these countries are often good and positive compared to those in the other countries.

- **Trip characteristics**

Trip characteristics such as trip distance and trip purpose also influence transport mode use. Trips with short distance could be taken by bicycle or walking. For longer trips, using private motorised transport or public transport is more common. However, in some countries, using electric bicycles (e-bikes) is becoming popular. E-bikes that could cover longer travel distance trips could substitute for a large number of urban car trips. Different designs in e-bikes enable people to carry children, goods, and many other things with them, which increases the convenience for their users.

- **Weather and topography conditions**

Among different transport modes, active transport seems to be the most sensitive to weather and topography conditions. A study found that in dry, calm, sunny and warm, but not too hot, stimulated cycling over other transport modes resulting from more pleasant emotions during cycling (Böcker, Dijst, & Faber, 2016). However, in the winter season, rainy days, hot days, the number of cycling trips and walking trips may reduce significantly.

Topography also affects the levels of walking and cycling of a city. Cities that are hilly and have streets with steep gradients are more likely to discourage walking and cycling than flat cities. Cycling and walking in hilly cities require extra physical efforts that may not be feasible for the elderly, children, and people with physical limitations. In addition, very steep terrain is a deterrent for cyclists who did not have end-of-trip facilities (e.g., showers, changing rooms) at their destinations (Winters & Cooper, 2008).

Overall, a cause-effect relationship between transport-related physical activity and health could be summarised in figure 2-20. Physical inactivity and physical insufficiency strongly impact health, causing many adverse health effects. However, these adverse health impacts are preventable. Promoting cycling, walking, and using public transport is a promising approach to address this issue.

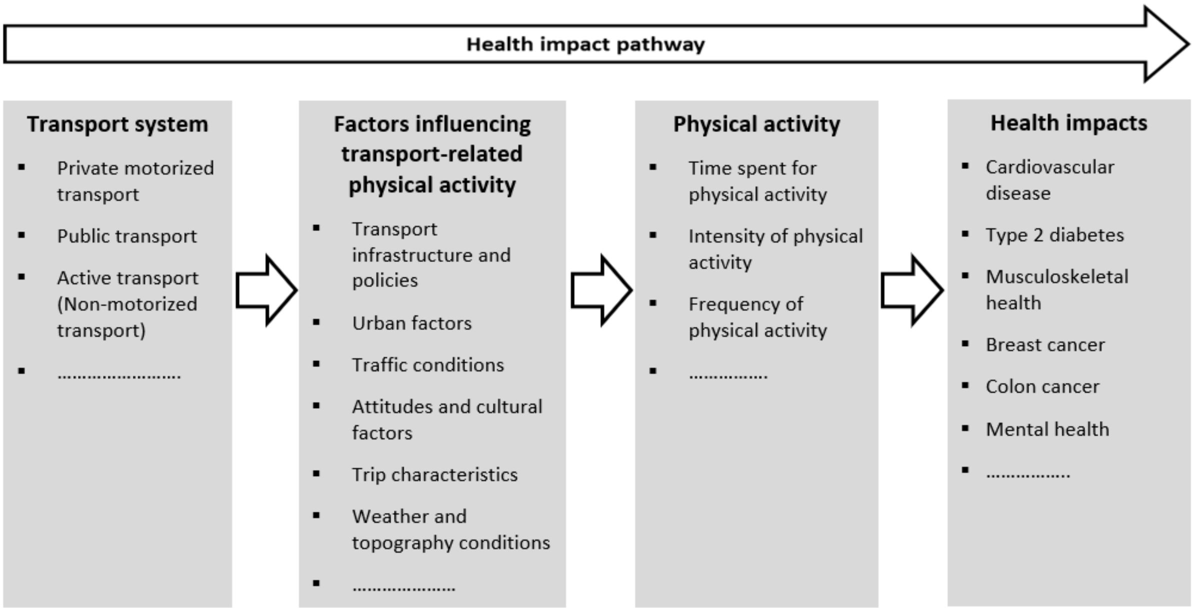

Figure 2-20: Health impact pathway between transport-related physical activity and health (Source: Author)

2.5 Accessibility

The greatest benefit of transport is providing accessibility to employment, education, food, goods, health care services, and a wide range of other services for people. Thus, transport should be accessible to everyone because people who are excluded from the transport system are excluded from the activities of daily life (Short, 1999). Healthy cities need to be inclusive and strive to ensure that people from all income groups have access to works, education, healthcare services, and other basic human needs (Carlos Dora, Jamie Hosking, Pierpaolo Mudu, 2011). However, historically, transport planning mainly focuses on the movement of motorised traffic. As a result, the accessibility for physically, economically and socially disadvantaged people (children, physical disability or who could not afford a motor vehicle) is limited. Focusing on the movement of private motorised vehicles also tends to exacerbate inequality and social exclusion (ITF, 2019a).

Transport has significant effects on both people's physical health and mental health. For example, it allows people to access health care services such as hospitals and medical professionals. Lack of transport connection could constrain people from accessing their basic needs, and that may threaten their lives. Additionally, transport allows people to connect and maintain their relationships with others, which is important for their mental health and well-being.

The term accessibility has been regularly misinterpreted or poorly defined. Accessibility is often used as a synonym for mobility, resulting in reinforce the policies that support the movement of motorised vehicles (El-Geneidy & Levinson, 2006). In fact, accessibility and mobility are different. Mobility is considered the physical movement of people and goods from one place to another measured by using indicators such as traffic speeds, level-of-service, and vehicle operating costs, which tends to favour private motorised transport over the other modes (Litman, 2019). Generally, transport planners and decision-makers have often focused on the mobility of private motorised transport, leading to many transport-related issues, including congestions, parking problems, traffic accidents, air pollution, and noise pollution. Accessibility is referred as "the ease of reaching destinations or activities rather than ease of travelling along the network itself" (El-Geneidy & Levinson, 2006). Therefore, accessibility is considered the ultimate goal of most transport planning systems, which place people at the centre of the transport system instead of private motorised vehicles (Litman, 2020). Figure 2-21 presents an example of a paradigm shift from the physical movement of vehicles to accessibility adapted in several countries.

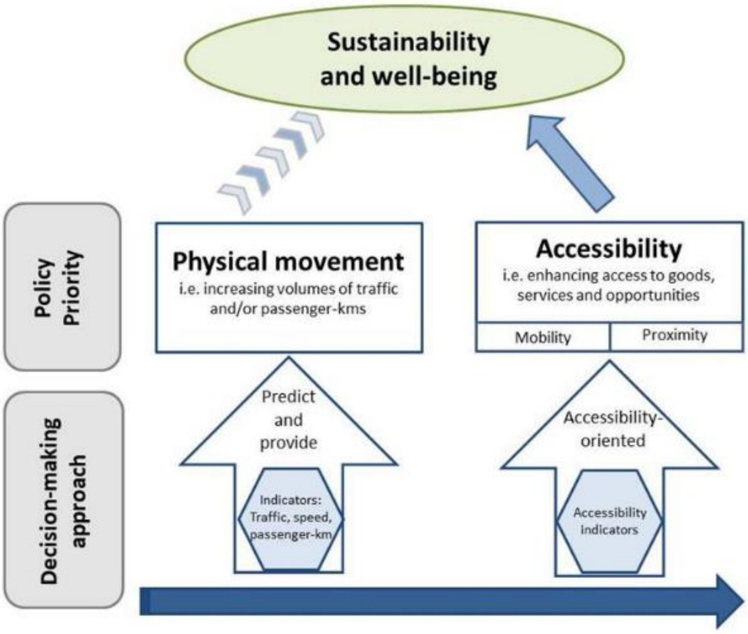

Figure 2-21: A paradigm shift from physical movement to accessibility (ITF, 2019a)

Factors influencing accessibility

A wide range of factors affects transport accessibility. Table 2-8 presents the list of factors that influence accessibility, how they are currently considered, and potential improvements for more comprehensive transport and land use planning. More detail of the impacts of these factors on accessibility could be found in the report "Evaluating Accessibility for Transport Planning: Measuring People's Ability to Reach Desired Goods and Activities" (Litman, 2020).

Table 2-8: List factors influencing accessibility (Litman, 2019)

Name	Description	Current Consideration	Improvements
Transport Demand	The amount of mobility and access people and businesses would choose.	Motorized travel demand is well measured, but non-motorized demand is not.	More comprehensive travel surveys, statistics and analysis of travel demands.
Mobility	Travel speed and distance.	Primarily evaluates motor vehicle traffic speeds and vehicle mileages traveled.	More comprehensive evaluation of mobility by other modes.
Transport Options (modes)	The quality (speed, convenience, comfort, safety, etc.) of transport options including walking, cycling, public transit, etc.	Motor vehicle travel speed and safety are usually considered, but other modes and other travel factors are often overlooked.	More multi-modal evaluation (speed, convenience, comfort, safety, etc. of walking, cycling, transit, etc.)
User information	Availability of reliable information on mobility and accessibility options.	Sometimes considered for particular modes or locations, but seldom comprehensive.	More comprehensive and integrated information to help users navigate transport systems.
Integration	The degree of integration among transport system links and modes.	Automobile transport is generally well integrated, but not connections between other modes.	More integrated planning to improve travelers' ability to connect between system components.
Affordability	The cost to users relative to their incomes.	Automobile operating costs and transit fares are usually considered.	More comprehensive evaluation of transport costs relative to users incomes.
Mobility Substitutes	Telecommunications and delivery services that substitute for physical travel.	Not usually considered in transport planning.	Consider mobility substitutes as part of the transport system.
Land Use Factors	Land use density and mix.	Usually considered in land use planning, but less in transport planning.	Measure how land use factors affect travel distances and costs.
Transport Network Connectivity	Density of road and path connections, and therefore the directness of travel between destinations.	Transport planning is starting to consider roadway connectivity impacts on accessibility.	Measure how roadway connectivity affects travel distances and costs.
Transport Management	How transport management affects accessibility.	Limited consideration.	Consider how various transport management strategies affect access.
Prioritization	Strategies that favor more efficient travel activity.	Limited consideration.	Consider transport prioritization strategies.
Inaccessibility	The value of inaccessibility and isolation.	Not generally considered in transport planning.	Recognize the value of sometimes limiting access.

2.6 Other health effects

2.6.1Climate change

Transport is a leading contributor to greenhouse gas emissions. For example, transport was responsible for nearly one-third of GHG emissions in the United States and Europe, 29% and 27% respectively (U.S Environmental Protection Agency, 2019) (European Environment Agency, 2018). Greenhouse gas emission causes climate change, which affects human health through a range of pathways.

The health impacts of climate change are presented in figure 2-22. Climate change could affect health directly through headways and other extreme weather events (such as flood, storm, and drought), or indirectly through the effects of climate change on ecosystems (e.g. water system, ecological change, and land-use change) (Watts, Adger, & Agnolucci, 2015). A changing climate leads to changes in the intensity, duration, frequency, spatial extent, and timing of extreme weather events, this could result in unprecedented extreme weather and climate events (IPCC, 2012). Health risks mediated by socioeconomic systems come from damage to infrastructure and health services, forced migration, reducing labour productivity (e.g. due to high temperatures), and conflict (Hobbhahn, Fears, Haines, & Meulen, 2019). The health effects of climate change come from a wide range of interconnected causes and consequences. For example, prolonged heatwaves might cause heat-related illnesses and deaths, and cause drought affecting food and nutrition security and wildfires resulting in air pollution (Hobbhahn et al., 2019).

Climate change may have some health benefits for some regions and people. For example, there are likely to be reductions in cold-related mortality and morbidity when the temperature increases. However, most of the recent assessment has determined that negative health impacts of climate change are greatly higher than its positive impacts. According to estimation from WHO, compared to a future without climate change, the following additional deaths are predicted for the year 2030: 95,000 deaths due to childhood undernutrition, 60,000 deaths due to malaria, 48,000 deaths due to diarrhoea, and 38,000 due to heat exposure in the elderly (WHO, 2014b). They also reported that low- and middle-income countries would suffer the greatest burden of climate change on health. By 2050, impacts of climate change on mortality are predicted to be the largest in South Asia.

Overall, the estimation of the impacts of climate change on human health is still facing many uncertainties and challenges. Despite these uncertainties and challenges, the impacts of climate change on health are projected to be significant. Under current situations, the impacts of climate change are increasingly recognised, and future trends represent an unacceptably high and potentially catastrophic risk to human health (Watts et al., 2015). Therefore, tackling climate change would bring the most remarkable human health benefits, which requires actions from both single individuals and the whole society.

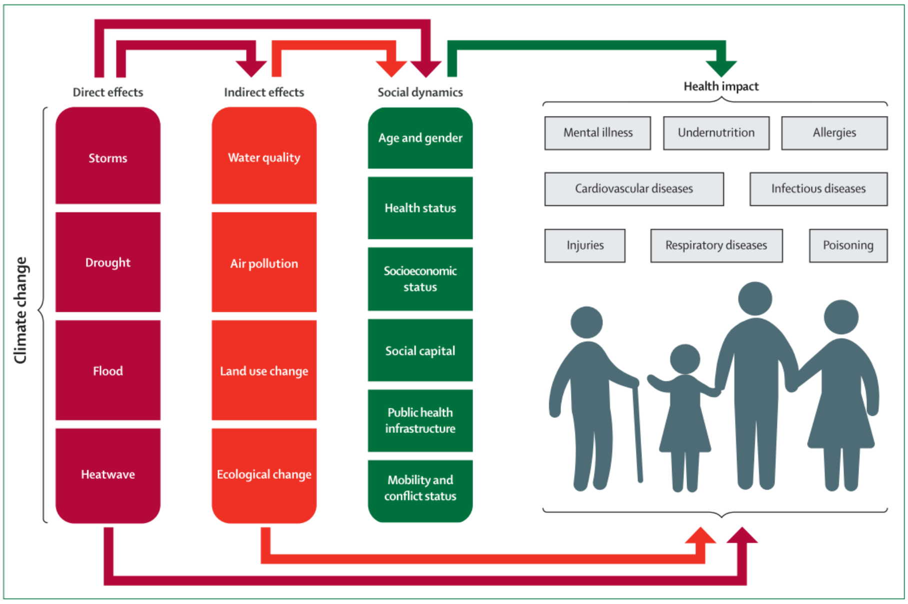

Figure 2-22: Health impact pathways of climate change (Watts et al., 2015)

2.6.2Land consumption

Land-use change is one of the considerable impacts of transport, affecting health in different ways. Historically, transport planning has been focused on the movement of vehicles, and a significant amount of space was devoted to roads and parking. The vehicle-oriented development causes an increase in the number of vehicles, which requires more space for road expansions and parking spaces. As a result, land area for other purposes such as parks, green space, public open spaces, and children playgrounds declines, which generates negative health impacts such as reduced physical activity and reduced social contact. The "vicious cycle" of car traffic, illustrated in figure 2-23, shows the interactions between traffic and land use patterns. The higher number of cars requires more land area for road and parking; the more land area for road and parking is, the higher number of cars is. Consequently, adverse health impacts of private motorised vehicles may never be addressed effectively.

Fortunately, land use planning together with transport planning that increases proximity and promotes active transport and public transport will generate notable health benefits through increased physical activity, reduced air pollution and noise from motorised transport, and saved land for green spaces, and improved social contacts (Dora & Hosking, 2011). Many studies concluded that more walkable neighbourhoods have better health and social outcomes. Residents in the "walkable" neighbourhoods are more connected to their neighbours, have higher levels of social capital. Better social networks and social capital are associated with better health (WHO, 2011).

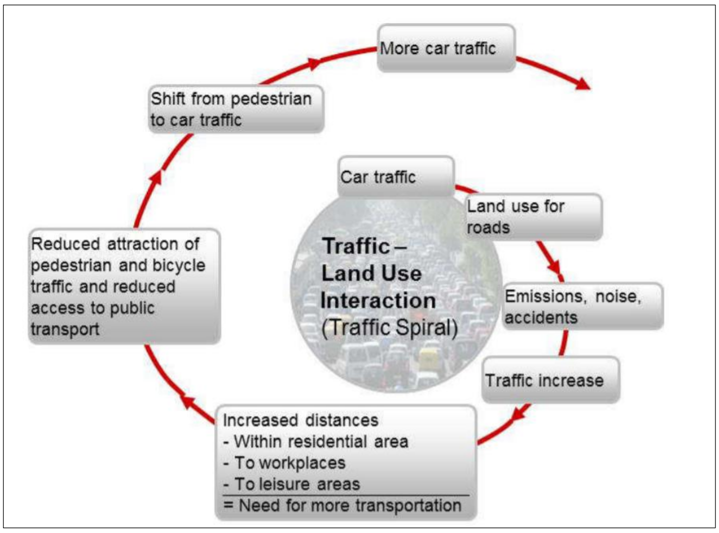

Figure 2-23: Traffic and land use interaction (Rudolf, 2004)

2.6.3Stress

Commuting is a crucial part of daily life for everyone, but it could also be a daily source of stress resulting in several adverse health effects. The commuting stress varies across different road users, mainly depending on their transport mode choices and traffic situations. The state of a driver's stress and their aggressive driving behaviours were generally greater in high-congestion conditions than in low-congestion conditions (Hennessy & Wiesenthal, 1999). In addition, if the drivers spend longer time standing in traffic (e.g., due to traffic congestion), they will have less time for other activities (e.g., sleeping, exercising), which cause many negative health effects such as physical inactivity. The study from Christian found that individuals with longer commutes are less engaged in health-related activities (Christian, 2012).

A study about the relationship between mode choice and commuting stress found that driving is the most stressful mode of transport compared to walking and using public transport (Legrain, Eluru, & El-Geneidy, 2015). They also confirm that commuting stress is produced by an interaction between objective stressors (e.g., time, control, and comfort) and subjective stressors (e.g., feelings, desires, and satisfaction); and stressors for some modes are not stressors for the others. For example, for pedestrians, travel time is not associated with stress. However, the feeling of unsafe from traffic is positively related to stress. Whereas for drivers, time is important, and long-time spending on traffic is strongly associated with stress. And for public transport users, delay, cancellation, and crowded may increase their stress during commuting time. Figure 2-24 illustrates an example of factors influencing commuting stress.

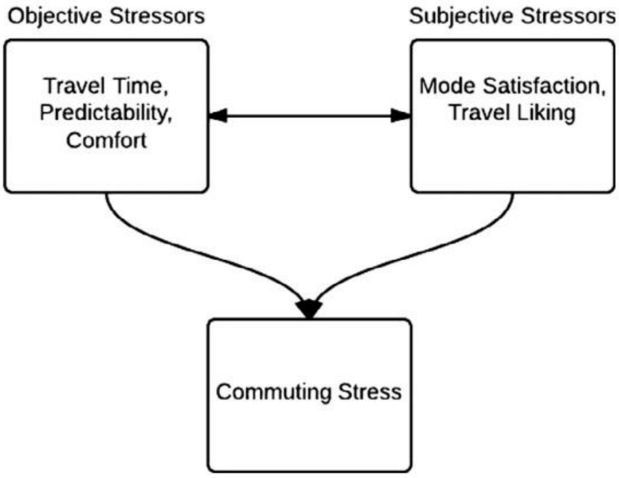

Figure 2-24: Factors contributing to commuting stress (Legrain et al., 2015)

2.6.4Community severance

Generally, community severance is used when transport infrastructure or motorised traffic acts as a physical or psychological barrier to the movement of pedestrians (Anciaes, Boniface, Dhanani, Mindell, & Groce, 2016). For example, multi-lane roads with physical barriers or streets with high motorised traffic volume and speeds may cause community severance by preventing pedestrians from crossing. The elements to define community severance are presented in figure 2-25.

“Transport-related community severance is the variable and cumulative negative impact of the presence of transport infrastructure or motorised traffic on the perceptions, behaviours, and wellbeing of people who use the surrounding areas or need to make trips along or across that infrastructure or traffic”(Anciaes, 2015). The “variable” and “cumulative” impacts of community severance vary with different needs, depending on age, gender, socio-economic status, and other characteristics. These impacts potentially reduce with the distance from the barriers (as the number of alternative destinations and routes increase) and with the time elapsed since the barrier was created (as people adapt their travel behaviours over time). It also highlighted that the impacts are for all users of the area, not only residents but also workers, shoppers, pedestrians and cyclists, motorcyclists, and car users.

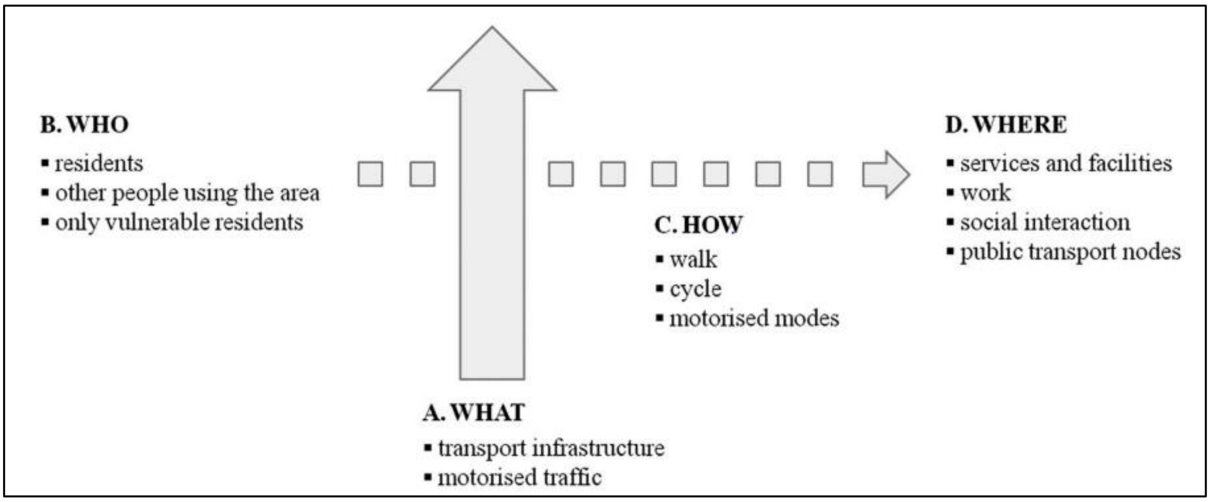

Figure 2-25: Elements to define community severance (Anciaes, Jones, & Mindell, 2016)

Community severance affects public health in different ways, including reduced number of trips, decreased travel independence (particularly for children and older people), reduced active travel, reduced social contacts (trips to visit family and friends, streets as social spaces), and increased social isolation traffic collisions. Figure 2-26 shows a theoretical model for the health effects of community severance that has been developed by Mindell & Karlsen (2012). Community severance may bring benefits for health in some positive perspectives. For example, if journeys are not made due to high motorised traffic volume, commuters will not be exposed to accident risks or high levels of exposure to air and noise pollution. However, accessibility and mobility are considered the basic needs of people; therefore, it should not be restrained. So far, the topic-related health impacts of community severance are still neglected by policymakers and researchers, which requires further studies on them (Anciaes, Jones, & Mindell, 2014).

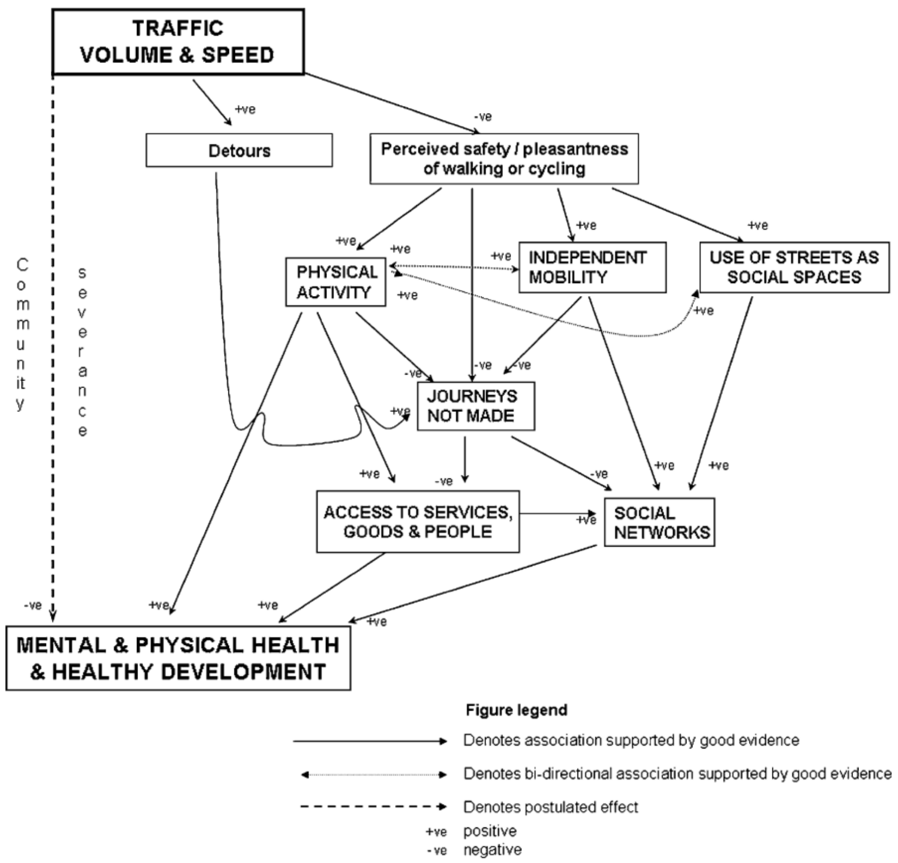

Figure 2-26: Theoretical model for health effects of community severance (J. S. Mindell & Karlsen, 2012)

2.6.5Security

The transport system design also affects the security of commuters, which affects their health as well. For example, the fear of theft when using public transport may discourage people from travelling by public transport. While walking or cycling to/from public transport stops/stations is a physical activity source providing benefits to passengers. In some countries, pickpockets and thefts when travelling by public transport happen quite often. Ngoc (2015) conducted an interview survey in Hanoi, asking bus users if they have met or observed pickpockets. The result showed that more than 60% of respondents have observed or been pocketed at bus stops and on buses (Ngoc, 2015). Ensuring passenger security is an important objective to encourage public transport use. For cyclists, security for their bicycles may be a big concern when deciding to use their bikes or not. Theft and vandalism at parking spaces may strongly discourage people to cycle.

2.6.6Exposure to ultraviolet (UV) radiation

UV radiation exposures may be higher during travel than in other activity. Some UV radiation is important to the body because it stimulates vitamin D production, which is essential for skeletal development, immune function, and blood cell formation. However, overexposure to UV radiation causes many adverse health effects such as skin diseases and eye diseases (Raja, Crane, & Dellavalle, 2009). Currently, studies about the health effects of exposure to UV radiation during travelling are still limited (De Nazelle et al., 2011).

2.7 Summary

In conclusion, the transport system poses significant impacts on health, both positively and negatively. The transport system generates health benefits by providing accessibility and transport-related physical activity. However, transport also causes tremendous adverse health effects. The primary sources of adverse health effects are traffic accidents, exposure to traffic-related noise air pollution and traffic-related noise pollution. In this chapter, the details of the situations on these major transport-related health impacts have been reviewed.

Regarding the health impacts of road traffic accidents, deaths and serious injuries remain a global health challenge. The magnitude of impacts varies across countries. The low- and middle-income countries suffer the greatest burden of health impacts. An accurate estimation for the numbers of people deaths and severe injuries due to road traffic accidents is difficult because of the lack of harmonized definitions, underreporting, and misreporting on road traffic deaths and level of injury severities. The health impacts of traffic accidents are not only for victims but also for their families and the whole society.

The health impacts of exposure to traffic-related air pollution are considered the second largest health impacts of transport. Vehicles emit a wide range of air pollutants, among which $PM_{2.5,}$ $PM_{10,}$ $NO_{x,}$ and O_3 are the most health-harmful pollutants. The primary health impacts of exposure to traffic-related air pollution include ischemic heart disease, strokes, lower respiratory infections, chronic obstructive pulmonary disease, and lung issues. In fact, it is difficult to precisely estimate the health impacts of exposure to traffic-related air pollution because people may expose to different emission sources. However, in urban areas, transport emission is the largest air pollution source, causing many adverse health effects. In many cities, air quality data is still largely unavailable by the lack of air monitoring stations, which generates further difficulties for estimating and monitoring the health impacts of exposure to traffic-related air pollution. So far, the studies on the health impacts of TRAP are mostly investigated in developed countries, while in developing countries, where the problems are expected to be more severe, studies about this topic were still limited.

Exposure to road traffic noise affects health negatively. Adverse health impacts include cardiovascular disease, cognitive impairment, sleep disturbance, annoyance, mental health and well-being, hearing impairment and tinnitus, and adverse birth outcomes. Among these health effects, sleep disturbance and annoyance are the most common and well-known health effects caused by exposure to traffic noise. The studies about the health impacts of exposure to road traffic are still limited and have gained very little attention in many countries, both for the general population and authorities.

Daily commuting by walking, cycling, and using public transport is a potential source of physical activity for people. Active travellers have proved better in both physical and mental health with a lower risk of obesity and a better body mass index than secondary travellers. Promoting active transport and public transport is a promising approach to address physical inactivity and physical insufficiency.

The cause-effect relationships have been developed for major transport-related health impacts. These cause-effect chains explain the health impact pathway of transport that helps the general population, transport planners, and decision-makers have a better general understanding. Notably, factors influencing transport-related health impacts have been described clearly in this chapter, providing meaningful knowledge for authorities, policymakers, and relevant stakeholders to develop interventions to mitigate negative health impacts and promote positive health impacts of transport.

The studies of other health impacts of transport such as climate change, land consumption, stress, community severance, security, exposure to UV radiation are still rare and require further studies. The health effects of transport are summarised in figure 2-27.

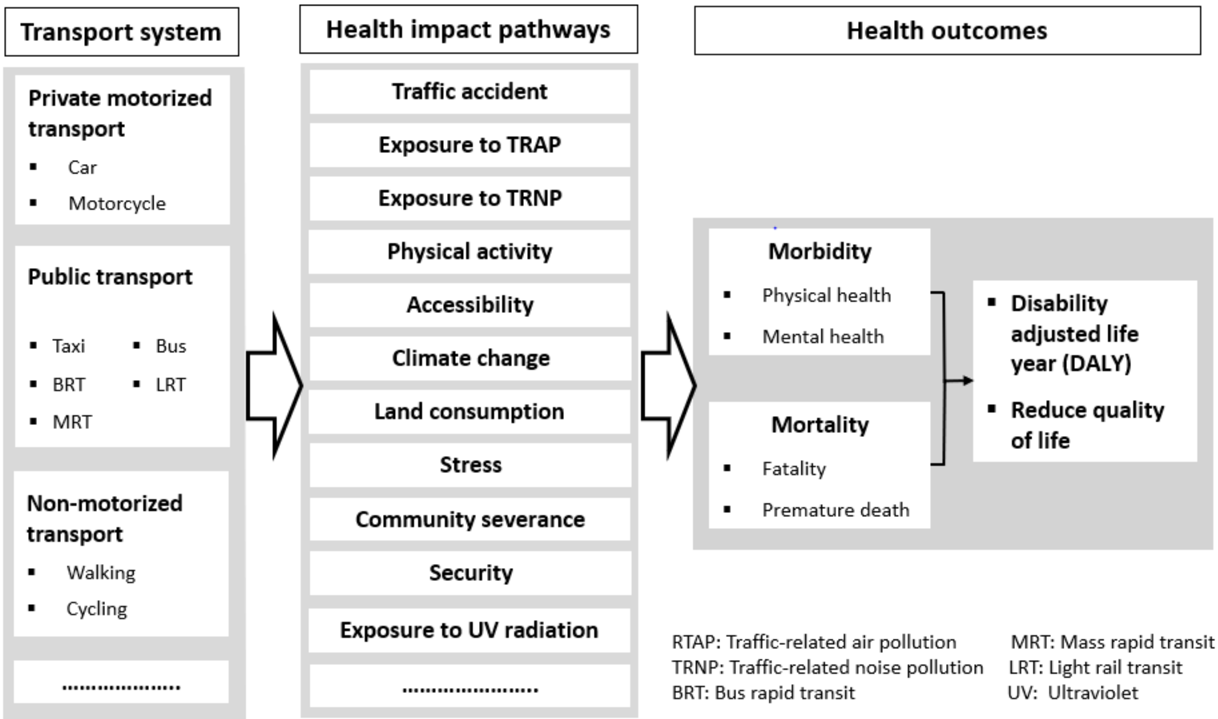

Figure 2-27: Summary of health impacts of transport (Source: Author)

3 Review of The Health Impacts of Different Transport Modes

The transport mode choice affects health in different ways, both positively and negatively. The main objective of this chapter is to investigate the association between transport mode use and its health impacts. The health impacts focus mainly on transport mode users; however, health impacts on other road users or/and the general population are also examined. In the first section, an introduction of transport modes in the urban transport system is presented, including new forms and modes of transport. In the following section, the impacts of transport mode use on health, including traffic accidents, exposure to traffic-related air pollution, exposure to traffic-related noise pollution, transport-related physical activity, and accessibility, will be reviewed and compared qualitatively. Finally, a short conclusion is presented.

3.1 Problems of insufficient traffic management

There are different ways to classify transport systems, an example of these classifications is presented in figure 3-1. Each transport system contains various transport modes and functions differently in providing mobility, accessibility, and traffic safety for users.

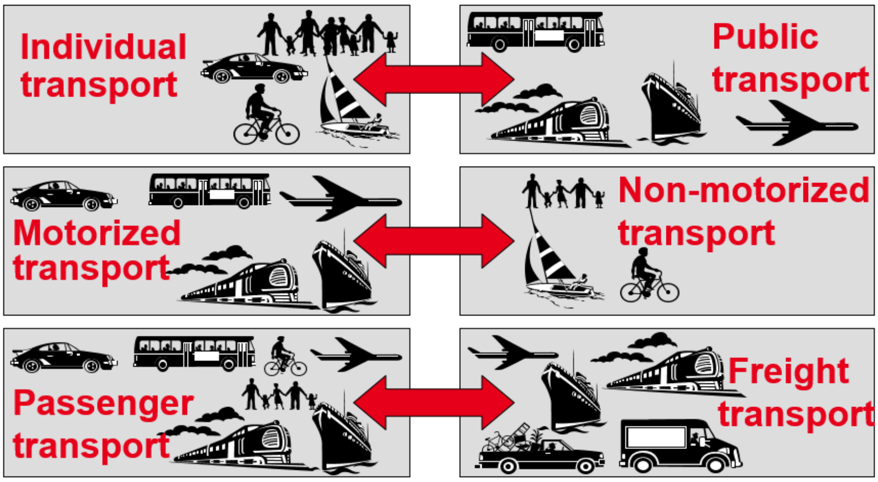

Figure 3-1: Classification of transport systems (source: Lecture from Boltze. M, 2013)

Regarding the passenger transport system, there are several transport modes providing accessibility and mobility for people. Basing on the people’s travel needs and the availability of transport supply (e.g., vehicles, information, multimodal facilities), people select the transport options that meet their travel demands. Classically, the urban passenger transport modes have been classified into three main groups: motorised transport, public transport, and non-motorised transport. However, the development of technology, the introduction of new vehicles, and innovations in and outside the transport sector are changing the urban transport system. Recently, new types of passenger transport have been introduced and become popular in the urban transport system in many countries such as shared transport and micro-mobility. Figure 3-2 presents the classification of transport modes in the urban transport system, including new travel options.

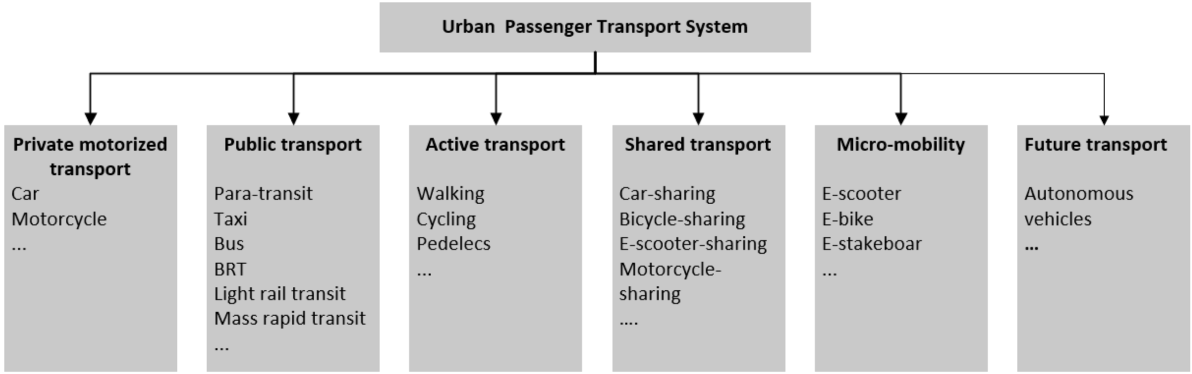

Figure 3-2: Classification of transport modes in the urban passenger transport system (Source: Author)

Shared mobility or shared transport is defined as the short-term access to shared vehicles based on users' needs and convenience instead of owning vehicles (Shaheen, Chan, Bansal, & Cohen, 2015). There are different forms of shared transport such as car-sharing, bike-sharing, ride-sharing, and on-demand ride services. The existing forms of shared mobility and its modalities are presented in figure 3-3 (Machado, Hue, Berssaneti, & Quintanilha, 2018). They also mentioned that shared mobility is changing the traditional transport sector, and it has the potential to improve efficiency, environmental quality, social equity, and quality of life in cities.

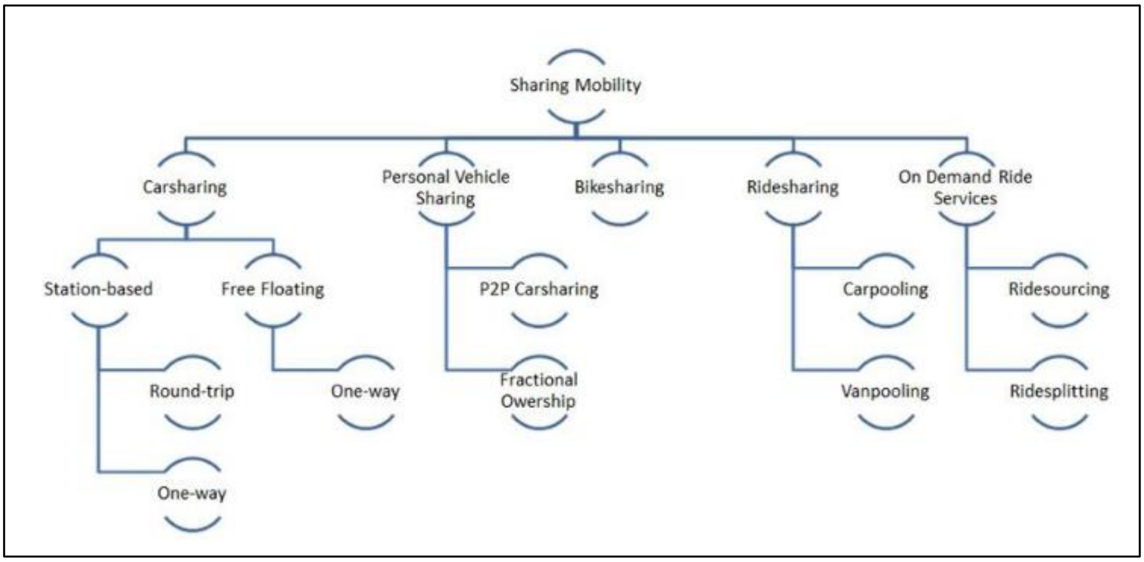

Figure 3-3: Shared mobility and its modalities (Machado et al., 2018)

Some new types of vehicles have been also introduced and operated in urban transport system including electric scooters, electric bicycles, and electric gyropods. These transport modes are classified as micro-mobility. The definition of micro-mobility was first introduced by (Dediu, Bruce, & Rubin, 2019) as "mobility that is enabled by a vehicle that weighs less than 500 kilograms". With the introduction of these micro-vehicles, micro-mobility services such as scooter-share schemes and dockless bike-sharing service have been introduced and become popular in many cities in the United States and in Europe. For example, e-scooter sharing programmes were firstly introduced in 2017, and now they exist in 129 cities in the United States, 30 in Europe, 7 in Asia, and 6 in Australia and New Zealand, and continue to expand in other cites (IEA, 2019). E-scooters have been promoted as well-suited for short-distance trips, solving the last-mile challenge problem. However, the popularity of e-scooters has been raising safety concerns, especially for pedestrians, as scooter riders often use sidewalks.

Furthermore, autonomous technology is developing rapidly, and the development of autonomous vehicles is also accelerating, which are referred as driverless vehicles or self-driving vehicles. Shared mobility, micro-mobility, electric vehicles, and autonomous driving are the major disruptive technologies that are predicted to change the transport system profoundly, representing a promising way to solve urban transport issues. However, these innovations may also create new problems such as data privacy and security (Bezai, Medjdoub, Al-Habaibeh, Chalal, & Fadli, 2020), (Shaheen, Cohen, & Zohdy, 2016), (ITF, 2019b). These disruptive innovations are changing quickly, and the public adoption of these changes is also increasing over time. To ensure the benefits of these changes, transport planners and decision-makers have to consider all potential effects of these disruptive technologies in their planning and decision-making process.

E-Gyropode (Source:urban-elec.com)

E-Scooter (Source: etsc.eu)

Figure 3-4: Example of e-scooter and e-Gyropode

In general, the urban transport system is changing continuously and is highly influenced by technology development. Therefore, the classification of transport modes in the urban passenger transport system is still confusing, overlapping, and changing. For example, taxi service can be classified as shared transport but also as public transport service in some countries.

In this study, the author focuses on the health effects of active transport modes (walking, traditional bicycle, and pedelecs), public transport modes (para-transit, buses, BTR, Light rail transit, mass rapid transit), and private motorised transport modes (cars and motorcycles). Taxi will not be considered public transport in this study because its health impacts are relatively similar to private car use. Commuter groups in this study are classified based on their transport mode uses, focusing mainly on active commuters (pedestrians and cyclists), private motorised transport users (car users and motorcycle users), and public transport commuters. To fully assess the health impacts of transport modes, it is highly recommended to consider the whole life cycle of transport modes, from the production phase to the end life of a vehicle. But, in this study, the author only focuses on the vehicles that are still operating on the road.

3.2 Traffic accidents

The number of road traffic accidents, injuries, and fatalities among road user groups varies considerably across regions, countries, and cities, depending on many factors such as transport modal shares, transport infrastructures, traffic regulations, travel behaviours, and demographic situations. In this section, firstly, the share of road fatalities by road user groups is briefly introduced. Secondly, the appropriate indicators for comparing the safety level across transport modes is discussed. Thirdly, the fatality risks and injury risks of transport modes on its users and other road users are reviewed. And finally, some safety concerns related to new types of vehicles (e-bikes and e-scooters) are also mentioned.

- **Distribution of road deaths by road user groups**

According to a global report on road safety from WHO, at the global scale, the shares of road traffic death between car occupants and 2-3 motorised wheelers are similar, 29% and 28%, respectively. Following is pedestrians with 23%, other road users 17%, and cyclists 3% (WHO, 2018b). However, when with regard to particular regions, there are significant differences that largely explain the transport system in each region. For example, in the European region, car commuting is dominant. Therefore, car users account for the largest share of road deaths. In South-East Asia, which has the highest ownership rate of motorised two- and three-wheelers and the lowest rate of car ownership, the users of two and three-wheelers constitute the largest number of road deaths. Figure 3-5 presents the distribution of road fatalities by road user types in different regions in 2018. It clearly shows that in all regions, the share of vulnerable road user groups (VRUs) (including pedestrians, cyclists, and motorcyclists) was high in the total number of fatalities, highlighting the importance to improve safety among these groups.

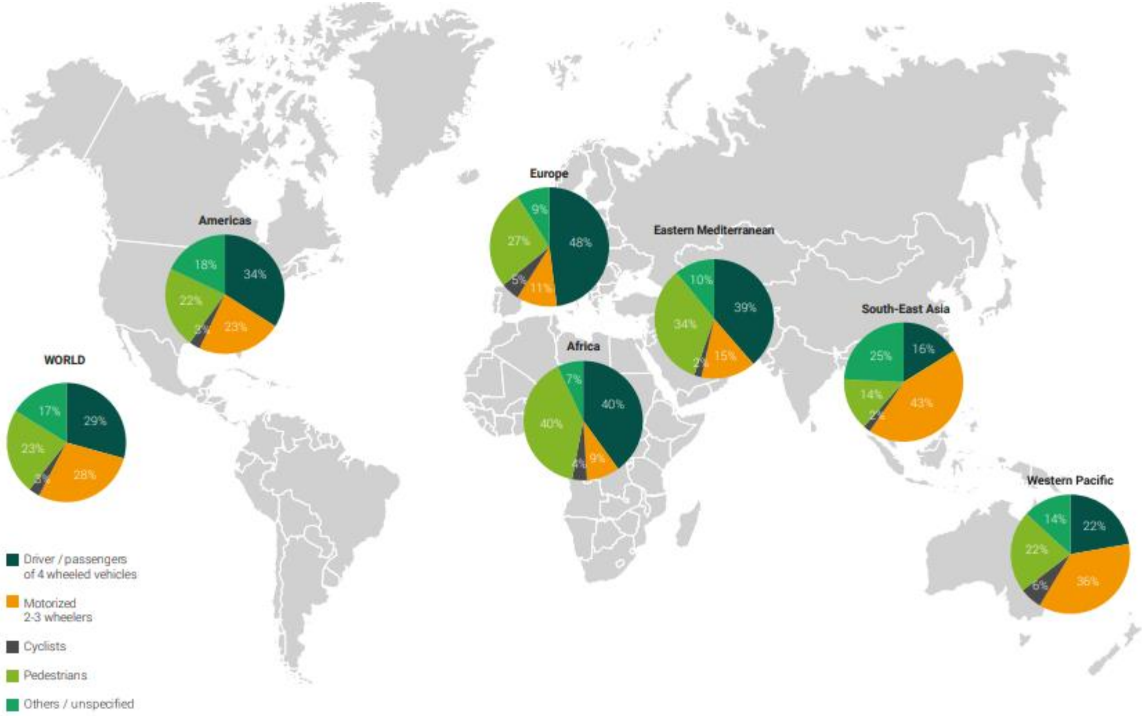

Figure 3-5: Distribution of deaths by types of road users by WHO region (WHO, 2018b)

The share of road deaths by road user groups in some countries is presented in figure 3-6, showing differences in the distribution of road fatalities in absolute number. The absolute numbers of road deaths and injuries are important indicators for monitoring safety trends and establishing safety targets. However, it is not suitable for comparing across countries or cities. For example, the share of bicycle fatalities in the Netherland is significantly higher than that in the United States. It does not mean that cycling in the United States is safer than cycling in Netherland. In reality, Netherland is one of the safest countries for cycling (Santacreu, 2018b).

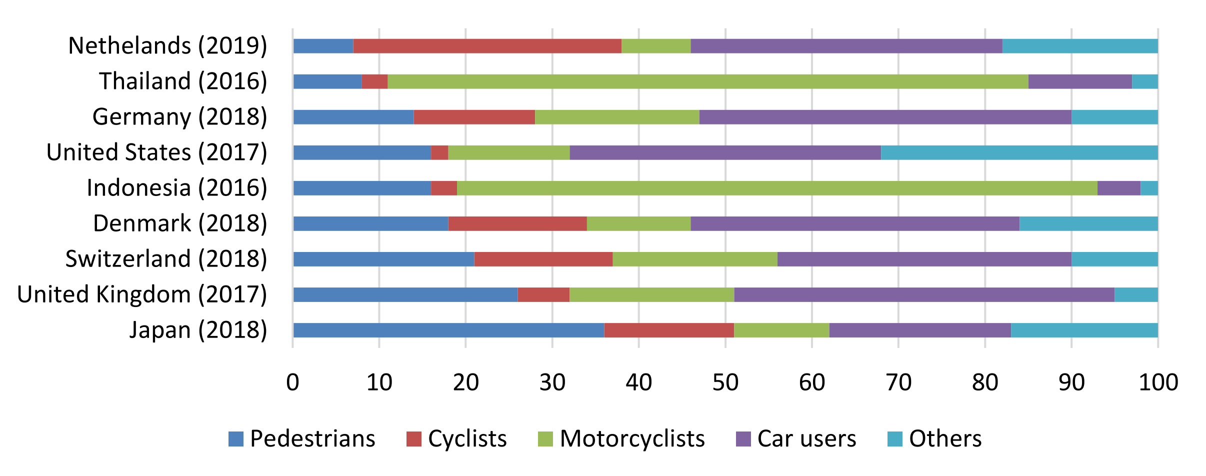

Figure 3-6: Road fatalities by road user groups in some countries (The Netherland (SWOV,2020); Thailand and Indonesia (WHO, 2018b); and others (ITF, 2020))

- **Indicators to compare safety level across transport modes**

To compare the safety level of different transport modes, the exposure levels should be taken into account. Regarding passenger transport, three exposure indicators have been found most relevant for comparison across all modes including passenger distance travelled, hours travelled, and the number of trips (Haddak, 2016) (ATSB, 2002)(Beck, Dellinger, & O'Neil, 2007). The fatality risk, injury risk, and accident risk (also called relatively safety rates) for each transport mode can be calculated by the numbers of fatalities, injuries, and accidents divided by the exposure indicators. The risk data make it possible to analyse road safety not only in terms of issues but also "risk level" and "probability" of occurrence of accidents, injuries, and fatalities (Thomas et al., 2009)**.**

In general, the number of fatalities for transport modes is recorded over time in many countries and available for use. The exposure data are limited because they are not recorded regularly and often require further effort to collect through travel surveys. Thus, the comparison of relatively safety risk between transport modes is difficult. Traditionally, the numbers of populations and/or the numbers of registered vehicles have often been used as the exposure indicators to compare safety levels across transport modes because of the availability of these data. These indicators have been widely used to compare safety level of various transport modes across cities and countries, providing a very coarse picture of the safety situation, but they could not reflect the real exposure to risks of road users (Hakkert & Braimaister, 2002).

- **Fatality risk and injury risk on road user groups**
  - **Fatality risks**

Based on the literature review, few studies compared the safety level among transport modes. For example, Haddak compared the road traffic fatality rates by various transport modes in France. The results showed that when exposure is taken into account, the fatality risk of motorised two-wheeler (MTW) users was greatly high compared to that of other road users. He reported that the risk of MTW users being killed was 20 to 32 times higher than that of car users. For cyclists, the risk of being died based on time spent travelling and the number of trips was 1.5 times higher than that for car users. For pedestrians, the risk was similar to car according to the time spent travelling, lower according to the number of trips, and higher according to the distance travelled. He estimated that the fatality rates per distance travelled unit for MTW users, cyclists, and pedestrians were 32, 6.4, and 11.6 times higher than those for car users, respectively (Haddak, 2016).

A study by Santacreu found similar trends in five European cities. With the same amount of travel distance, the risks of fatality for MTW users, cyclists, and pedestrians were 32, 7.8, and 10 times higher than that for car users, respectively (Santacreu, 2018b). Another study conducted in the United States to estimate the fatality rates per number of personal trips. The finding showed that the fatality rates per 100 million trips for motorcyclists, cyclists, and pedestrians were 58, 2.3 and 1.5 times higher than that for car users, respectively (Beck et al., 2007). The risks of fatality per unit distance travelled by mode in several cities are presented in figure 3-7. These fatality risks vary across cities that may be explained by the differences in transport mode share, road infrastructure, transport policies, and travel behaviours among these cities. In general, cycling and walking seem to be safer than driving MTW in most of the cities.

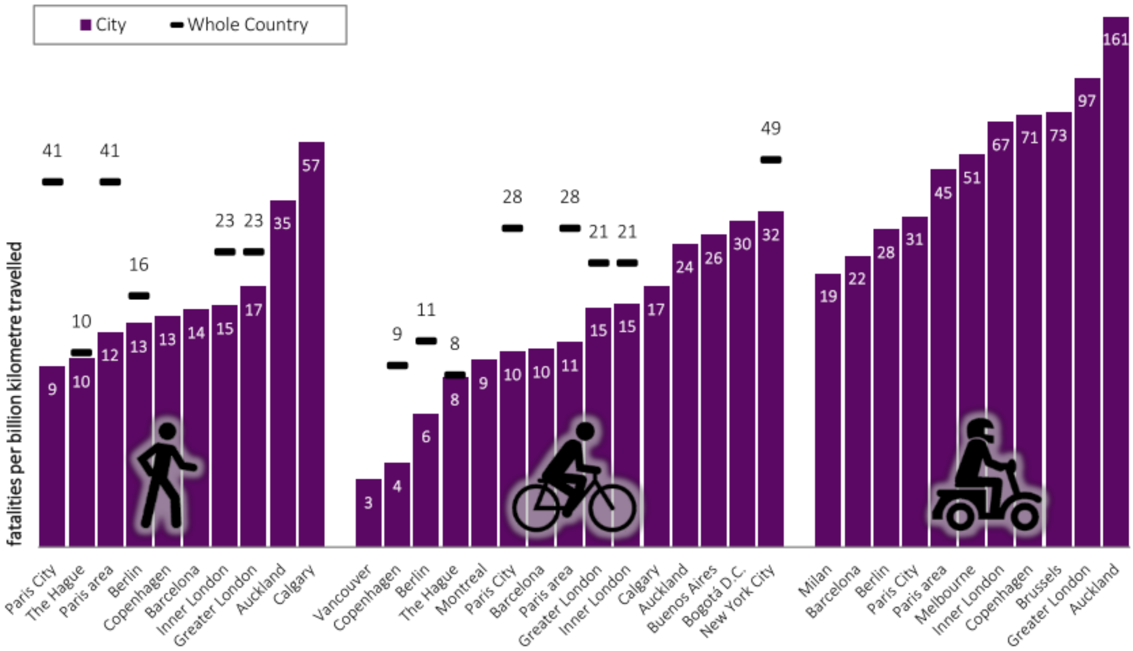

Figure 3-7: Risk of fatality per unit distance travelled, by mode, in cities and at country level 2011-2015 (Santacreu, 2018b)

Travelling by public transport has been seen as the safest transport option. Table 3-1 presents fatality risks across transport modes in five selected cities. In all five cities, travelling by MTW is the most dangerous mode, followed by walking and cycling. However, it is important to note that the fatality risk also varies within the road user group. For example, the fatality risk may be higher among older cyclists compared to other cyclists.

Table 3-1: Number of road deaths per billion passenger-kilometres, 2011-2015 (Santacreu, 2018b).

City	Bus	Passenger car	Pedal cycle	Pedestrian	Powered-2-wheeler
Auckland	0.4	1.9	24	35	161
Barcelona	0.0	0.7	10	14	22
Berlin	0.0	0.5	6	13	28
Greater London	0.2	1.4	15	17	97
Paris area	NA	1.4	11	12	45
Median	0.1	1.4	11	14	45

The studies comparing fatality risks among road user groups in developing countries are not found yet. However, fatality risks of pedestrians, cyclists, and motorcyclists are predicted significantly higher than those of car commuters in these countries. In many low-income countries, walking and cycling are the main transport modes for most of the population. However, the infrastructure for these transport modes such as safe sidewalks, bicycle lanes or bicycle paths is inadequate or largely missing. A study investigating the distribution of road traffic deaths by road user groups and income levels found that the share of pedestrian fatalities in low- and middle-income countries in the total road traffic deaths were 45% and 29%, respectively. In contrast, this figure was only 18% in high-income countries (Naci, Chisholm, & Baker, 2009).

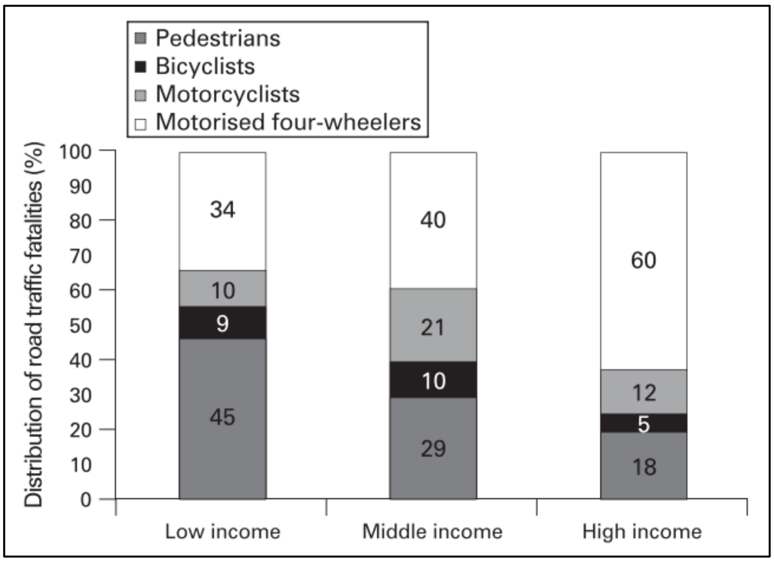

Figure 3-8: Distribution of road fatalities by road user groups (Naci et al., 2009)

Although studies comparing the fatality risks among road user groups are still limited, it is clear that motorcyclists have the highest risk of being died on the road; followed by pedestrians and cyclists. Unlike car users, these vulnerable road users are not or almost not protected from their vehicles. If an accident happens, they are more likely to be killed. Public transport is considered the safest travel option. The fatality risks vary greatly across commuter groups and cities, but also within a group. For example, older cyclists are more likely to be killed than younger cyclists due to the low reaction in accidents and their physical conditions. Usually, fatality rates and injury rates increase with age, or male drivers have higher death rates than female drivers across travel modes (Martínez-Ruiz et al., 2015).

- **Injury risk**

The literature review search found that very few studies compare the injury risk for different transport modes. One study conducted in France to compare the injury incidence rates of cyclist, pedestrians, car occupants, and motorised two-wheeler riders by using the data from the medical registry and mobility data showed that with the same hours of travelled, cyclists were 8 times more likely to be injured and 16 times more to be seriously injured compared to car users; PTW riders were 42 times more likely to be injured and 120 to be more seriously injured compared to car occupants; pedestrians were half as much likely to be injured but two times as much likely to be seriously injured compared to car users (Blaizot, Papon, Haddak, & Amoros, 2013).

Although the injury risk of different road user groups can be estimated by using the same exposure indicators as fatality risk, the data of injury and level of injury severity are not widely available as fatality. The leading causes are under-report problems and lack of a harmonised definition of injury severity. Therefore, quantitative comparisons of injury risks among various travel modes across cities and countries remain largely unknown. The study of injury risks among transport modes within a city or a country is also rare. However, the risk of being injured and seriously injured when walking, cycling, and using motorised-two wheelers considerably higher than travelling by car and public transport

- **Fatality risk and injury risk imposed on other road users**

The previous part presented the fatality risk among road user groups classified by their transport mode use. However, it is important to note that this fatality risk is only considered for its' user and that it does not accurately portray the impacts of driving on road traffic fatalities (Scholes, Wardlaw, Anciaes, Heydecker, & Mindell, 2018). For example, car commuters are highly protected from the risk of being killed in traffic accidents, but they may pose a significant risk to other road users, such as cyclists, who may be killed in accidents with cars. Some studies investigated the risk imposed by transport modes on other road users. For example, a study comparing the risk posed to other road users for six transport modes in England found that with the same distance travelled, buses and lorries pose a considerably high risk compared to others, while bicycles pose the lowest risk (Aldred, Johnson, Jackson, & Woodcock, 2020) . Their result is presented in table 3-2. Another study analysing fatality rates associated with driving and cycling for all road users in Great Britain showed that the fatality rate for cyclists was higher than that for car passengers, but the fatality rate to third-party road users showed the opposite (Scholes et al., 2018). These studies could reveal the high impacts of motorised vehicles on the overall number of road traffic deaths and indicate the road safety benefits of shifting towards active transport (Santacreu, 2018b) (Santacreu, 2018a).

Table 3-2: Estimating the risk imposed on other road users by different transport modes in England (Aldred et al., 2020)

	Fatal	Serious	Slight
Car/taxi	3.25	49.68	436.49
Van	2.59	25.66	217.89
Lorry	17.07	62.46	427.17
Motorcycle	7.63	100.10	613.83
Bus	19.18	144.72	973.84
Cycle	1.09	32.79	182.92

The injury risks of motorised transport modes imposed on the other road users are also estimated remarkable high compared to those of cycling or walking. An example of injury risk imposed on other road users can be seen in table 3-2. The bus is the safest transport mode for its passengers, but it is the most dangerous mode for other road users. Motorcycles are dangerous modes for its users and also for other road users. In contrast, bicycles are relatively unsafe for its users, but they are the safest mode for other road users.

- **Safety concerns related to electric-bikes (e-bikes) and electric scooters (e-scooters)**

Recently, e-bikes and e-scooters are becoming popular in many cities, and the number of accidents related to these types of vehicle are also increasing. Some studies compared the safety between electric bikes and conventional bikes, but the results were inconsistent. For example, Siman-Tov et al. found that there was lower casualty rate for e-bike users than traditional bike users; however, the e-bike riders were injured more severely, especially with head, face, neck and lower extremities injuries (Siman-Tov et al., 2018). Whereas, another study in the Netherlands found that e-bike riders were more likely to be involved in traffic accidents, but no difference of injury severity between two modes after controlling factors such as age, gender, amount of bicycle user (Schepers, Fishman, Den Hertog, Wolt, & Schwab, 2014). In Germany, a study found that when e-bike riders had an accident, they were more likely to be seriously injured or killed than cyclists, and when taken into account the age factor, the older riders involved in crashes with e-bikes were significantly more than pedal bicyclists (GDV, 2017). In Switzerland, it is recommended for further investigation before making any conclusion about the injury severity between e-bikers and bicyclists(Weber, Scaramuzza, & Schmitt, 2014).

Electric scooters are considered an effective option to solve first and last-mile travel problems, and travelling by this vehicle is increasing in many countries such as the United States and European countries due to the popularity of shared e-scooter services in these countries. Thus, questions related to e-scooter safety have arisen, and several studies have analysed the accident and injury patterns related to these vehicles. A study in Auckland (New Zealand) estimated that the injury rate for e-scooter users was 60 injuries per 100,000 trips, and the hospitalisation rate was 20 injuries per 100,000 trips. That has generated a considerable burden on primary care facilities and hospital in the city (Bekhit, Le Fevre, & Bergin, 2020). Another study in Salt Lake City (the United States) found a substantial increase in the number of injuries related to e-scooters after the e-scooter share service was launched in the city, with 8% was major head injuries and 36% was major musculoskeletal injuries (Badeau et al., 2019). Another study found that using e-scooters is associated with safety risks and incidence of injuries for pedestrians as scooter riders often use sidewalks. They also highlighted the importance of policy and regulation to ensure the safety of e-scooter riders and other road users (Sikka, Vila, Stratton, Ghassemi, & Pourmand, 2019).

These new types of vehicles have their own characteristics, but they currently use the same road infrastructure with formal vehicles. For example, e-scooter riders share sidewalks with pedestrians, and e-bikers share bicycle paths with normal bikers. In many cities, the regulations or policies for these new types of vehicles are still insufficient or missing. Furthermore, new types of vehicles or services such as autonomous vehicles may come soon, increasing safety concerns. Therefore, there is an urgent need to have comprehensive regulations, policy frameworks, and infrastructure interventions to integrate these new modes of transport in the urban transport system to maximise its benefits and minimise its drawbacks.

It is important to note that different people use different modes, with differences in ages, physical conditions, health issues, attitudes and travel behaviours, and travelling in different areas at different times for different purposes. These factors should be taken into account when analysing the safety of transport modes, which may provide insights for developing measures to improve the safety of different traveller groups.

3.3 Exposure to traffic-related air pollution

Among various population groups, commuters are considered the most affected by TRAP because of their proximity to traffic. They are directly exposed to vehicle emissions from their vehicles and also from other vehicles on the road.

This part aims to review the level of exposure to TRAP and its health impacts on commuter groups according to their transport mode uses. Firstly, the levels of exposure and inhaled doses of air pollution among transport modes are examined. The levels of exposure to air pollution vary greatly among commuter groups, affected by many factors. Thus, more detail of the effects of these factors on the level of exposure to TRAP among road user groups is presented. Thirdly, the health impacts associated to exposure to TRAP of road user groups are determined. Finally, the impacts of TRAP on the health of the other road users and the general population are discussed.

- **Level of exposure to TRAP of difference commuter groups**

Several systematic reviews were conducted to investigate the level of exposure to air pollution of different commuter groups. For example, Knibbs, Cole-Hunter and Morawska reviewed the commuter exposures to UFP and its health impacts across six transport modes, including cars, bicycles, buses, ferries, rail, and walking. They found that cyclists exposed to the lowest level of UFP, while those travelling by ferry and car through tunnels exposed to the highest level of UFP. Their results are presented in figure 3-9 (Knibbs, Cole-Hunter, & Morawska, 2011). The other study reviewed the levels of exposures to $PM_{2.5}$, BC, UFP, and CO in active and passive transport modes in European cities (de Nazelle, Bode, & Orjuela, 2017a). They found that pedestrians were the most consistently least exposed to these air pollutants across studies and car commuters tended to be the most exposed. Regarding $PM_{2.5}$, the result showed that cyclists, car occupants, and bus passengers were exposed to about 30%, 40%, 50% higher than pedestrians on average, respectively; the mean ratios between car users and pedestrians for BC, CO, and UFP were 2.9, 2.9, and 1.9, respectively. They also reported that air pollution concentration in transport microenvironments was from 40% to more than 4-fold higher than that in urban background sites.

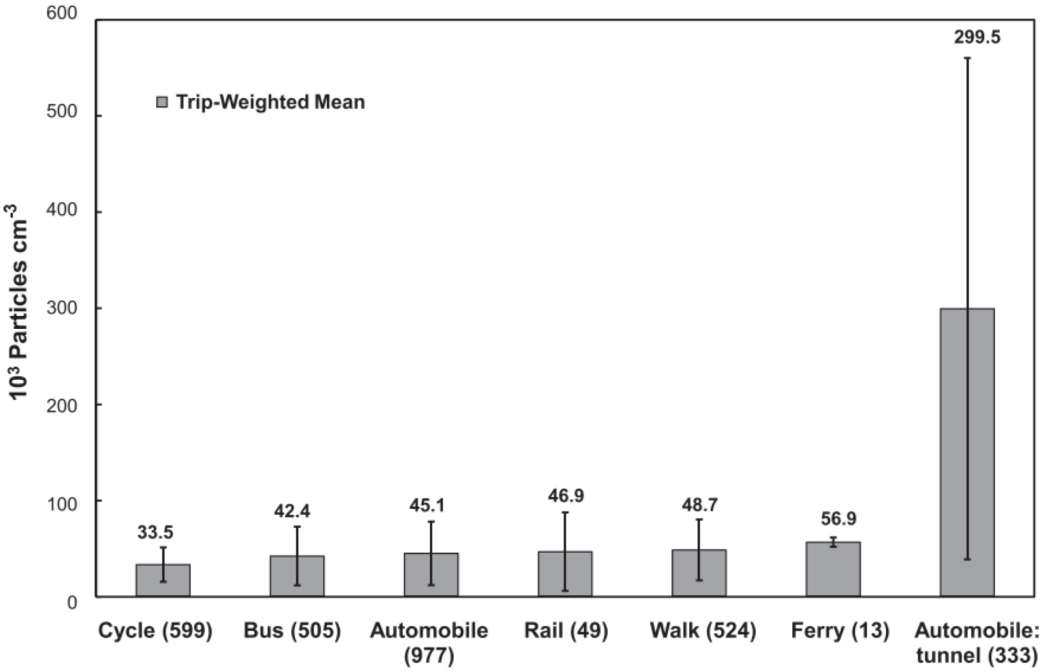

Figure 3-9: Trip-weighted mean UFP concentrations in each transport mode (bold numbers). Number of trips showed in brackets, error bars denote the trip-weighted standard deviation (Knibbs et al., 2011)

Another review by Cepeda et al. also found similar results that car and bus commuters had higher exposure to air pollution than active commuters (Cepeda et al., 2017) . However, when inhalation rates and commuting times were taken into account, the active commuters inhaled a considerably higher amount of air pollutants than other commuter groups because of increasing minute ventilation and trip time. They also calculated the ratio of exposure to pollutants with the ratio of an inhaled dose of pollutants between other transport modes and bicycles (presented in figure 3-10).

According to the results of these systematic reviews, it is evident that car commuters tend to expose to the higher levels of pollution than active commuters. Most of the studies included in these reviews were conducted in developed countries. In these countries, cyclists and pedestrians usually travel on their dedicated infrastructure such as bicycle lanes and sidewalks, which reduce their proximity to vehicular emissions, explaining the lower exposure to air pollutants of active commuters compared to car and motorcycle users (Knibbs et al., 2011), (Cepeda et al., 2017), (de Nazelle et al., 2017a) (de Nazelle et al., 2012) . This trend may be different in developing countries, where the infrastructure for cycling and walking is largely missing. Pedestrians and cyclists have forced to travel close to motorised traffic. Therefore, their levels of exposure to TRAP may significantly higher than that of car commuters. For example, a measurement survey in Ho Chi Minh City found that cyclists and pedestrians exposed to UFP are nearly 20 and 12 times higher than car commuters, respectively. The detail of this survey result will be presented in section 5.4.1 in chapter 5.

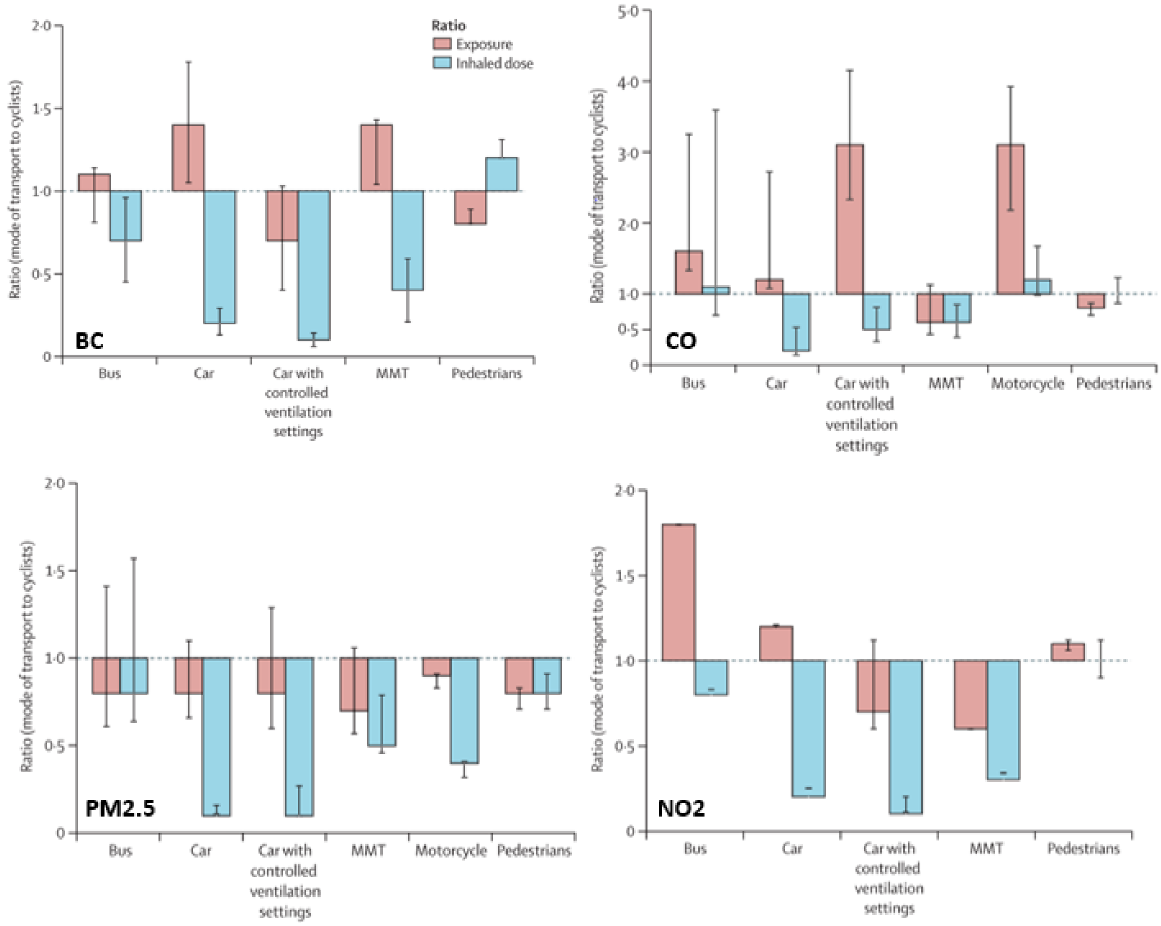

Figure 3-10: Comparison of the ratio of exposure to pollutants with the ratio of inhaled dose of pollutants according to mode of transport and pollutants to that of cyclists (MMT-Mass motorised transport) (Cepeda et al., 2017)

In general, levels of exposure to TRAP vary across transport modes. Active commuters may expose to higher or lower level of TRAP. But when breathing factors and journey time are taken into account, they inhale significantly higher level of air pollutants than other road user groups. Therefore, in terms of health impacts related to exposure to TRAP, pedestrians and cyclists are the most affected.

- **Factors influencing the levels of exposure to air pollution of different commuter groups.**

Transport mode choices affect individuals' exposure to air pollution significantly. However, the level of exposure to air pollution is also influenced by many other factors such as vehicle characteristics, driving behaviours, traffic conditions, street types, meteorological factors, and other local factors.

For this study, a review was carried out to compare the levels of $PM_{2.5}$, UFP, CO, and BC concentrations while commuting by different transport modes in different cities, which includes some recent studies in developing countries. The detailed information of these studies is shown in appendix A. It is important to note that the main purpose of the review is to show the general trend in the level of air pollution that commuters exposed in different areas of the world. For the comparing purpose, it is recommended to have a deeper look at each study because there are differences among studies (e.g., study designs, measuring devices).

Figure 3-11 presents the level of $PM_{2.5}$ concentrations while commuting by car, bus, bicycle, and walking in various cities. It clearly showed the high variation across transport modes and cities. For example, travelling by car in London exposed the lowest $PM_{2.5}$ concentration, while travelling by car in Lagos exposed the highest $PM_{2.5}$ concentration. That may associate with vehicle emission standards or the operation factors in these cities. Although there are few studies in developing cities, the existing evidence shows that commuters of all transport modes in these countries have exposed to considerably higher air pollution levels than those in developed countries.

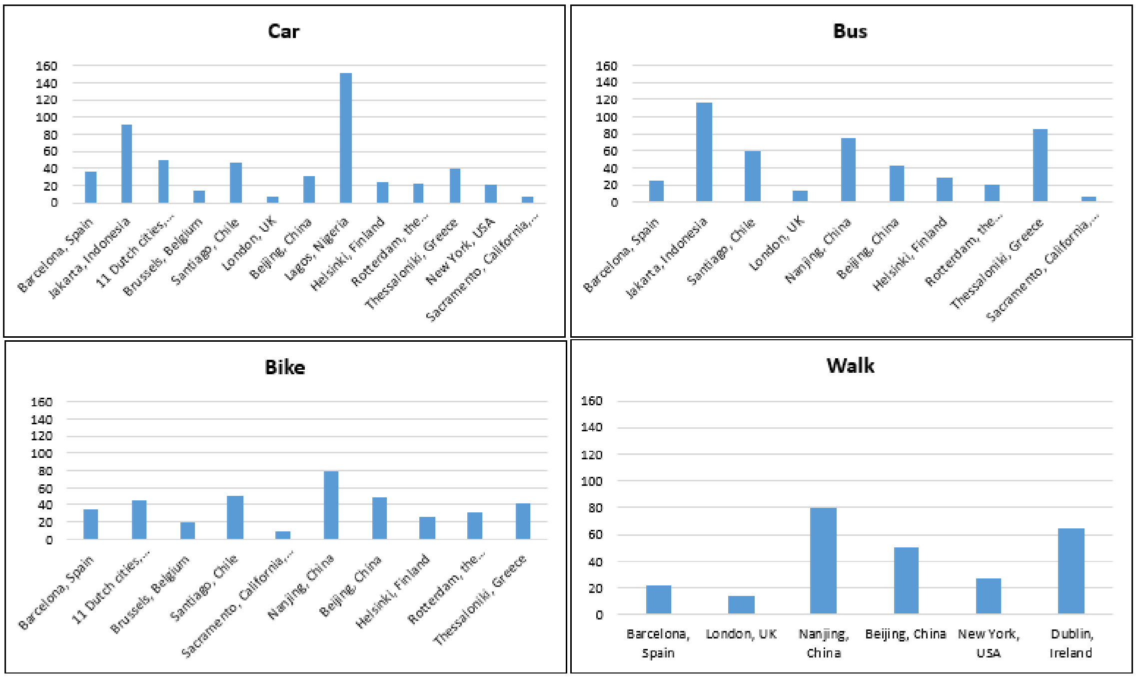

Figure 3-11: PM2.5 concentrations by transport modes in different cities (microgram/m3)
(The number collected by the author based on the literature review)

Many factors affect the exposure levels of commuters; however, their influences are different for different road user groups. For example, changing ventilation settings can significantly reduce the air pollution concentration inside cars, while travelling on the bicycle paths far away from traffic may help reduce the exposure levels of cyclists. Some highlights of these influencing factors on various road user groups are mentioned below.

- **Commuting by car**

For car users, the changes in vehicle air exchange rates (AER), which are a function of some parameters including driving speed, fan settings, cabin filter loading, vehicle make, vehicle age, and air conditioning (AC) ventilation conditions, can significantly influence the concentration of air pollutants inside vehicles such as PM2.5, BC and UFP (Hudda et al., 2012) , (Zhu, Eiguren-Fernandez, Hinds, & Miguel, 2007) (Ham, Vijayan, Schulte, & Herner, 2017). While there are many factors difficult to control (e.g. vehicle emission standards), the changing in-vehicle ventilation settings can be easily modified by commuters, which contributes to reducing the in-vehicle air pollutants concentration significantly. A study from Ham et al. evaluating three ventilation conditions, including windows fully open (WO), windows closed with the air conditioner on outside air mode (OA), and windows closed with the air conditioner on recirculate (RC) showed that depending on the quality of the air filter in-cabin, the in-vehicle air pollutants concentration of PM2.5, BC, and UFP can reduce to 15% to 75% below on-road air pollutant concentrations for OA and WO conditions, respectively (Ham et al., 2017) ,. A similar result is also reported in another study (Wu et al., 2013).

Regarding types of fuel, Zuurbier et al. compared the effect of fuel types on UFP concentrations in both diesel cars and gasoline cars, the result showed no significant differences in average levels of UPF concentration based on 14 simultaneous trips under standard ventilation settings (both types of car new) (Zuurbier et al., 2010). However, the relevance to the broader passenger vehicle fleet is unknown. And it is difficult to separate the effect of fuel type from those due to differences in ventilation under a standard-setting between vehicles of different manufacturers. Further investigation on this issue is recommended, which should include electric cars as they are predicted to increase in next coming years.

In general, there are many factors that commuters cannot or find difficult to control such as urban factors, traffic conditions, and weather conditions. Changing ventilation settings is a simple way that car users can do themself to reduce their exposure levels to air pollution.

- **Commuting by bus**

The level of exposure to air pollution of bus commuters varies greatly among studies mainly because of differences in vehicle' characteristics, traffic situations, and operating conditions. According to Targino, Rodrigues, Krecl, Cipoli, & Ribeiro, traffic volume (especially the number of heavy-duty diesel vehicles), self-pollution from bus exhaust, and the number of bus stops contributed highly to the level of BC concentration inside buses (Targino, Rodrigues, Krecl, Cipoli, & Ribeiro, 2018). Some factors related to buses such as age and type of fuel have strongly influenced the exposure levels of bus passengers. Travelling on diesel buses was found exposure a significantly higher level of air pollution compared to that on Compressed natural gas (CNG) buses and electric buses (Knibbs et al., 2011) (Zuurbier et al., 2010). The high level of air pollution concentration on buses was also found at bus stops (when bus doors are opened for boarding and alighting), which facilitates the infiltration of air pollution from outside into the bus (Targino et al., 2018) (Wu et al., 2013).

In addition to time spent on buses, bus commuters usually have to conduct short walking trips to/from bus stops and wait at bus stops, which may increase the average exposure levels to air pollution of the whole bus trips considerably. A study showed that the number of particle concentrations at bus stops was on average 3.5 times higher than that at the background level (Velasco & Tan, 2016).

- **Commuting by bicycle**

Route choices and travelling time are the factors most influencing the level of exposure to air pollution of cyclists. A study found that bicycle route choice can reduce the level of exposure to air pollutants by 15-75%, dedicated bicycle paths located away from traffic sources have the lowest level of concentrations (Ham et al., 2017) . They observed that a route with high automobile traffic had UFP concentrations three times higher than a bicycle path away from traffic. This study compared the air pollution concentration levels at three types of bicycle routes: a bicycle path located far away from the traffic source, a street with a dedicated bicycle lane, and a street with dedicated bicycle land located near highway. On the street with a dedicated bicycle lane, it was dominated by stop and go traffic, resulting in higher levels of incomplete combustion and increased brake dust emissions. A bicycle lane located near a highway is dominated by vehicles travelling at highway speeds, resulting in more complete combustion, increased UFP emissions, and dust. Another study also reported that cycling in bike boulevards decreased exposure concentrations by 31.5% for PM and 36.6% for UFP compared to traffic roadsides (Qiu, Wang, Zheng, & Lv, 2019). They determined the major pollution “hotspots” for cyclists, including passing ageing or diesel vehicles, cycling through intersections and past bus stops, cycling through a heavy-traffic street canyon. Another study from Luengo-Oroz and Reis also presented similar results. They also found that designing bicycle boxes located next to the traffic lights at intersections can reduce a large amount of UFP exposure for cyclists (Luengo-Oroz & Reis, 2019). Therefore, travelling on bicycle paths, bicycle lanes, or on less traffic roads may reduce the level of exposure to air pollution of cyclists substantially.

Many countries are encouraging people to cycle by providing more cycling infrastructures and facilities. Therefore, it is important to understand how these infrastructures influence cyclists' exposure to air pollution to provide better protection against air pollution for cyclists. This could increase the health benefits of cycling as it increases in the physical activity level and reduces the negative health effects of exposure to air pollution.

- **Pedestrians**

Like cyclists, pedestrians walking on the roads with less traffic or far away from the main traffic flow have greatly reduced their exposure to air pollution from traffic sources (Luo, Boriboonsomsin, & Barth, 2018). Many studies found that pedestrians were exposed to lower level of air pollution compared to other road users such as cyclists and car occupants (de Nazelle, Bode, & Orjuela, 2017b), (Ragettli et al., 2013) (Dons, Int Panis, Van Poppel, Theunis, & Wets, 2012). The main reason is that pedestrians are using sidewalks, which increase their distance to traffic. These studies were mainly in European cities, where the sidewalks for pedestrians are widely provided and primarily used for walking. However, in other countries like Vietnam, the sidewalks are often occupied for parking, business purposes, and residential purposes, forcing pedestrians to walk on the roads. Furthermore, cooking and selling food on the sidewalks are popular in Vietnam. Street vendors often use charcoal or gas for their cooking. These issues increase the level of exposure to air pollution of pedestrian considerably.

The walking position of pedestrians on the sidewalk may also strongly affect the exposure levels of pedestrians. A study reported that walking close to traffic (e.g., kerbside) can double the average exposure of pedestrians compared with walking close to the buildings (Buonanno, Fuoco, & Stabile, 2011). The other factors such as temperatures, wind speeds and wind directions, time of the day, traffic flows, and street geometry are also found highly influence the exposures of pedestrians; however, these factors also affect the other road users (Buonanno et al., 2011) (Boarnet et al., 2011) (Ragettli et al., 2013).

- **Health impacts of exposure to air pollution of different commuter groups**

Time spent in the traffic microenvironment contributes greatly to total daily air pollution exposure of a person that causes harmful health effects. Although several studies have compared the levels of exposure to TRAP among transport modes, studies comparing the health impacts of exposure to air pollution among different road user groups are still limited.

Based on the literature review, only some studies investigated the health impacts of exposure to air pollution of active commuters. For example, Strak et al. reported that short-term exposure to ultrafine particles and soot contributed to increasing airway inflammation and reducing lung function of cyclists 6 hours after exposure (Strak et al., 2010). However, they also highlighted that their study had a very small sample size, and further examination should be conducted. Another study examining the health effects of active commuters' exposure to TRAP in Stockholm (Sweden) showed that 23% of the annual inhaled dose of NO2 of active commuters was from commuting, which increased the risk of premature death among active commuters by 2.5% (Engström & Forsberg, 2019). Although active travellers have experienced negative health impacts through exposure to air pollution, they also gain health benefits by increasing the physical activity level. That triggers the question, "do health benefits of active commuting exceed the risks?".

Some studies examined the health benefits of shifting from cars to bicycles. For example, de Hartog, Boogaard, Nijland, and Hoek estimated the health effects of people shifting from short-car trips to bicycles in the Netherlands. They found that the health benefits to an individual who shifts from cars to bicycles were considerably higher than the risks (de Hartog, Boogaard, Nijland, & Hoek, 2010). The health effects were expressed by life-year gained or lost. A person who shifted from car to bicycle was estimated to gain 3 to 14 months due to increased physical activity, lost 0.8 to 40 days because of exposure to air pollution, and lost 5 to 9 days because of traffic accidents. Together with other societal benefits such as reducing air pollution, greenhouse gas emissions, and traffic accidents, the benefits of changing transport mode from cars to bicycles in the Netherland were substantially higher than the risks. Studies in Brazil and Sweden also reported that the health benefits of shifting from cars to walking and cycling were higher than health risks both for active commuters and the general population (Haines et al., 2017) (Almström et al., 2017).

A systematic review about the health impact assessment of active transport found that the health benefit-risk or benefit-cost ratios of shifting toward active modes ranged between 2 and 360 (median value is 9). Most health benefits were gained from increased physical activity level, which exceeded the health risks from accidents and air pollution (Mueller et al., 2015) . However, it should be noted that most of the existing studies have been carried out in developed cities where the air pollution levels are relatively low compared to those in developing cities.

This situation raises the question, **"Are the health benefits of physical activity still over its negative health impacts of exposure to a very high level of air pollution for people who shift from cars to active transport modes in highly polluted cities?".**

Some studies have been carried out to answer this question. For example, Tainio et al. identified two thresholds to compare health benefits from physical activity and health risks from exposure to air pollution including "tipping point" and "break-even point" (Tainio et al., 2016). Their definition of tipping point is "at this point an incremental increase in active travel will no longer lead to an increase in health benefits" and definition of break-even point is "increase active travel from this point, the risk from air pollution starts outweighing the benefits of physical activity". Their results of tipping points and break-even points for cycling and walking are presented in figure 3-12. In general, they concluded that the health risks of air pollution would not exceed the health benefits of active travel in the majority of cities. Even when in the areas with high ambient PM2.5 concentrations (100 μg/m^3), the risk would only exceed benefits after 90 minutes of cycling and 600 minutes of walking per day. Recently, a study examining the long-term impacts of restricting cycling and walking during high air pollution days in six cities (Helsinki, London, Sao Paulo, Warsaw, Beijing, New Delhi) also found that the benefits of everyday active commuting exceed the risks of exposure to air pollution, even in highly polluted cities (e.g., Beijing, New Delhi) and also on days with $PM_{2.5}$ concentrations below 150 μg/m^3 (Giallouros, Kouis, Papatheodorou, Woodcock, & Tainio, 2020). Another study analysing the effects of outdoor physical exercise and air pollution exposure showed that a person who did outdoor exercise had a lower risk of developing cardiovascular and metabolic diseases despite the greatest O_3 exposure (Marmett, Carvalho, Dorneles, Nunes, & Rhoden, 2020). Jarjour et al. investigated the links of cyclist route choice, level of exposure to air pollution, and lung function among healthy adults. People travelled on two routes, a low-traffic route and a high-traffic route, air pollutants were measured during cycling time, and lung functions were measured before and after each bike ride. They found that $PM_{2.5}$, UFP, CO, and BC were significantly high on the high-traffic volume. However, there were no corresponding changes in the lung function of cyclists (Jarjour et al., 2013).

Overall, the existing evidence supports the idea that the health benefits of active travel through physical activity exceed its adverse effects caused by air pollution.

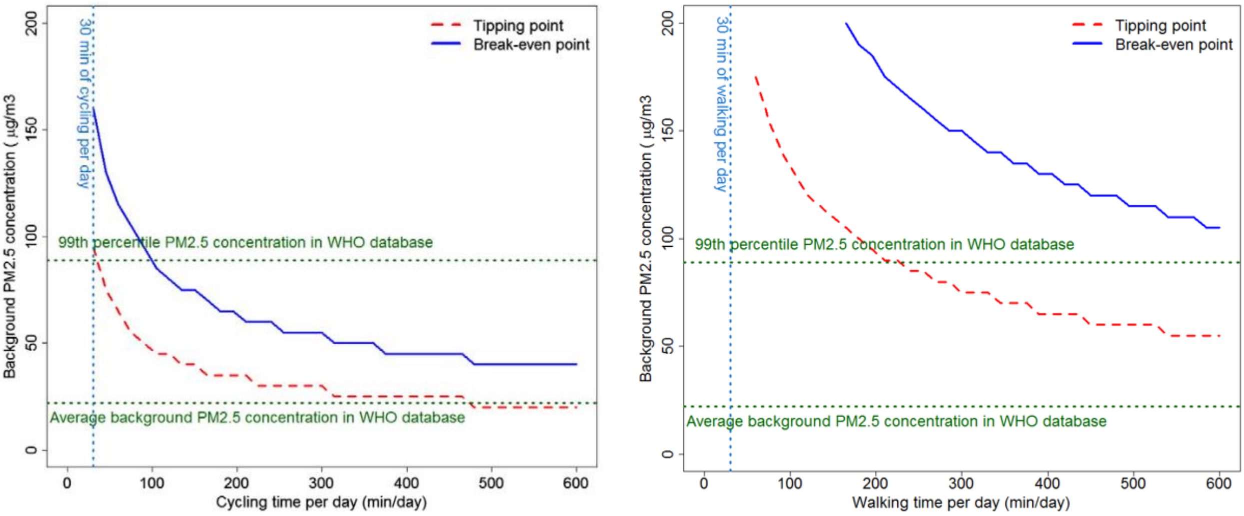

Figure 3-12: Tipping point and break-even point for different level of cycling and walking (Tainio et al., 2016)

- **The risk imposed on other road users and the general population**

Vehicle emissions immediately disperse into the atmosphere after being emitted, which affects the health of vehicle users, other road users, and the general population. It is difficult to rank which vehicles the least polluted because of differences in vehicles' characteristics and operating conditions. However, it is clear that in terms of risk imposed on other road users and the general population due to emissions from vehicles, private motorised transport is responsible for the greatest contribution. Walking and cycling generate almost no risk at all.

Overall, based on existing evidence, the levels of exposure to TRAP of active commuters may be higher or lower than motorised transport travelers. However, when considering the respiratory minute ventilation and journey time, the inhaled dose of active commuters has been significantly higher than in non-active modes. Therefore, in terms of health impacts from exposure to air pollution only, pedestrians and cyclists are the most affected. However, if health benefits of increased physical activity level are taken into account, substantial evidence supports that active commuting's health benefits outweigh its negative impacts. The health effects of exposure to TRAP on public transport commuters and motorised vehicle users vary greatly, depending on vehicle characteristics, operation conditions, traffic situation and many other factors.

3.4 Exposure to traffic-related noise pollution

This section aims to review the level of noise exposure of various commuter groups. Then, the impacts of exposure to road traffic noise on health of commuters and the others are presented.

- **Noise exposure level of different commuter groups**

The reviewing result showed that studies that measured or/and compared noise exposures among traveller groups are still limited, and most studies are from developed countries. A study compared the noise exposure of commuters while travelling by bicycle, bus, and car in three European cities (Helsinki, Rotterdam, Thessaloniki). On average, the level of noise exposure of these transport mode ranged from 67 to 75 dB(A). In all three cities, cyclists were exposed to higher noise level than bus passengers and car occupants (Okokon et al., 2017a). This result was relatively similar to a study in 11 Dutch cities with noise levels during cycling varied between 63 to 66 dB(A) (Boogaard, Borgman, Kamminga, & Hoek, 2009). In Montreal (Canada), cyclists exposed to slightly higher noise level, with an average noise level was 70.5 dB(A), ranged between 54.6 and 87.6 dB(A) (Apparicio, Carrier, Gelb, Séguin, & Kingham, 2016). Authors reported that type of roads and bicycle paths or lanes have significant impacts on their exposure to noise pollution. The closer cyclists travelled to traffic or main streets, the higher noise exposure levels were. The level of cyclist protection from road traffic noise based on cycling infrastructure in this city is presented in figure 3-13.

Another study in Ho Chi Minh City, Vietnam found that cyclists exposed to the relatively high noise level at an average of 78.5 dB(A) (Jeremy & Apparicio, 2019). In Ho Chi Minh city, the infrastructures and facilities for cycling are not provided. Cyclists have travelled on the same infrastructure for motorised transport, explaining why cyclists exposed to high noise levels. In addition, the habit of using horn while commuting also contributes to increased road traffic noise in this city. A study that measured daily noise levels at roadsides in this city found that for all monitoring sides, the daily average noise level (LAeq, day) was higher than 69 dB(A) (Phan, Yano, Sato, & Nishimura, 2010). They also reported that horn sounds contributed up to 4 dB(A) on the noise level in this city compared to the traffic condition without horn sounds. The similar situation was also reported in cities in India. Horn sounds increased noise level between 0.5 and 13 dB(A) in heterogeneous traffic conditions than homogenous traffic conditions (Kalaiselvi & Ramachandraiah, 2016). They explained that differences in vehicle types (speeds, sizes, operating characteristics), together with ignoring traffic rules, honking become inevitable in heterogeneous traffic flows.

Figure 3-13: Types of bicycle paths and bike lanes in Montreal, Canada (Apparicio et al., 2016)

A study in China measuring noise levels when commuting by car, bus, subway, and shared bike reported that travelling by car exposed the lowest noise level (62.3 dB(A) in the summer and 64.3 dB(A) in the winter while travelling by subway exposed the highest noise level (76.1 dB(A) in summer, and 75.5 dB(A) in winter) (Y. Liu et al., 2019). On average, noise levels in all four transport modes exceeded 60 dB(A) and taking a bus or subway resulted in higher noise levels. A similar trend was found in Toronto (Canada). People who travelled by subways and buses exposed to higher noise levels than those travelled by car, with average noise levels on subways, buses, and cars were 79.8 dB(A), 78.1 dB(A), and 71.5 dB(A), respectively (Yao, Ma, Cushing, & Lin, 2017). This study also reported that subway passengers were frequently exposed to peak noise events up to 125 dB(A) both inside vehicles and at the transit stations, raising concerns for noise-induced hearing loss. Another study measuring noise level during travelling by underground train in London showed that the average noise level was consistently above 80 dB(A) and sometimes reached over 100 dB(A) (Singh et al., 2020).

Overall, the existing evidence showed that cyclists are exposed to higher noise level compared to car users and bus passengers. People who travel by subway and underground transit are often exposed to high-frequency peak noise levels compared to other modes. There is great variation in the levels of exposure to noise pollution among commuter groups across cities. For cyclists, noise exposure levels are strongly affected by route choices. For car commuters, the type of vehicle engines and vehicle operations seem to be most affected.

- **Health impacts of exposure to road traffic noise of different commuter groups**

Health impacts of exposure to road traffic noise already mentioned in section 2.3 in chapter 2. In general, exposure to road traffic noise has been found associated with many adverse health outcomes including cardiovascular diseases, cognitive impairment, sleep disturbance, annoyance, mental health problems, and hearing impairment. An example of the health impacts of exposure to road traffic noise in European countries is presented in figure 3-14.

Unlike the health effects of exposure to TRAP, the quantitative study that examined the health impacts of exposure to road traffic noise for different road user groups is not available yet. The publications related to this issue have been not found from the literature search. However, it is clear that commuters who expose to higher noise level are more likely to be associated with more adverse health outcomes. Further studies on this issue are required to investigate the association between transport mode uses, noise exposure level, and its health consequences of understanding the problems and providing practical solutions.

Figure 3-14: Health impacts of noise pollution in Europe (EEA, 2016b)

- **Noise risk imposed on other road users and the general population**

Private motorised vehicles are responsible for most of the road traffic noises in urban areas, which largely affect the health of other road user groups and the general population. In contrast, cyclists and pedestrians are considered the quietest commuters both for commuters and other commuters and the general population. But they are more likely most affected by road traffic noise.

Based on available evidence, car occupants may be exposed to the lowest noise level during their commuting time. People who travel by subways or underground transits have exposed to more frequent peak noise levels than other commuters. Pedestrians, cyclists, and motorcyclists travelling close to traffic have exposed to higher noise level than car commuters. The study examined the health consequences of exposure to road traffic noise for different road user groups is very limited, and further studies on this issue are highly recommended.

3.5 Transport-related physical activity

Recently, transport related-physical activity is gaining great attention and is considered a potential way to improve the level of physical activity in many countries. Many studies concluded that personal transport mode choice is associated with their physical activity level and health status. This part aims to review the association between transport mode use, transport-related physical activity level, and their health impacts on different commuter groups. Firstly, the relationship between commuting modes and their contribution to the level of physical activity is reviewed. the contribution of using e-bikes on the physical activity level of the e-bikers is also described. Thirdly, the linkage of transport-related physical activity and body mass index among various commuter groups is examined. Then, the other health benefits linked to transport-related physical activity are also reviewed. And finally, the importance of active commuting to school in preventing obesity and overweight among school children are described.

- **Transport-related physical activity of different commuter groups**

Methods to measure physical activity generated by commuting are varying. It can be collected by self-report questionnaires or directly measured by using GPS, accelerometers, and pedometers (Sener, Lee, & Elgart, 2016). Regardless of what methods were used, the results from the literature review found a general agreement that people who walk or cycle for their daily commuting have a higher level of physical activity and more likely to meet the physical recommendation level than those travelled with motorised vehicles.

A study examined the levels of physical activity and transport mode use among the adult working population in the United Kingdom (Batista Ferrer, Cooper, & Audrey, 2018). Their results showed that people who walk or use public transport to work were more likely to meet the recommendation level for physical activity than those travelled by car. They reported that in overall, the daily accumulated minutes of moderate to vigorous physical activity of walkers and public transport commuters were 71.3 and 59.5 minutes, respectively, and car users were only 46.3 minutes. In which commuting contributed to 34.3, 25.7, and 7.3 minutes for walkers, public transport users and car commuters, respectively. Wener and Evans compared the physical activity levels of car commuters and train commuters by using pedometers and self-report physical activity index (Wener & Evans, 2007). Their results showed that on average, train commuters walked 30% more steps per day, and 4 times more likely to walk 10,000 steps per day than car commuters. Another study in seven European cities (Antwerp, Barcelona, London, Örebro, Rome, Vienna, and Zurich) also reported that 90% of regular cyclists achieved at least 30 minutes of active travel per day (WHO's recommendation) only by routine trips regardless many differences in transport systems or transport policies of these cities (Raser et al., 2018). A cross-sectional study in New Zealand showed that people who walk or cycle to their main activities were 76% possibility to meet national recommendation for physical activity than those travel by motor vehicles (Shaw, Keall, & Guiney, 2017). The similar trend also found in other studies (Humphreys, Goodman, & Ogilvie, 2013), (Wanner, Götschi, Martin-Diener, Kahlmeier, & Martin, 2012), (Sahlqvist, Song, & Ogilvie, 2012)(Oja, Vuori, & Paronen, 1998).

A study examined the changes in active commuting time and total physical activity in adults in Cambridge, United Kingdom. The result showed that people who decreased active commuting were linked with a greater likelihood of decrease in their total physical activity. The opposite trend was seen in people who increased active commuting (Foley, Panter, Heinen, Prins, & Ogilvie, 2015). They also reported that there were no associations between change in active commuting time and change in other physical activities. A most recent study examined the association of active school commuting with physical activity and secondary behaviour among adolescent from 80 countries. Overall, they reported that active school commuting is significantly and positively associated with achieving recommended physical activity level in all countries (A. Khan, Mandic, & Uddin, 2020).

Public transport commuting also facilitates the physical activity level of commuters as passengers often have to walk or cycle to public transport stops or stations. A study from Langlois, Wasfi, Ross and El-Geneidy estimated the Metabolic Equivalent of Task (MET) to compare physical activity levels by trip purpose and travel mode choice (Langlois, Wasfi, Ross, & El-Geneidy, 2016). Figure 3-15 illustrates an example of MET by trip purpose and transport mode choice. It is evident that the physical activity level of transit passengers was significantly higher than that of car users. It is important to note that the trip distances for each transport modes were different, and there was an assumption that 2.5 METs were added to each return walking or cycling segment of a shopping trip as people have to carry groceries.

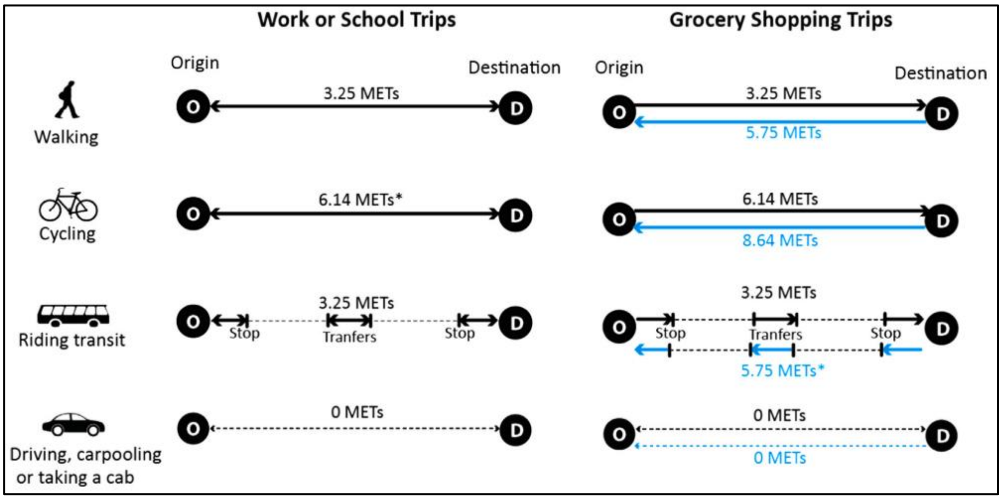

Figure 3-15: METs by trip purpose and travel mode choice (Langlois et al., 2016)

Morency, Trépanier Martin, and Demers also reported that on average, a transit trip involved 1250 steps to access and egress the network, which equals to 25% of daily physical activity recommendation in Montreal, Canada (C. Morency, Trépanier Martin, & Demers, 2011). A systematic review from Sener et al. reported a general agreement that commuting by public transport is associated with increased physical activity levels and improved health outcomes (Sener et al., 2016). However, they also emphasised that the magnitude of these effects varied because of differences in methodologies and study contexts. Furthermore, some studies reported that people who commute by public transport tend to conduct more walking trips (not related to transit access) for other purposes compared to non-users (Lachapelle & Pinto, 2016) , (Saelens, Moudon, Kang, Hurvitz, & Zhou, 2014).

- **E-bikes and physical activity**

The use of electric bikes (pedal-assist electric bikes) is becoming popular in many cities. Some studies have compared the physical activity of electric bikes with conventional bicycles. For example, Langford, Cherry, Bassett, Fitzhugh, and Dhakal estimated the oxygen consumption rate (VO2 in ml/kg/min) and energy expenditure (EE - kcal/kg.min) for 17 participants who travelled on the same route by walk, conventional bicycle, and pedal-assist electric bicycle (Langford, Cherry, Bassett, Fitzhugh, & Dhakal, 2017). Their result showed that total EE and VO2 while using e-bikes were 24% and 64% lower than those while travelling by conventional bikes and walking, respectively. As with the same distance, e-bike users required less physical effort and shorter travel time than normal bikes and walking did. They also noted that in their study, e-bikers were required to choose the highest power setting; and the change in power settings can help e-bike users gain more physical activity intensity. Another study reported that the level of exercise intensity was lower when travelling by e-bike compared to when using normal bicycles. Travelling on the same route, using an e-bike resulted in 30% and 15% fewer minutes in vigorous intensity on the hilly and flat roads, respectively (Berntsen, Malnes, Langåker, & Bere, 2017). A study comparing the physical activity of e-bike users to conventional bicycle users, and non-cyclists based on health and transport survey data in seven European cities found that physical activity levels were similar among e-bikers and cyclist

(Castro et al., 2019). The reason was that e-bike users often travelled longer distances and conducted more e-bike trips than those who travelled by traditional bicycles. They also estimated that people who shifted from private motorised vehicles and public transport to e-bike gained around 550 and 800 MET min/week, respectively, while people who switched from conventional bicycles to e-bikes decreased by around 200 MET min/week.

In general, existing evidence supports that electric bikes can attract sedentary commuters to be more active. Cyclists who shifted from conventional bicycles to e-bikes can compensate for losing physical activity by increasing travel distance and travel time with e-bikes. Generally, using e-bikes increase physical activity level for its users. Therefore, in this study, the author also grouped e-bikes into active transport modes.

- **Transport-related physical activity and body mass index**

Some cross-sectional studies examined the association among transport mode use, transport-related physical activity, and body mass index or body weight. For example, a study investigating links between transport modes involving transport-related physical activity (cars and motorcycles, public transport, and active transport) and the risk of overweight among Taiwanese adults, showed that people who travel by active transport and public transport have higher physical activity levels and lower risk of overweight than those who travel by car or motorcycle (Liao et al., 2016). Commuting modes to work were also found significantly associated with overweight and obesity in Sweden. People who walk and cycle to work were significantly negatively associated with overweight and obesity both in men and women. Public transport was inversely associated with overweight and obesity among men (Lindström, 2008). Another study in Sweden found that car commuters have an increased risk of poor self-reported health, being overweight, and being insufficient physically active than active commuters (Berglund, Lytsy, & Westerling, 2016). Another study examined the association between public transport commuting and obesity among older people (more than 60 years old) in England. They reported that older people who used public transport were less likely to be obese and less likely to become obese than those who did not use it (Webb, Netuveli, & Millett, 2012).

A study in the United States reported that people who commute by subway have a lower probability of being obese than those using cars; however, people who use city buses have a higher possibility of being obese than car commuters (Tajalli & Hajbabaie, 2017). They mentioned that differences in sample characteristics and daily lifestyles were reasons why bus users were positively associated with obesity. City bus users were older, lower-income, lower level of exercise, poor diet, more consumption of unhealthy food than other transport mode users. The result for public transport commuters is inconsistent and can be explained by differences in study design, sample characteristics, cultural behaviours. However, walking or cycling to/from bus stops should be considered a promising way to increase physical activity level. Additionally, some studies also reported that people who use public transport users tend to conduct more walking trips (not related to transit access) for other purposes compared to non-users (Lachapelle & Pinto, 2016) , (Saelens et al., 2014).

Another study in the United Kingdom analysing the association between commuting modes and body mass index (BMI) and body fat (Flint, Cummins, & Sacker, 2014) found that public transport commuters and active commuters have significantly lower BMI and percentage of body fat than car commuters. Women who travelled by active transport and public transport had 0.72 and 0.87 points of BMI scores lower than those travelled by car. Men who used active transport and public transport had 1.1 and 0.97 points of BMI scores lower than those travelled by car. They also reported the similar result of body fat in terms of magnitude, significance, and directions. Dons et al. examined the association between transport mode choice and BIM in seven European cities and reported a significant one(Dons et al., 2018). Cyclists tend to have lower BIM than their non-active peers; people who start or increase cycling will most likely lose weight.

Several longitudinal studies investigated the association among transport mode use, weight, and body mass index over time. For example, a study examining the association between car commuting and weight gain over four year-period among adults in Australia found that after adjusting for potential demographic and behavioural confounders, people who used cars for daily commuting tended to gain more weight than non-car commuters and occasional car commuters (Sugiyama, Ding, & Owen, 2013b). Another study analysed body mass index (BMI) changes of people who used the same transport mode from 2007 to 2013, in Australia (Turrell, Hewitt, Rachele, Giles-Corti, & Brown, 2017). Their result showed that people who consistently walked or cycled had maintained lower BIM than those travelled by motorised vehicle regardless of man or woman. However, they found no difference between BIM of public transport users and car occupants for men; women who mainly travelled with public transport had higher BIM compared to those travelled by car.

Changing commuting mode from active modes to passive modes or vice-versa also influences commuter physical activity level and BMI. Martin, Panter, Suhrcke, and Ogilvie investigated changes in transport mode use and changes in body mass index based on the British Household Panel survey (Martin, Panter, Suhrcke, & Ogilvie, 2015). After adjusting for socioeconomic and health-related factors, they found that people who shifted from private motor vehicle to active modes or public transport were associated with a considerably lower BMI compared to those continued using personal motor vehicles. People who switched from active travel or public transport to private motorised vehicles experienced the opposite trend. Flint, Webb, and Cummins found similar results (Flint, Webb, & Cummins, 2016b). They reported that a person who shifted from active transport (including walking, cycling, and public transport) to more passive mode (e.g., cars, motorcycles) increased about 0.3 kg/m^2 in their BIM. The same magnitude was found for people who shifted from passive modes to active modes but in the opposite direction. Another study in the United States also measured the BIM of American who changed their transport mode. He found that a person who shifted from car to active transport or public transport could reduce more than 3 kg in body mass after six years compared to a similarly situated person who did not change their transport mode (Smart, 2018) .

Regarding car commuters, there was a systematic review on the association between vehicle travel time and distance and weight status in Adults (McCormack & Virk, 2014). They reported that 80% of reviewed studies found a statistically significant positive association between travelled time and travelled distance and weight status. Another study examined the relationship between car use and weight gain in Australian adults over 4 years (Sugiyama et al., 2013b). They found that people who commuted daily with cars tended to gain more weight than those who did not or occasional commuted with cars. Car commuters were also found to be associated with higher odds for smoking, insufficient physical activity, short sleep, obesity, and worse physical and mental health, especially for people who spent more than 120 minutes for daily driving in Australia (Ding, Gebel, Phongsavan, Bauman, & Merom, 2014) .

In general, there is consistent evidence that walking and cycling are associated with higher physical activity levels and lower body weight or lower body mass index, less likely to be overweight or obese compared to car commuters. However, the evidence for public transport commuting is inconsistent, explained mainly by differences in local contexts and commuters' characteristics.

- **Transport-related physical activity and other health impacts**

Transport-related physical activity does not only reduce the risk of being obese and overweight, but also is associated with many other health benefits. For example, Furie and Desai analysed the association between active transport and cardiovascular disease risk factors among American adults (Furie & Desai, 2012). Their results showed that highly active commuters had 31% lower possibility of having hypertension and diabetes than non-active commuters. A systematic review of walking for prevention of cardiovascular disease also reported that walking was positively linked with reduced cardiovascular risk in both men and women, and longer walking time or walking distance added more benefits (Boone-Heinonen, Evenson, Taber, & Gordon-Larsen, 2009). Another study examining the transport mode use and cardiovascular risk factors in the United Kingdom found that people who walk or cycle to work were associated with lower possibility of having diabetes, and walking was associated with lower chance of having hypertension than car users (Laverty, Mindell, Webb, & Millett, 2013).

A systematic review of the relationship between walking and cycling and reduction in all-cause mortality reported that walking and cycling contributed to reducing the risk of all-cause mortality even after adjustment for other physical activities (Kelly et al., 2014). The most recent publication has investigated the associations between commute mode and cardiovascular disease, cancer, all-cause mortality, and cancer incidence by using linked Census data over 25 years in England (Patterson et al., 2020). This study showed that compared with private motorised transport modes, commuting by bicycle was associated with lower rate of all-cause mortality, cardiovascular disease mortality, cancer mortality, and cancer incidence. Walking was associated with lower rate of cancer incidence, and rail commuting was associated with lower rates of all-cause mortality, cardiovascular disease mortality, and cancer incidence than private motorised modes. They also reported that these associations were similar across socio-economic groups.

- **Transport-related physical activity and obesity among school children**

The topic of active commuting to school has gained significant attention for decades as a potential approach for addressing overweight and obesity problems in children, especially in developed countries. A number of studies were examined whether walking and cycling contribute to reducing overweight and obesity rates among schoolchildren. A systematic review of the association between active school transport and physical activity, body composition, and cardiovascular fitness was carried out by Larouche, Saunders, Faulkner, Colley, and Tremblay. Their finding showed that active commuting to school increases physical activity levels in children and adolescents, and cycling to/from school is linked with enhanced cardiovascular fitness (Larouche, Saunders, Faulkner, Colley, & Tremblay, 2014). A cross-sectional study in Norway found that children cycling or walking to school were associated with better body composition, better cardiorespiratory, and muscular fitness than those travelling by car (Østergaard, Kolle, Steene-Johannessen, Anderssen, & Andersen, 2013).

Another study examined the association between commuting modes to school with demographic variables and weight status in eight European countries (te Velde et al., 2017). After adjustment for demographic variables, they found that commuting modes were not associated with being overweight in children. However, the result from the non-adjusted analysis indicated that cycling was inversely associated with overweight among children. This result may explain the differences among countries. For example, in countries where cycling to school is most common, such as Netherland and Norway, overweigh rates among children are among the lowest. Whereas, in Greece, where cycling to school is very uncommon, the overweight rate among children is the highest.

In addition, a study that examined the passive commuting and dietary intake in fourth and fifth-grade students in California reported that students who commuted by car consumed more sweets and snake foods and purchased more foods than students who walked or cycled to schools (Madsen et al., 2015). Children who passively commute to schools may associate with other unhealthy habits in their daily lives.

In summary, transport mode choice strongly influences the amount of physical activity of an individual. Physical activity is well known as a good way to maintain a healthy body, healthy mind, and it is cheap and effective. People who travel by active transport and public transport are more likely to meet physical activity level recommendation than those travelling by motorised transport modes. This is associated with health benefits, including preventing obesity and overweight, reducing the risk of cardiovascular diseases, and having a healthy BMI. Health benefits of transport-related physical activity on active commuters and public transport commuters are higher than negative health impacts from exposure to increased air and noise level and risk of traffic accidents, which is mentioned in part 3.3 already.

3.6 Accessibility

Providing accessibility for all travel demand is considered the ultimate goal of the transport system. The urban transport system consists of various transport modes that have differences in technical and operating characteristics. Different transport modes function differently in providing accessibility, mobility, and safety for the users. For example, short-distance trips can be conducted by walking and cycling; long-distance trips can be conducted by motorcycles, cars, and public transport. For each individual, their transport mode choice is affected by many factors, including their personal factors (e.g., age, gender, income, married status), availability of transport options, vehicle's attributes, weather conditions, etc. Therefore, their evaluation of transport accessibility is also different.

Studies investigating the health impacts of transport accessibility for different commuter groups have not found from the literature yet. It is difficult to compare accessibility across transport modes because they are functioning differently, and the assessment of commuters on transport accessibility is also different. Therefore, further studies on this issue are needed.

In addition, it is important to note that transport modes interact with each other either support, substitute, or compete with each other (presented in table 3-3). Thus, it should be careful when planning for accessibility improvement. Improving the accessibility of cycling and walking improves the accessibility of public transport. Whereas improving accessibility of cars and motorcycle will hinder the accessibility of walking, cycling, and public transport. The enhancing accessibility of walking, cycling, and public transport should be given priority to optimise its positive health impacts.

Table 3-3: Interactions among transport modes (Van, 2018)

(Note: WAL: Walking; CYL: Cycling; TAX/PAR: Taxi/Para-transit; LRT: Light rail transit; BRT/MRT: Bus rapid transit/Mass rapid transit)

MODE	WAL	CYL	MCL	CAR	PAR/TAX	BUS/LRT	BRT/MRT
WAL							
CYL	S C						
MCL	S I	S C					
CAR	I	C	S C				
TAX/PAR	S C	S C	S C	S C			
BUS/LRT	I	S C I	S C I	S C I	S I		
BTR/MRT	I	S C I	S C I	S C I	S I	S C I	

S: Potential substitute for full trip
I: Intermodal combination use within one trip
C: Competitive use for the trip

Figure 3-16 presents the interactions of transport modes in the urban transport system. Basically, there are three types of interactions including (1) potential substitute for the full trip (type S), (2) intermodal combination use within one trip (type I), and (3) competitive use for the trip (transport modes compete against each other, the increased use of a mode decreases the use of the other (type C) (Van, 2018).

3.7 Summary

In summary, individual transport mode choices not only affect commuters' health but also health of other road users, and the general population. The magnitude of impacts varies greatly among commuter groups and within these groups. The literature review found that most of the studies investigating the health impacts of transport mode use have originated from developed countries. These studies in developing countries are still very limited. In general, the qualitative assessment of the health impacts of transport mode on commuters and other road users (or/and the general population) is presented in table 3-4.

Regarding the health impacts of traffic accidents, motorcycles seem to be the most dangerous mode for users, while public transport and car seem to be the safest for its users; cycling and walking are much safer than riding motorcycles in developed countries. However, when taking into account the health risk imposed on other road users, cycling and walking have the lowest risks, compared to other road users, while motorised vehicles (e.g. cars, buses, motorcycles) impose considerably higher risk.

Studies that compared the safety level of various transport modes by using exposure-based indicators in developing countries have not yet found from the literature review. However, fatality rates and injury rates of all transport modes are estimated to be much higher than in developed countries. Especially, the risks of being killed or injured of cyclists and pedestrians in developing countries have been estimated considerably higher than those in developed countries because of the lack of safe infrastructure and facilities supporting these groups.

Table 3-4: Health impacts of transport mode use on commuters and others (Source: Author) (note: (*) evaluation for all public transport modes)

Transport mode uses and its health impacts on **commuter groups**

Health impacts	Negative impacts			Positive impact
Transport modes	**Traffic accidents**	**Exposure to air pollution**	**Exposure to noise pollution**	**Physical activity level**
Walking	High	High	High	High
Cycling (inl.E-bike)	High	High	High	High
Public transport	Low	Medium	High	Medium
Motorcycle	Very high	High	High	Very Low
Car	Low	Low	Low	Very Low

Transport mode use and health imposed on **others**

Health impacts	Negative impacts			Positive impacts
Transport modes	**Traffic accidents**	**Exposure to air pollution**	**Exposure to noise pollution**	**Physical activity level**
Walking	Very low	Non	Non	Low/Medium
Cycling (inl.E-bike)	Low	Non	Non	Low/Medium
Public transport	High (*)	Medium	High	Low/Medium
Motorcycle	Very High	High	High	Non
Car	Very high	Very high	High	Non

Regarding the health impacts of exposure to TRAP, existing evidence has shown that levels of exposure to TRAP of active travellers may be higher or lower than those of motorised transport travellers. However, when taking under consideration the respiratory minute ventilation and travel time, the inhaled dose of active commuters has found significantly higher than that in non-active modes. Therefore, pedestrians and cyclists are most affected by exposure to TRAP. In contrast, cycling and walking emit almost no air pollution at all. As a result, there are no negative impacts on the other road users and the general population. A similar trend is also found in the health impacts of exposure to traffic-related noise pollution.

Regarding transport-related physical activity, people who travel by active transport and public transport are more likely to meet physical activity level recommendation than those travelling by motorised transport modes, which are associated with many health benefits. The existing evidence strongly supports that the health benefits of transport-related physical activity on active commuters and public transport commuters are higher than negative health impacts from exposure to increased air and noise level and the risk of traffic accidents. Therefore, promoting active transport and public transport could significantly improve the health of active commuters, other road users, and the general population.

It is important to note that health is a complex issue and is affected by many factors. For example, an individual's health is affected by her/his housing condition, working environment, eating behaviours, and many others. More information of factors influencing population health is mentioned later in chapter 6 of this thesis. Transport mode choice is one of the factors that affects commuters' health. In addition, the magnitude of health impacts also varies within commuter groups. For example, many people cycle every day, but the health benefits may not be the same. People who cycle longer, more frequently, may be healthier.

4 Investigation Transport-related Health Impacts in HCMC

This chapter focuses on investigating transport-related health impacts in HCMC. In the first section, the background information of the city and its urban transport system are introduced. In the second section, more details of major transport-related health impacts in HCMC are reviewed mainly through existing evidence. Finally, a short conclusion of the chapter is presented.

4.1 Introduction of urban transport in HCMC

4.1.1General introduction of the city

- **Population**

Ho Chi Minh City is located in the Southern part of Vietnam, with a total area of 2,095 km^2 (equivalent to 0.6% of the whole country). HCMC is the Vietnamese's largest city by population and economic development. In 2019, the population of HCMC was approximately 9 million inhabitants, accounting for 9.3% of the national population. The city also has the highest population density, with an average of 4,363 inhabitants per km^2 (PSO.HCMC, 2020). However, the population distribution is unequal across the city; some districts have high population density, such as district 4, 10, 11, 3, 5 with population density over 37,000 inhabitants per km^2, other areas such as Can Gio district's density is only 102 inhabitants per km^2. In 2019, 75.5% of the city's population was at working-age (15-64 years old). Table 4-1 shows the population increase in HCMC over the period 1989-2019. Immigration and natural growth have been the results of the population increase in HCMC. From 1989 to 2009, six newly developed districts have been established as a result of urban expansion, which contributes to the increase in urban population. The percentage of urban populations from 2009 to 2019 reduced from 83.24% to 79.23%, while this figure increased in rural area from 16.76% to 20.77%. However, in absolute number, the population in HCMC increased by 1,157,109 inhabitants in the urban area, and only 673,109 inhabitants in the rural area; while the birth rate in the rural area is higher than in urban area. This number shows that urbanization continues to happen in HCMC, both in urban and rural areas.

Table 4-1: Total population and population distribution by area and gender in HCMC period 1989-2019 (Source: Ho Chi Minh statistics office (1989, 1999, 2009, 2019)

Year		1989		1999		2009		2019	
Total population (inhabitants)		3,988,124	100%	5,037,155	100%	7,123,340	100%	8,993,082	100%
By area	Urban	2,946,426	73.88%	4,204,662	83.47%	5,929,479	83.24%	7,125,493	79.23%
	Rural	1,041,698	26.12%	832,493	16.53%	1,193,861	16.76%	1,867,589	20.77%
By gender	Male	1,890,343	47.40%	2,424,415	48.13%	3,425,925	48.09%	4,381,242	48.72%
	Female	2,097,781	52.60%	2,612,740	51.87%	3,697,415	51.91%	4,611,840	51.28%

According to the Construction master plan, HCMC is divided into three areas, including the central city area (area1), newly developed area (area 2), and the suburban area (area 3). The boundaries of these areas are presented in figure 4-1. In 2020, a part of the suburban area in HCMC (including Thu Duc district, district 2 and district 9) were separated and formed Thu Duc City. The transport infrastructure and land users are different between these areas. For example, many high-rise buildings, shopping malls, schools, and hospitals concentrate in the city centre. The public transport coverage and density in the city area are relatively high. Whereas in the suburban area, the majority of the land area is still agricultural land, road infrastructure and public transport are under development.

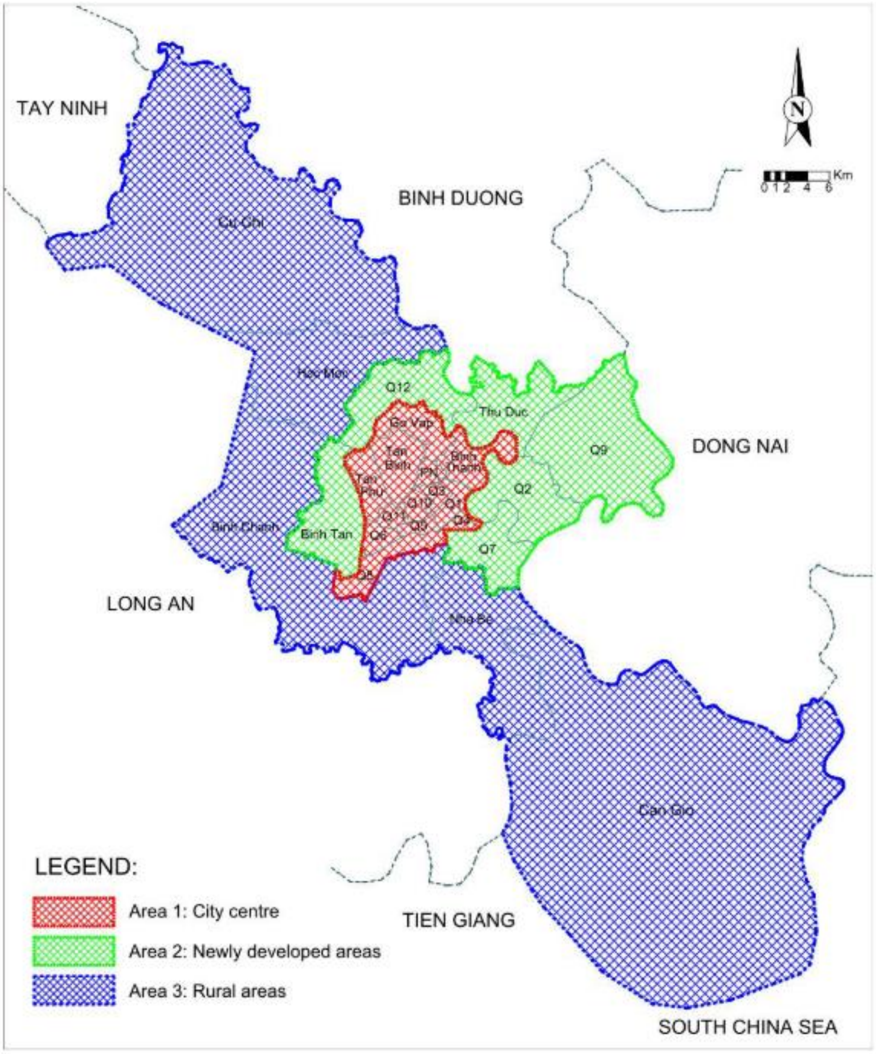

Figure 4-1: Ho Chi Minh City map and developed areas (Tuan & Son, 2015)

- **Economic development**

Ho Chi Minh City is the economic and financial hub of Vietnam. The city is the core of the Southern Economic Focal Zone and contributes significantly to the economic development of the region. The city contributes approximately one-fourth of the national Gross Domestics Product (GDP) (HCMCPV, 2020) . The Industrial and service sectors are primary economic drivers of the city.

4.1.2Ho Chi Minh City urban transport system

- **Road network**

Table 4-2 presents some indicators of road transport network development in HCMC over the period 2011-2017. The road infrastructure has been expanded every year; for example, road length increased from 3850 km in 2011 to 4202 km in 2017. However, only 14% of the road network is over 12 meters wide, which is sufficient for bus operation; 51% of roads have widths of 7-12 meters, accessible by cars, and 35% of road has a width less than 7 meters in which a large proportion of the urban population are living (MOT, 2017). Although cars are accessible to road wider than 7 meters, the lack of parking space and costs (purchasing and operating costs) makes it still inaccessible for the major population. The characteristics of the road network is one of the major reasons explaining the high motorcycle share in the city.

Table 4-2: Some indicators on road transport network development in HCMC period 2011-2017 (source: HCMC Department of Transport)

Indicators	2011	2012	2013	2014	2015	2016	2017
Road length (km)	3851	3895	3950	3981	4044	4155	4203
Rad density (km/km2)	1.84	1.86	1.88	1.9	1.93	1.98	2.01
Land area for transport (ha)	5729	5833	5962	7163	7670	7842	8041

- **Private motorised transport**

Figure 4-2 shows the numbers of motorcycles and cars as well as motorcycle and car ownership rates in HCMC period 2010-2017. These figures have been increasing every year. In 2017, the city had nearly 7.5 million motorcycles, with the motorcycle ownership rate is 861 vehicles per 1,000 inhabitants. Motorcycles are responsible for more than 80% of travel demand in the city. HCMC is one of the cities that has the highest motorcycle ownership rate around the world. Table 4-3 shows the modal split, average travel distance, and average journey time in HCMC.

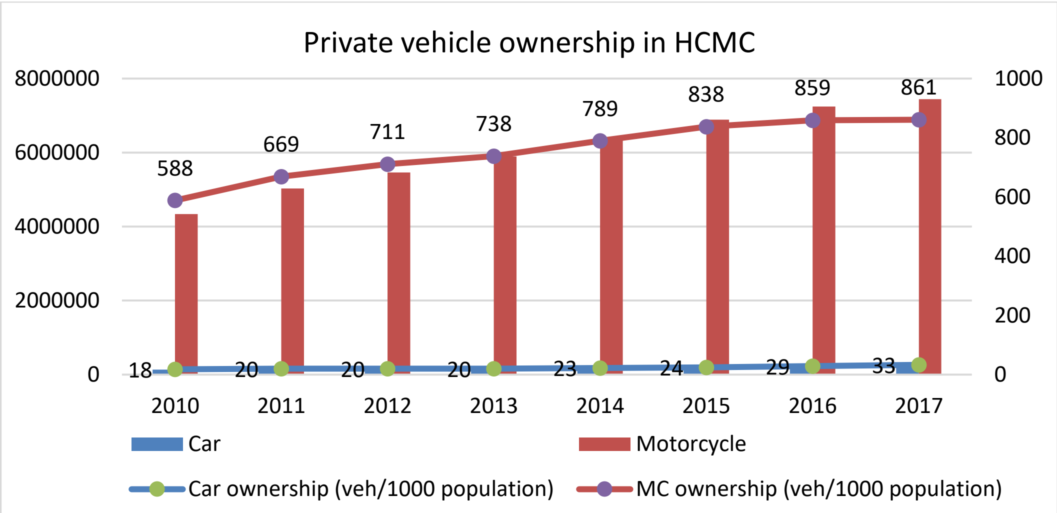

Figure 4-2: Private motorised vehicle in HCMC over the period 2010-2017 (source: Collected from annual reported of the traffic police department in HCMC) (note: car: passenger car less than 9 seats)

In contrast, the number of cars and car ownership rate remains relatively low, with only 33 cars per 1,000 inhabitants. However, private car ownership is increasing faster than motorcycles recently due to the increase in income levels; owning a car is becoming more affordable for many citizens. Despite the rise in car ownership, motorcycles are still selected for daily travel among car owners in HCMC (VGTRC, 2018).

There are some major reasons for the dominance of motorcycle in HCMC. Firstly, as income grows, owning and operating a motorcycle is reasonable for most of the population. Secondly, under the current road network in the city, motorcycles' characteristics, including small size, high maneuvering flexibility, and practical parking, provide convenience for users. Thirdly, lack of parking spaces, low quality of public transport, and lack of safe infrastructure for walking and cycling are increasing the attractiveness of motorcycles over cars, buses, walking, and cycling. And finally, urban activities and daily lifestyles in HCMC are further enhancing its motorcycle culture. For example, many activities are happening along the sidewalks or even on the roads (e.g., wet markets, street vendors, and shops). For joining these activities, motorcyclists do not need to search for a parking place; they can shortly park their vehicle on sidewalks/roads, or even sitting on their motorcycles, going to buy food, eating and then leaving. Daily habits such as buying fresh food, bringing children to school and working trips, going in the late evening can be easily conducted with motorcycles as they do not need to search for parking places (car commuters) or wait for buses. Figure 4-3 gives some examples of common activities that are happening daily in HCMC.

Source: tienphong.vn

Source: dangcongsan.vn

Figure 4-3: Common daily activies in HCMC

The traffic flow in HCMC is a mixed traffic flow with the dominance of motorcycles that create chaos in the city, resulting in traffic congestions and traffic accidents. However, under the current road infrastructure and urban transport system, the motorcycle is the most effective transport mode. Because of the small size and high maneuver, the road-space use by motorcycles is more efficient than cars; therefore, road capacity is higher.

Table 4-3: Some indicators related to travel demand in HCMC (source: Adapted from (VGTRC, 2016)

Transport mode	Modal split by trip (%)	Average travel distance/trip	Average travel time/trip
Motorcycle	83	3.3	17
Car	5.3	6.8	29
Bus	6.3	7.1	11
Bicycle	2.8	1.9	15
Others	2.6	N/A	N/A

- **Public transport services**

For a long time, buses and taxis are two primary public transport services in HCMC, estimated to meet 8 to 10% of the total travel demand in the city. In 2016, the city had 142 bus lines with 2,985 vehicles, with 75% of these bus lines have received the subsidy from the government.

The vehicle fleet was renovated in 2014-2017, around 1680 old buses have been replaced, 300 of these buses used used compressed natural gas (CNG) (Decision No. 2545/QĐ-UBND date 23/05/2014). In addition, other actions were also implemented, including renovating bus stops and bus stations, providing real-time information at some bus stops/stations, and launching public transport application (BusMap) on mobile phone devices. These actions have contributed to improving public transport service in the city considerably. The application of information technology in bus service has allowed people to access bus information more easily and to better plan for their bus trips.

Despite the improvement, public transport still remains an unattractive transport option for large populations, and even public transport ridership has decreased in HCMC. Figure 4-4 shows the number of public transport trips in the HCMC over the period 2010-2016. There are some main reasons for the reducing public transport ridership. Firstly, the major bus passengers are students, the elderly, and the low-income population; as incomes increase, owning and operating a motorcycle is affordable for many of them. The bus service is incomparable with motorcycling in terms of convenience, flexibility, and door-to-door mobility. Therefore, bus passengers tend to shift to motorcycles when they can afford it. Secondly, despite some improvements, the quality of the bus service is still relatively poor in general that is difficult to attract new passengers and keep the current passengers. A large number of buses is still quite old and powered by diesel, which is highly polluted and uncomfortable. Lack of integrated ticketing system, lack of priority and highly influenced by traffic conditions, lack of information at bus stops/stations, low quality of bus stops/stations, and lack of equipment for disable people are some of the factors explaining the low service quality of public transport in the city. Thirdly, there is a lack of promotion campaigns for public transport. Non-bus users rarely recognize the improvement of bus services; their perceptions of public transport as crowded, uncomfortable, and long waiting time remain unchanged. The awareness of the importance of public transport in addressing urban transport problems among the large population is limited. Finally, the evolution of shared mobility, especially motorcycle ride-hailing service in HCMC, may recently threaten public transport demand.

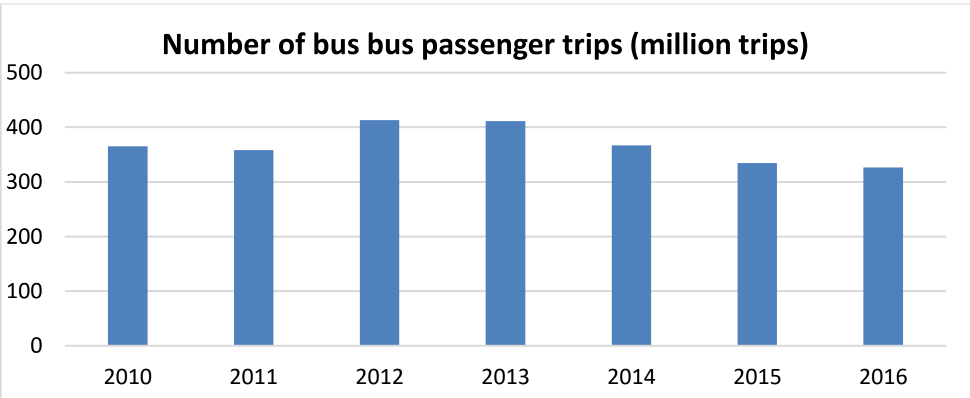

Figure 4-4: Number of bus passenger trips in HCMC period 2010-2016 (million trips) (MOT, 2017)

Together with conventional bus services, the city also approved to conduct a piloted electric bus project, with three non-subsidised bus routes since 2017 (Decision No. 5882/QĐ-UBND date 09/11/2016). The passengers of these electric buses are mainly tourists as these bus lines run through tourist locations. After three years of operation, this service has gained positive feedback from citizens and authorities as an environmentally friendly mode. Therefore, the city authority has approved expanding the number of e-bus lines and e-buses in the city. In addition, the first waterbus route started to operate in 2017. The route is 10.8 km in length and has 12 stops, running from district 1 to several districts in the city. The waterbus service aims to reduce the pressure for road traffic in the city. However, lack of supported facilities (e.g. park and ride) and inappropriate operating time, this service is still unattractive with the population. Tourists are the major passengers of this waterbus service.

Source: vietnaminsider.vn Source: e.vnexpress.net Source: e.vnexpress.net

Figure 4-5: Conventional bus, electric bus, and waterbus in HCMC

The importance of the public transport system in serving travel demand and addressing urban transport problems is gaining significant attention from the city government. That has been shown by the approval of the adjustment of transport development planning of HCMC to 2020 and vision after 2020 (Decision No. 568/QĐ-TTg date 08/04/2013). The city has planned to build an urban railway network that consists of 8 metro lines, one tramway, and two monorails, connecting major locations. The urban railway network is presented in figure 4-6. They also plan to build 6 bus rapid transit lines (BRT). The city authority has set an ambitious goal that this public transport system (including bus, rail, BRT, taxi) can serve 35%-45% of city travel demand in 2030 and 50%-60% after 2030. However, under the current conditions so far, this goal is unachievable as the first metro line is still under construction since 2012, and bus ridership is decreasing.

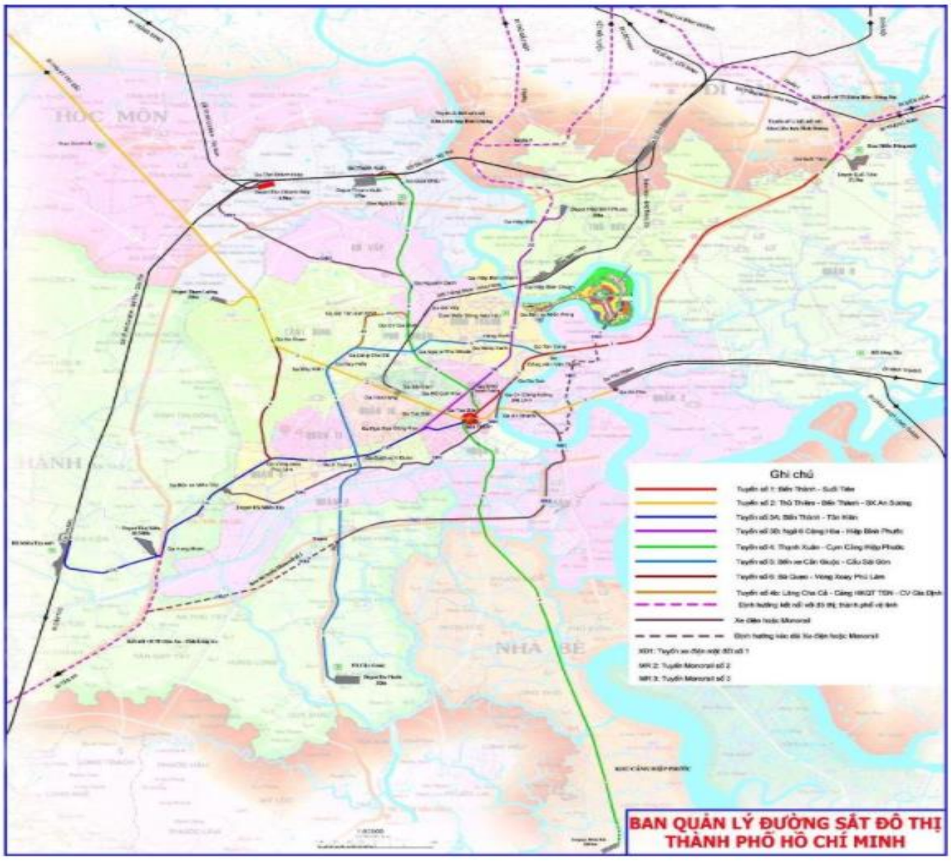

Figure 4-6: Master plan of HCMC urban railway system (source: Management Authority for Urban Railway)

- **Walking and cycling**

Walking and cycling are not common transport options in HCMC; the modal splits of these modes are very limited. Cycling facilities, such as bicycle lanes and bicycle routes, are not available. Pedestrian infrastructure, such as sidewalks and crossings, is often low quality, occupied, and inadequately provided. Sidewalks are often occupied by street vendors, parked vehicles, running motorcycles, and other obstacles that force pedestrians to walk on the streets and increase their accident risks. Due to the road network, a large percentage of the roads are narrow (alleys). On these roads, the sidewalks or pavements are not provided, pedestrians are sharing the same road space with other motorised transport modes. The quality of sidewalks is also inadequate. In the city centre, the sidewalk quality is generally in good conditions, whereas that in other areas is low and even degraded as lack of maintenance. At intersections or crossing points, the prioritised traffic signals for pedestrians are almost unavailable. The walking facilities for disabled people are also unavailable. These conditions make walking unfavoured transport option among the population, resulting in the reduction of its modal share. In addition, this may contribute to reducing the number of bus users as people feel difficult to walk to or from bus stops or stations.

Source: laodong.vn

Source: nld.com.vn

Figure 4-7: Example of occupied sidewalks and pedestrians crossing at wrong crossing location in HCMC

In 2015, the first walking street was opened in the city centre; however, the main purposes of this walking street are to provide a public open space for HCMC citizens and attract tourists. This street has attracted a large number of visitors since it was opened and is becoming one of the most attractive places for the population in the city, especially at the weekend. Recently, the city is planning to expand the walking network around the city, also with the main objectives to provide open space for the public and attract more tourists. In general, planning for walking and cycling as daily commuting modes has received little attention from the city government. In general, the awareness of walking and cycling benefits in addressing urban transport problems and improving citizens' health among the population and city government is still low.

- **Shared mobility**

Shared mobility or shared transport is becoming popular in many cities. In HCMC and other large cities in Vietnam, ride-hailing services are the most common. This is an on-demand ride service, in which a customer books their ride online, usually via a smartphone application, and the driver will take them to their destination without sharing the vehicle with others. Although this service has been introduced in recent years, its market share is growing rapidly. The major companies providing ride-hailing services in HCMC include Grab, GO-Viet, and BE Group. They offer both the motorcycle ride-hailing service and the car ride-hailing service. The introduction of these app-based motorcycle/car taxi services has contributed to diversifying the travel options in HCMC. By offering better service quality and more affordable, the entry of these services has quickly captured the travel demand of the traditional taxi and motorcycle taxi in the city and even public transport and non-motorised transport. These companies are also expanding their services, including rideshare, food delivery, and good delivery. These services are expected to change the travel behaviours of road users in HCMC gradually. However, the details of changes and effects of these services on total travel demand and traffic situation have not been reported yet.

In addition, a pilot project of public-bicycle sharing (PBS) has been approved by the HCMC government. The project is conducted for one year, starting from 2021. The project aims to enhance the accessibility to bus services, reduce air pollution, and encourage people to cycle. The first metro line in HCMC is planning to be operated in 2022. The PBS and ride-hailing services can be integrated with the public transport system to provide better access to public transport services.

- **Parking facilities and the parking situation**

The parking facilities in HCMC are very limited. Total land area for parking space accounts for less than 0.1% of the total land area (MOT, 2017). The details of current parking facilities such as the number of parking places, parking lots, parking occupancy, and parking turnovers are largely unavailable. However, it is evident that parking facilities in HCMC are greatly insufficient for parking demand. Although some public parking places are provided, most of the parking places are provided by the private owners at activity destinations (e.g. schools, hospitals, parks, offices). Many of these private parking places are operating illegally, without any control and permission from local authorities.

Illegal parking is popular in the city due to high parking demand but limited parking capacity, improper parking management, low police enforcement, and daily lifestyles. The fact that vehicles are parked on the streets, and sidewalks are common images in HCMC. Thanh who investigated the parking situation in some Asian cities found that illegal motorcycle parking is a unique parking situation in urban areas of Asian developing cities. People prefer the lowest parking searching time and are willing to park illegally in a short duration for their purposes such as shopping or eating (Thanh, 2017). This finding is also reflecting the same situation of HCMC; motorcycles can be practically parked everywhere. Figure 4-8 shows some typical parking situations in HCMC. Illegal parking has negatively affected traffic quality in the city. On-street parking reduces the road space for traffic resulting in traffic congestion. Parking on the sidewalks forces pedestrians to walk on the road that increases their exposure to traffic accidents and discourages people from walking.

Recently, parking planning has gained attention from the city government. They aim to improve the parking management and to construct new parking spaces. Some public on-street parking places have been established to cope with parking demand in the city. Whereas, the progress of constructing new parking spaces is very slow due to lack of finance. Private motorised transport continues to rise, leading to increased parking demand. Consequently, the gap between parking demand and parking supply is further widening.

Figure 4-8: Illegal parking in HCMC (Source: vnexpress.net)

- **Intermodal and multimodal facilities**

There is a lack of intermodal and multimodal facilities in HCMC. The public transport system is not well-connected and integrated. There is a lack of an integrated ticketing system; passengers have to pay for every bus trip with a paper-based ticket. Therefore, the cost of using buses could be higher than private motorcycles if a person has to transfer two or three times to reach their destinations. The basic information such as bus maps and timetable are largely missing at bus stops. Park and ride facilities are rarely provided.

In summary, despite the improvements, the road infrastructure and public transport services have remained poor and cannot keep up with the increase of private motorised transport demand in HCMC. Figure 4-9 shows some indicators related to transport development in HCMC over the period 2011-2016. For example, the numbers of cars and motorcycles have increased 7 and 5 times higher than the increase in road length. Private motorised vehicle ownership, especially car ownership, is predicted to continue to grow in the city due to increases in population and income. Meanwhile, the city has already experienced serious congestions, traffic accidents, air pollution, and noise pollution. Although the urban transport system in HCMC faces many challenges, there are huge opportunities to improve the situation by improving the public transport system, restricting private motorised transport, and promoting non-motorised transport. These require strong commitment and support from both city authority and the general population.

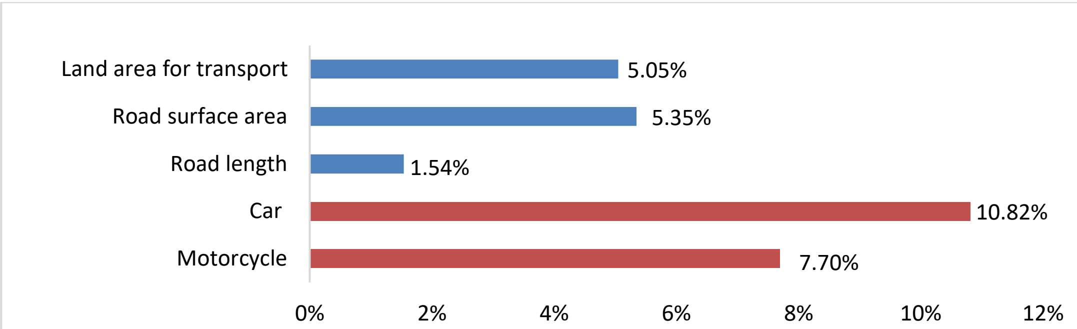

Figure 4-9: Some indicators related to transport development in HCMC period 2011-2016 (MOT, 2017)

4.2 Transport-related health impacts in HCMC

This section focuses on investigating the major transport-related health impacts in HCMC. The impacts include traffic accidents, exposure to traffic-related air and noise pollution, transport-related physical activity, and transport accessibility.

4.2.1Traffic accidents

Road traffic accidents cause tremendous health and economic burdens in Vietnam. In 2016, according to a report of road safety performance review of Vietnam, 19280 injuries and 8417 fatalities caused by traffic accidents, based on the official number of National Transport Safety Committee (NTSC) (United Nations, 2018). However, according to WHO estimation, the number of fatalities caused by traffic accidents in Vietnam was approximately three times higher than the reported number from NTSC, with 24970 deaths in 2016 (WHO, 2018b). Two main reasons for this difference are (1) different definitions of deaths caused by traffic accidents and (2) underreport issue. In Vietnam, the deaths caused by traffic accidents were mainly counted right at the scenes. While the most common definition of road death is the person killed immediately or dying within 30 days due to a road traffic accident, this definition has been widely adopted in many countries (WHO, 2018b). Additionally, a large number of road traffic accidents were not reported to the police due to the negotiations of road users. They negotiated to solve their problems without reporting to the police. Thus, these cases were not included in the traffic safety database.

Road traffic safety has received significant attention from authorities, and huge efforts have been made to reduce the number of fatalities and injuries in Vietnam since the last decade. The number of accidents, fatalities, and injuries have decreased continuously (figure 4-10). Despite improvement, the road accident is still one of the leading causes of death at the national level, based on the health statistics report of Ministry of Health (MOH, 2018). Compared to the international level, the death rate due to traffic accidents in Vietnam was 26.4 for 100,000 populations, which is 45% higher than the global average and 28% higher than the regional average in Southeast Asia (WHO, 2018b). Therefore, a huge effort is still required to improve the country's traffic safety situation.

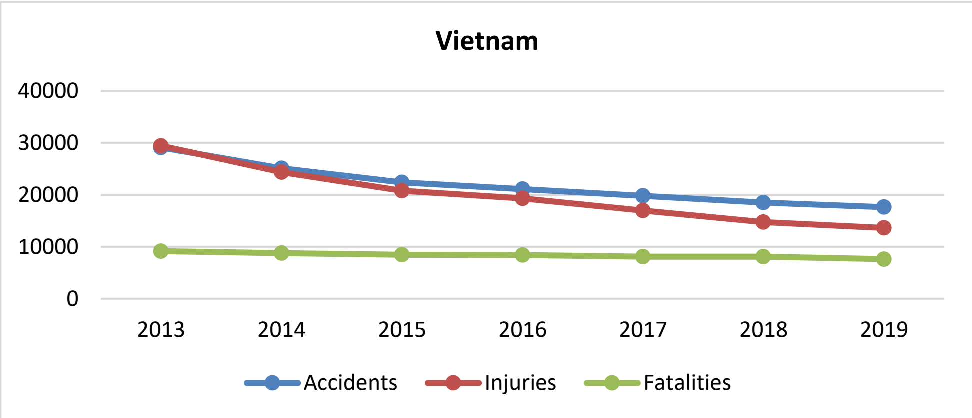

Figure 4-10: Road traffic accidents in Vietnam, period 2013-2019 (Source: Department of traffic safey of HCMC)

Ho Chi Minh City is one of the leading cities with a high number of road traffic accidents, injuries, and fatalities in Vietnam. Figure 4-11 presents the situation of road traffic safety in the city over the period from 2013 to 2019. The data were taken from the annual report of the Transport Safety Department in HCMC, which is considered the official source of traffic safety data in the city. Similar to the country situation, the traffic safety in HCMC was also improving every year. In 2019, the numbers of accidents, injuries and fatalities were 3407, 2406, 634, respectively. The number of road deaths in HCMC alone was equivalent to approximately 20% of road deaths of the whole of Germany; the number of traffic fatalities was 3275 in Germany in 2018 (ITF, 2019c). However, if the WHO’s definition of road traffic deaths (people killed immediately or dying within 30 days caused by traffic accidents) is applied similarly to Germany, it means the number of non-reported traffic accidents, and data from hospitals are taken into consideration. In that case, the number of deaths, injuries due to traffic accidents in HCMC, and the whole of Vietnam could be significantly higher.

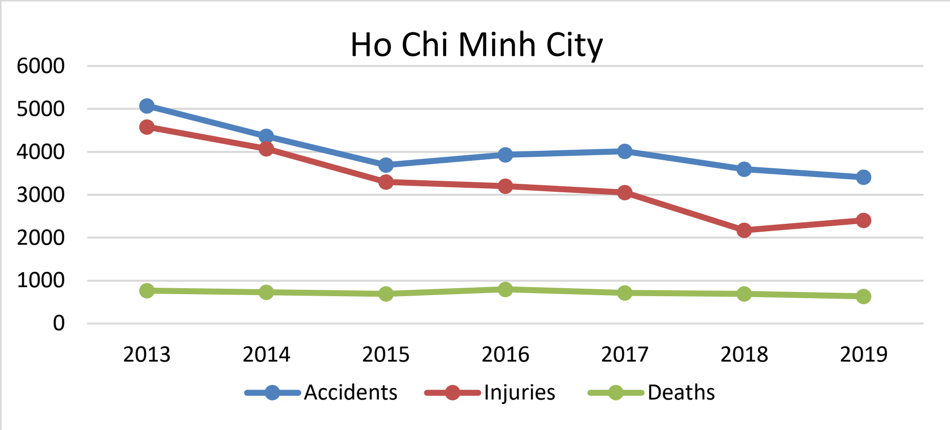

Figure 4-11: Road traffic safety in Ho Chi Minh city and in Vietnam

- **Distribution of road traffic deaths by age groups**

Figure 4-12 presents the distribution of road deaths by age groups in HCMC. People aged between 25 and 60 have the highest percentages of road deaths, accounted for more than half of the total road traffic deaths every year, followed by people between 19 and 24. These groups are playing an important role in the economic development of the society as well as in their families. Thus, their deaths could cause a strong economic burden for society and for their own families. Especially for their families, when they have kids and parents to take care of, it can change the whole family's life, affecting not only family incomes but also causing the psychological effects on their family members. Regarding the traffic fatalities of under 18 year-old, HCMC has the highest number of deaths for this group. Within this group, high school students (aged from 15 to 18) are at the highest risk of being killed in road traffic accidents, with a fatality rate was 32 deaths per 100,000 population aged under 18 years old, which was 3 to 4 times higher than that for average people in the city (T. Vu, 2016). For all age groups, the number of deaths was significantly higher for males than females.

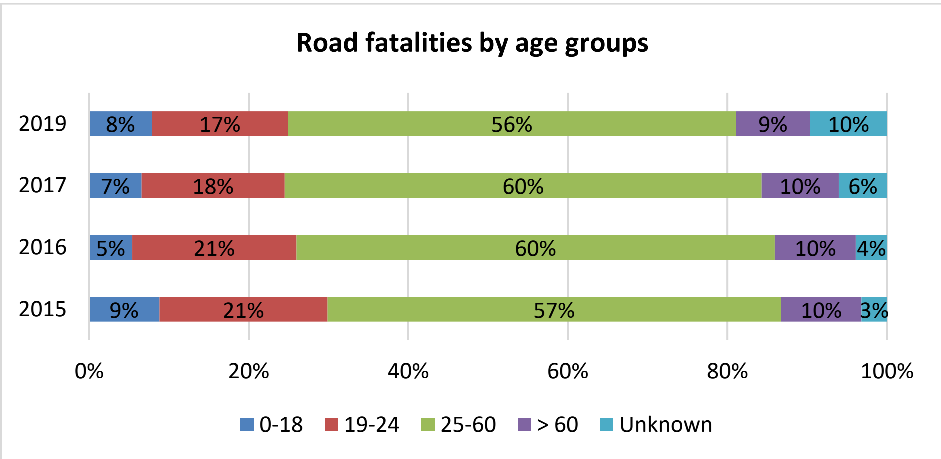

Figure 4-12: Distribution of road fatalities by age groups in Ho chichi Minh city (Source:Annual report from National Traffic Safety Committee)

- **Fatalities and injuries by road user groups**

The data on the deaths, injuries, and injury severities classified by road user groups are not available in the country and in HCM city. Road traffic accidents in Vietnam are classified based on the property damages, the number of injured people and their severities, and the number of deaths. The annual report of road traffic safety provided information about the type of vehicles that caused traffic accidents and vehicles involved in traffic accidents (presented in figure 4-13). Motorcycles and cars were ranked two leading causes of accidents, responsible for 70% and 25% of the total road accidents in 2019, respectively. Followed by pedestrians, ranked as the third leading causes.

Due to the nature of the human body and unprotected from vehicles, the probability of being killed in traffic accidents of the pedestrians and motorcyclists is significantly higher than that of car users. Therefore, it can be certain to state that motorcyclists and pedestrians account for the largest share of fatalities and injuries. Quantitative comparison of safety level among road user groups in HCMC is not feasible because of unavailable data.

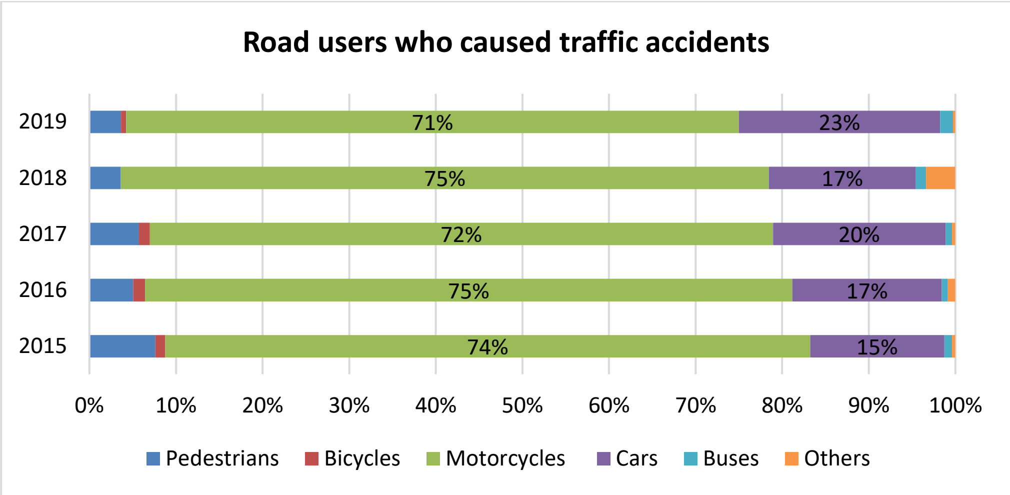

Figure 4-13: The road users who caused traffic accidents in HCMC, period 2015-2019 (Note: only consider the accidents classified from least serious)

Motorcycle users, together with pedestrians and cyclists, are most vulnerable to traffic accidents. If they are injured, the likelihood of being seriously injured will be very high, which may explain why traffic injuries in HCMC generate the massive burden on the health and finance of the victims, their families, and their societies. These burdens are estimated much higher than in car dominant city. Doan and Hobday conducted a study to analyse the characteristics and injury severity of motorcyclists based on the hospital data in HCMC (Doan & Hobday, 2019). The study found that the most two common injured parts of motorcyclists' bodies were extremities and head, which might cause permanent disabilities or take a long time to recover. Another study estimated the economic burden of road traffic injuries based on data collected from a provincial general hospital in Vietnam. On average, a hospitalized road injury would cost approximately six months of the salary of the injured person. The costs included direct medical cost (medicine, treatment, diagnostic examination test, etc.), direct-non medical cost (transport cost to the hospital, meals, etc.), and indirect cost (loss of productivity of injured person and person who take care of them) (H. Nguyen et al., 2013). Although the impacts of road traffic injuries are profound, the government is still focusing primarily on reducing the number of people killed in traffic accidents. Therefore, increasing awareness of the impacts of road traffic injury among public authorities is needed. It can simply start by improving the data quality of road traffic deaths and injuries in the city.

- **Causes of road traffic accidents**

The causes of road traffic accidents are classified into five groups including causes by vehicle users, vehicles, road infrastructures and facilities, pedestrians, and others (Thông Tư 58/2009/TT-BCA (C11)). Based on the annual report from the Department of Traffic Safety in HCMC, more than 90% of accidents caused by inappropriate behaviours of vehicle users. The most common inappropriate behaviours are driving in the wrong lane and/or direction, speeding, changing direction without carefully watching the traffic, not complying with the road signs or traffic signals, and driving under the influence of alcohol.

These causes are also listed as among the most prevalent causes of children-related accidents in HCM city (A. T. Vu & Man Nguyen, 2018). Figure 4-14 presents the leading causes of children-related road traffic accidents HCMC, from 2013-2015. Among children-related accidents, 80% of accidents happened while the children were driving (mainly high school children), and 20% of them happened while the parents were driving. One reason for this situation is that the children might imitate the improper travel behaviours of adults or their parents when driving in the traffic. Thus, measures to change road users' safety perception and travel behaviours of all age groups are urgently needed.

Regarding traffic accidents that involve pedestrians, there are two leading causes: pedestrians crossing the streets at wrong crossing locations and pedestrians walking on the roadway. These causes are classified as human factors. However, the root cause of the problem is lack of safe infrastructure for pedestrians, inappropriate crossing points, low quality of sidewalks, and occupied sidewalks. Therefore, providing infrastructures that ensure safety and convenience for pedestrians is crucial to encourage walking in HCMC.

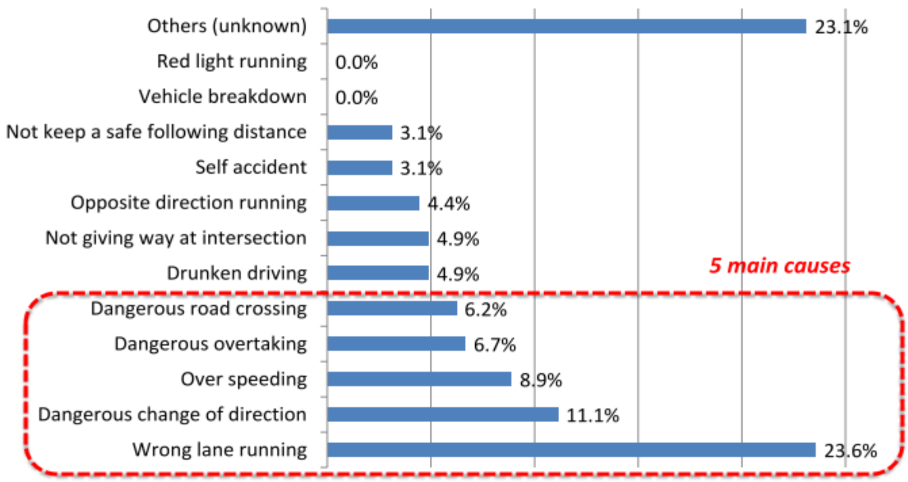

Figure 4-14: Causes of road traffic accidents related to children in HCMC, period 2013-2015 (A. T. Vu & Man Nguyen, 2018)

- **Awareness of the health impacts of traffic accidents**

In general, over the past 10 years, road traffic accidents in Vietnam have gained significant attention from the government. Many actions have been implemented to improve safety for road users. Two remarkable improvements are regulated by traffic law in the country: (1) compulsory wearing helmets when driving motorcycles in 2007, and (2) drinking and driving legislation in 2020 (people are not allowed to drive when they drink alcohol). These regulations have improved traffic safety in Vietnam. For example, Ha et al. reported a significant reduction in the number of injuries and deaths related to motorcycles after implementing the mandatory helmet law (Ha et al., 2019) . The health impacts of traffic accidents can be seen immediately. Therefore, overall, the awareness of public authority and the general population on traffic safety is increasing.

4.2.2Exposure to traffic-related air pollution

- **Air quality in HCMC**

Air quality data in HCMC is poor. Currently, the most reliable source of information about air quality is from the United States consulate monitoring station, which monitors the real-time air quality and data is publicly provided. At this station, the hourly concentration of $PM_{2.5}$ is measured to calculate the air quality index (AQI), which is publicly reported on the website https://aqicn.org/city/vietnam/ho-chi-minh-city/us-consulate. Figure 4-15 presents an example of real-time air quality index in HCMC, the data from the US monitoring station. It is important to note that the air quality data from this station cannot fully reflect the current status of the air quality of the whole city. However, this is still considered as a good reference source of air pollution for HCMC citizens.

The monitor equipment was placed inside the US consulate, and this is not so close to traffic. Therefore, air pollution level may lower than on-road level but may higher than background air quality. In 2018, the annual average concentration of $PM_{2.5}$ measured at the US consulate station was 26.4 µg/m^3, and air quality was classified as at the "moderate" level (Thu, Hang, & Blume, 2019). This value is slightly higher than the limited value regulated in the VN air quality standard (25 µg/m^3) but 2.6 times higher than limited values from WHO AQG (10 µg/m^3). Compared to Hanoi, air quality in HCMC was much better. The annual average $PM_{2.2}$ concentration in Hanoi at the US embassy station in 2018 was 40.6 µg/m^3.

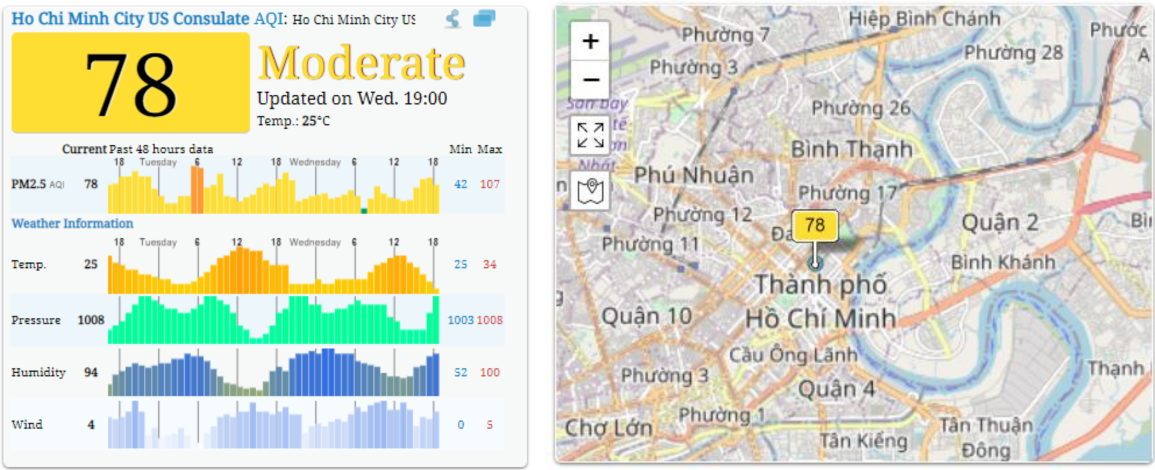

Figure 4-15: An example of the real-time air quality index in HCMC, data from US consulate (source: https://aqicn.org/city/vietnam/ho-chi-minh-city/us-consulate/)

The other source of information about air quality in HCMC is from the government agency. Currently, they are operating 20 fix-monitoring stations, including background stations, traffic stations, industrial stations, and residential stations. Collected data are total suspended particle (TPS), PM_{10}, CO, SO_2, NO_2, noise levels, temperature, wind speed, wind direction, and humidity. However, not all of these data are collected for all monitoring stations, and the data is not accessible for the general population. The air quality data is mainly collected by manual methods every few hours per day and several days per month (CEMHCM, 2018) . TPS is defined in the Vietnam national air quality standard as particles with a diameter less than 100 µm, and this indicator is considered one of the main indicators to assess the air quality in the city. However, in terms of health impacts, the existing evidence has shown that $PM_{2.5}$ and O_3 can cause many harmful effects to human health. These pollutants were not collected from HCMC monitoring system.

According to report from HCMC Centre for Natural Resources and Environmental Monitoring, annual concentration levels of NO_2, PM_{10}, and TBS were all higher than the limited values (Vietnam air quality standard) (CEMHCM, 2018). Levels of air pollution concentrations during the period 2014-2017 varied from 48 to 104 µg/m^3 for PM_{10} , from 37.4 to 230 µg/m^3 for NO_2, and from 244 to 810 µg/m^3 for TBS. The level of TBS concentration reported was significantly higher than the limited value from 2.5 to 8 times. Table 4-4 presents the limited values for several air pollutions, based on WHO AQG and Vietnamese air quality standard.

Table 4-4: Air quality standards of different regulations

Pollutants (unit µg/m^3)	Average exposure time	WHO AQG	Vietnamese standard
PM_{10}	24 hours	50	150
	Annual	20	50
$PM_{2.5}$	24 hours	25	50
	Annual	10	25
NO_2	1 hour	200	200
	24 hours	-	100
	Annual	40	40
SO_2	10 minutes	500	-
	1 hour	-	350
	24 hours	20	125
	Annual	-	50
O_3	1 hour	-	200
	8 hours	100	120
CO	1 hour	30000	30000
	8 hours	10000	10000

Since 2018, several organizations/companies have provided information on real-time air quality in HCMC through their websites and mobile applications. The reliability of these air quality data is still being questionable. However, these data are widely published and accessible by everyone. This is contributing to increasing the awareness of the general population in HCMC gradually.

- **Traffic-related air pollution in HCMC**

Vehicle emission is estimated as one of the main sources of air pollution in the city. The primary transport-related air pollutants are TSP, O_3, CO, SO_2, NO_x, and VOC (volatile organic carbon), which can cause harmful effects on human health (MONRE, 2016). According to a report from HCMC Centre for Natural Resources and Environmental Monitoring, the levels of NO_2, PM_{10} and TPS at traffic stations were higher than those from background stations and higher than the limited values regulated in Vietnamese air quality standards (QCVN 05:2013/BTNMT), especially for the concentration of TPS that was 2 to 8 times higher than the limited value (CEMHCM, 2018). Figure 4-16 presents an example of PM_{10} and NO_2 monthly concentration at one traffic station and one background station in HCM city in 2017. It clearly shows that PM_{10} and NO_2 concentrations at the traffic station were significantly higher than those at the background station and the limited values.

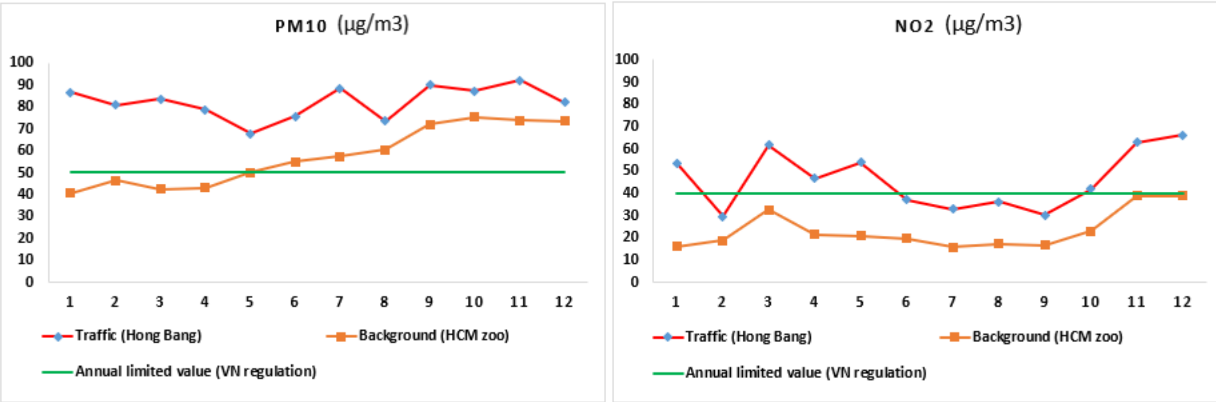

Figure 4-16: Level of PM10 and NO2 concentration at traffic and background monitoring stations in HCM, in 2017 (Source: HCMC Centre for Natural Resources and Environmental Monitoring)

Motorcycles are responsible for the largest traffic emissions in HCMC. In 2019, the total motorised vehicle population in the city was more than 8 million, with approximately 7.3 million motorcycles. The city had the highest motorcycle ownership rate per 1000 population in the country, with around 810 motorcycles/1000 inhabitants. Table 4-5 presents the motorcycle share of total transportation emissions in some selected Asian cities. Motorcycles contributed 90% of the VOC emission and 70% of the CO in the total traffic emission in HCMC. VOC is the result of vapours escaping from the vehicle's fuel system when vehicles are operated and parked, which reacts with nitrogen oxides (NO_x) and carbon monoxide (CO) under the presence of sunlight to form the ground-level ozone (O_3). Therefore, it can be predicted that the level of O_3 concentration in HCMC is relatively high. Figure 4-17 presents the contribution of transport modes to air pollution in Vietnam.

Table 4-5: Motorcycle share of total transport emissions in selected Asian cities (Meszler, 2007)

City	VOC	CO	PM	NOx	CO_2
Ho Chi Minh City, Vietnam	90%	70%	no estimate	12%	40%
Delhi, India	70%	50%	no estimate	no estimate	no estimate
Bangkok, Thailand	70%	32%	4%	<1%	no estimate
Dhaka, Bangladesh	60%	26%	42%	4%	no estimate

Some studies have estimated the emission from the transport sector in HCMC. For example, a study reported that road traffic was the major contributor to total transport emission, accounting for 88% of NO_x, 99% of CO, 79% of SO_2, and 88% of PM in the total transport emission sector (Ho, Vu, Nguyen, & Nguyen, 2020). Another study measured the $PM_{2.5}$ concentrations at some roadside locations in HCMC. The result showed that the daily average $PM_{2.5}$ concentration was

97 µg/m3, which was significantly higher than the WHO's limited value (25 µg/m^3) (Huong Giang & Kim Oanh, 2014).

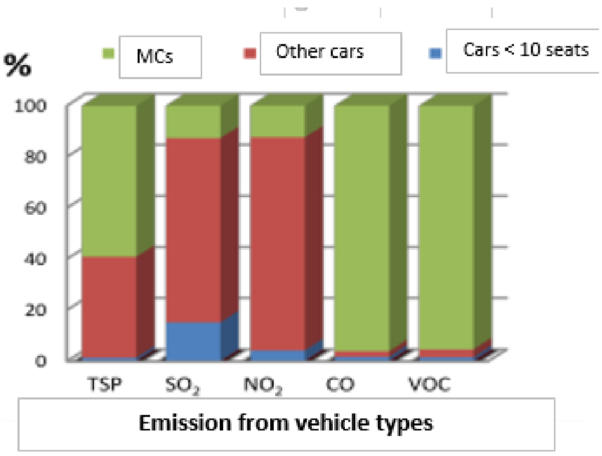

Figure 4-17: Transport-related air pollution in Vietnam in 2014 (note: TSP-Total suspended particle) (MONRE, 2016)

Overall, the air quality data in HCMC is limited and cannot represent the air quality status in the whole city. However, the existing data shows that the air quality in the city is at an alarming level, especially at the roadside locations. The primary sources of air pollution in HCMC are transport, construction, industry, and resident activities. It is difficult to differentiate and estimate the contributions of these sources to the air pollution in the city accurately. However, regarding the contribution of transport activities, there are some main reasons why transport is one of the major sources of air pollution in the city, which are listed below:

- A high number of motorcycles and cars are daily operating in the city.
- Low vehicle emission standards for motorised vehicles, especially for motorcycles. A study reported that a large number of motorcycles were not equipped with exhaust control devices, 47% of the fleet complied with EURO 2, and 18% complied with EURO3, and 35% fleet did not comply with any EURO standards (Kim Oanh, Thuy Phuong, & Permadi, 2012). They also estimated that if the entire motorcycle population adopted the EURO3 standard, the air pollution-related to motorcycles would reduce substantially.
- Lack of inspection maintenance regulations for motorcycles, the large motorcycles are not regularly checked and maintained.
- A large number of old vehicles are still running on the road. There are approximately 800,000 motorcycles aged from 10 years old still operating on the road. These vehicles may be responsible for a large amount of air pollution in the city. A study conducted by Hassani and Hosseini reported that one year of ageing for a 125 cc motorcycle caused a 6% increase in the CO emission rate and 2% increase in fuel consumption (Hassani & Hosseini, 2016).

- **Health impacts of exposure to traffic-related air pollution in HCMC**

At the national level, Vietnam was ranked in the top 15 countries of premature mortality related to outdoor air pollution (Lelieveld et al., 2015). Figure 4-18 presents the leading causes of death in Vietnam in 2017. Some of the diseases that may be related to air pollution exposure were ischemic heart diseases, lung cancer, chronic obstructive pulmonary disease (COPD), and lower respiratory. They are all listed as the top 10 causes of death in the country (IHME, 2020).

Air pollution was also ranked in the top 10 risk factors leading to the most death and disability combined in the country in 2017 (IHME, 2020).

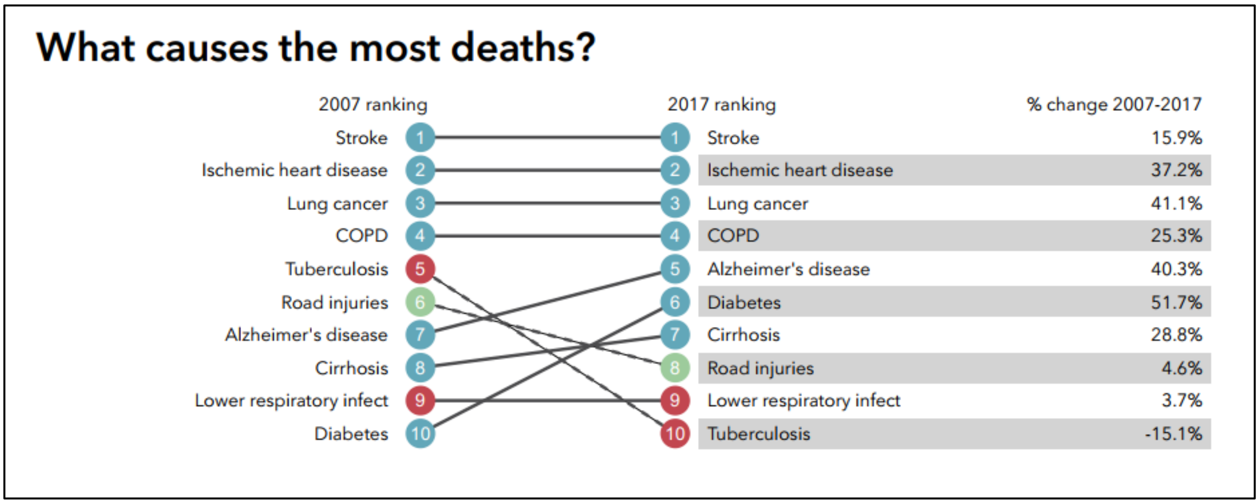

Figure 4-18: Top 10 causes of death in Vietnam in 2017 and percentage change, 2007-2017 (IHME, 2020) (note: Chronic obstructive pulmonary disease (COPD)

In HCMC, it is difficult to estimate the health impacts of traffic-related air pollution because of the lack of data and knowledge related to this issue. Recently, some studies have estimated the health impacts of exposure to ambient air pollution in the city. For example, Luong et al. examined the association between $PM_{2.5}$ and hospital admission due to acute lower respiratory infection (ALRI) among children aged under 5 years old in the city (L. T. M. Luong et al., 2020). They found that exposure to $PM_{2.5}$ was significantly associated with the hospital admission for ALRI among children under 5 years old; each 10 µg/m^3 increase in the level of $PM_{2.5}$ caused 3.5% of the increase in the risk of ALRI hospital admission among children. Data of $P_{2.5}$ concentration was obtained from the US Consulate monitoring station in HCMC.

Another study examined the effects of ambient air pollutants (PM_{10}, NO_2, SO_2, and O_3) on respiratory and cardiovascular hospitalisations in HCMC. The data for these air pollutants was collected from the public air monitoring stations, focusing mainly on the background stations. The results concluded that air pollutants (PM_{10}, NO_2, SO_2) were positively associated with daily hospital admission for respiratory and cardiovascular diseases. With a 10 µg/m^3 increase in each of these pollutants, the risk of hospital admissions for respiratory and cardiovascular diseases increased from 0.7% to 8% and from 0.5% to 4%, respectively (Phung et al., 2016). Le and Leung estimated that each year the emission of $PM_{2.5}$ from on-road vehicles causes 780 hospital admissions, 302 premature deaths, and 4600 years of life lost in HCMC (Le & Leung, 2018). They also found that health impacts are distributed unequally among the population. The people at lower socio-economic status are at higher risk of adverse health impacts than people with higher socio-economic status.

Because of the limited air quality data in these two studies, their results cannot represent the whole city. The actual ambient air pollution levels could be significantly higher than the values in their studies. Therefore, the health impacts of exposure to air pollution in HCMC could be considerably higher. In HCMC, many activities are happening along the roads and on sidewalks, such as eating and selling foods. While existing data shows that air pollution levels at the traffic stations are considerably higher than limited values. Therefore, the number of people exposed to high air pollution concentration is relatively high. It increases the magnitude of the health impacts of exposure to traffic-related air pollution in this city.

There were also some studies conducted in Hanoi about the health impacts of exposure to outdoor air pollution. Nhung et al. reported that exposure to PM_{10}, and $PM_{2.5}$ was positively associated with daily hospital admissions for cardiovascular problems among adults (e.g., ischemic heart disease, stroke, cardiac failure) (Nhung et al., 2020). Another study reported that the elevated levels of PM_{10}, $PM_{2.5}$ PM_1 were associated with respiratory admissions among young children in Ha Noi, with an increase of 10 μg/m^3 of PM_{10}, $PM_{2.5}$ or PM_1 was associated with an increase in risk of admission of 1.4%, 2.2% or 2.5% on the same day of exposure, respectively (L. M. T. Luong, Phung, Sly, Morawska, & Thai, 2017). This study showed that exposure to PM_{10} and $PM_{2.5}$, and PM_1 posed a larger risk of hospitalisation for respiratory diseases among children (under 5 years old) in Ha Noi. An eight-year time series study that examined the effects of exposure to ambient air pollution on lower respiratory infections among children (under 18 years old) in Ha Noi also found a strong association between daily levels of ambient air pollution (PM_{10}, $PM_{2.5}$, PM_1 and NO_2) and hospital admissions for lower respiratory infections in children. Children aged from 1 to 5 were most affected (Nhung et al., 2018). The health impacts of exposure to traffic-related air pollution have been estimated much higher than the health impacts from traffic accidents (Hieu, Quynh, Ho, & Hens, 2013).

Among commuter groups, motorcyclists, cyclists, and pedestrians are most affected by the air pollution because they are directly exposed to a high level of traffic-related air pollutants. To investigate the level of exposure to air pollution in HCMC, the author conducted a measurement survey. The detailed findings of this survey will be presented in section 5.4 in chapter 5. The analysed result showed that motorcyclists and cyclists expose to the concentration of ultrafine particle number 23 and 19 times higher than car commuters, respectively. When the breathing parameter and travel time were taken into account, the number of ultrafine particles that cyclists inhaled were extremely higher than all other commuters under the same route and similar traffic condition. Another study that measured personal exposure to benzene in HCMC found that commuting time contributed to the main part of daily benzene exposure, and motorcyclists exposed to greatly higher benzene concentration than bus commuters and car commuters (Lan, Liem, & Binh, 2013). The studies that examined the health impacts of exposure to traffic-related air pollution of different commuter groups in HCMC are unavailable mainly because of the lack of data and knowledge in this issue.

- **Awareness of the health impacts of exposure to ambient air pollution**
  - **Awareness of public authorities**

  Generally, public authorities and the general population have recognised the negative impacts of exposure to outdoor air pollution. Several actions have been implemented in the transport sectors to reduce vehicle emissions, such as improving traffic management, improving public transport services, and tightening vehicle emission standards for new motorcycles and cars. Table 4-6 presents the road map for the application of vehicle emission standards in Vietnam. According to Decision No.49/2011/QĐ-TTg, it requires that manufactured, assembled, and imported new cars have to comply with Euro 4 exhaust emission standard from 1 January 2017 and Euro 5 exhaust emission standard from 1 January 2022. It also requires that manufactured, assembled, and imported new motorcycles have to comply with Euro 3 exhaust emission standard from 1 January 2017. These are expected to significantly reduce the emissions from new vehicles. However, most in-use vehicles in HCMC are still operating with Euro 2 or lower emission standards. Regarding motorcycles, there are no regulations for controlling or examining the emissions of these vehicles so far. The regulations for conducting regular inspection and maintenance of motorcycles are unavailable as well. Therefore, interventions aiming to reduce in-use vehicle emissions are urgently needed to improve air quality in the city.

Recently, the government is developing a proposal to gradually limit motorcycle use in HCMC and Hanoi to combat air pollutions, congestions, accidents, and noise pollutions. For example, Ha Noi is planning on banning motorcycle use by 2030 (Resolution 04/2017/NQ-HĐND). However, this proposal is still being debated because it will affect many people who depend on motorcycles for their daily mobility. The low-income group will be the most affected by this proposal because they cannot afford to own a car, and the public transport hardly reaches to their homes. In HCMC, the pilot projects on collecting old motorcycles and checking motorcycle emissions are being implemented.

Table 4-6: Road map for application vehicle emission standard in Vietnam (Decision No.49/2011/QĐ-TTg) (Note: Car- includes light-duty vehicles and heavy-duty vehicles)

Emission standard	Cars	Motorcycles	Fuel quality
Euro 2	1 July 2007	1 July 2007	-
Euro 3	-	1 January 2017	-
Euro 4	1 January 2017	-	1 January 2016
Euro 5	1 January 2022	-	1 January 2021

In addition, the People's Committee and Department of transport of HCMC also focus on improving the public transport system to improve environmental quality and reduce traffic-related problems. Meanwhile, the only means of public transport in the city is buses. However, the share of public transport is relatively low (less than 10% of the total travel demand). Meanwhile, metro line 1 is under construction and expected to be in operation in 2022. It is expected that when this first metro line starts to operate, the travel demand of the public transport system will increase gradually and shifting people from private motorised transport to public transport. Several interventions have been implemented to reduce traffic congestions, including parking restriction in the city centre, improving traffic signals, providing real-time traffic information for road users through a mobile-phone application, websites, and radio channels. These interventions also contribute to reducing traffic-related air pollution in the city.

- **The awareness of road users and the general population**

The awareness of the health impacts of exposure to air pollution is gradually increasing among the general population. From the public side, the environmental problems were ranked in the top of the most concerns among the Vietnamese population in 2019, based on the report of the Vietnam provincial governance and public administration performance Index-Measuring citizens' experiences (CECODES, VFF-CRT, RTA, & UNDP, 2020). Figure 4-19 presents the most concerning issues that the country has facing from the population perspective. Air pollution has been considered one of the environmental issues in the country. Leung and Le conducted an interview survey asking people’s perceptions about the health impacts of exposure to air pollution during commuting in HCMC (Leung & Le, 2019). Most of the respondents perceived that exposure to air pollution during their daily travel negatively affects their health.

Concerning air pollution, many commuters in HCMC are wearing facemasks and sunglasses during their travelling time, aiming to reduce exposure to air pollution and UV radiation from sun lights. Some studies have shown that wearing facemasks may lessen the negative health impacts of exposure to air pollution. However, the effectiveness varies, depending on the type of facemasks, face shape and size, and the way to wear it (Shi et al., 2017) (Langrish et al., 2009)(Pacitto et al., 2019). Wearing facemasks during commuting time may not be appropriate for people who have breathing problems, children, and the elderly.

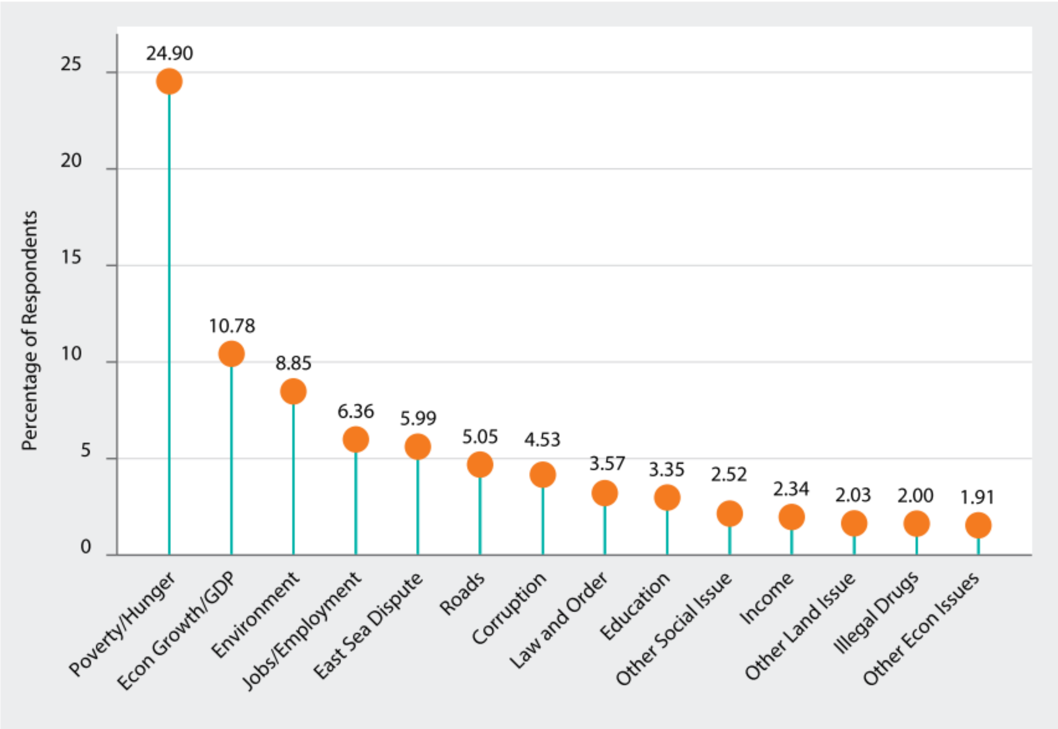

Figure 4-19: The most concerning issues in Vietnam from citizens' perspective in 2019 (CECODES et al., 2020).

In general, it is a challenge to precisely estimate the contribution of transport activities to total air pollution and its health impacts on road users and the general population in HCMC mainly because of lacking relevant data. However, based on the existing data, it is confident that transport is the primary source of air pollution in the HCM city, and exposure to traffic-related air pollution causes substantial health impacts. There is an urgent need to improve the air quality data in the city to understand the existing problems and magnitude of impacts, which is essential for development solutions.

4.2.3 Exposure to traffic-related noise pollution

- **Noise emission from road traffic**

Road traffic noise and its health impacts have received little attention in Vietnam. Although noise emitted from road traffic is increasing and causing adverse effects on health, the study and knowledge related to this issue are very limited at the national and city level. The major sources of noise pollution in urban are generated from vehicle traffic, construction activities, industrial activities, and residential activities (e.g., karaoke).

In HCMC, some studies have measured the noise level at different roadside locations. For example, Phan et al. reported that the average noise level was 76 dB(A) for 24 hours at the roadsides (Phan, Yano, Sato, et al., 2010). They also found that the high number of motorcycles and frequent horn sounds were associated with the high noise level. The sound of horns contributed to an increase of 0-4 dB in the noise level in HCMC. The mixed traffic flows and chaos of motorcycles have made using vehicles' horns a habit for many road users in the city.

Another study from Jeremy and Apparicio measured the noise exposure level of cyclists in HCMC in 2017. Three participants cycled through the streets of the city and measured the noise level at the same time. The measurement results showed that the average noise level that cyclist exposed to was 78.8 dB(A), and the noise levels in the central neighborhoods or areas closed the airport were considerably higher than the noise levels in suburban or rural areas (Jeremy & Apparicio, 2019). For this study, the author also measured noise exposure of different road user groups in HCMC. The analyzed result found that commuters in HCMC exposed to an average noise level of 88.6 dB (A) during their commuting time. Cyclists and motorcyclists were exposed to higher noise levels than car and bus commuters. Different measurement locations and times can explain the large variation between the two studies. In the author's study, the noise level was measured at two busy roads in the city area, with high traffic volume and passing many large road intersections, while Jeremy and Apparicio measured along the roads in the city centre and also in suburban areas. All the noise level values reported in existing studies clearly show that noise levels in HCMC are significantly higher than the national regulation (70 dB for day time) and WHO's recommendation thresholds (55 dB for day time).

- **Health impacts of exposure to road traffic noise**

Only one study examined the level of annoyance and disturbance among the population in HCMC and Hanoi from the literature search. The study reported that the population in these cities exposed to much higher road traffic noise levels than populations in developed countries. The noise annoyance and disturbance among Vietnamese population were found to be somewhat scattered and not as severe as expected (Phan, Yano, Phan, et al., 2010). However, this study was conducted more than a decade ago, and road traffic noise at that time may be not as high as recently. For this study, the author also conducted an interview survey to examine the health impacts of transport mode use. The details of this survey are presented in part 5.4 in chapter 5. In this interview survey, the respondents were asked to rate their feeling of annoyance due to traffic noise, and approximately 46 % of respondents answered that they were annoyed quite a lot and extremely annoyed by traffic noise; only 4.5 % responded that they were not annoyed by traffic noise at all. The result suggested that the perception of noise annoyance has increased among HCMC population.

In addition, according to the noise guideline for European Region developed by WHO, it is strongly recommended that the noise levels produced by road traffic should be reduced to below 53 decibels (dB). Exposure to road traffic noise above this level is associated with harmful health effects (WHO, 2018a). Available evidence showed that the noise level in HCMC is considerably higher than WHO recommendation. Although the studies investigating the health impacts of exposure to road traffic noise in the city have remained rare, it is predicted that road traffic noise causes significant health effects in the city. In HCMC, many kindergartens, schools, universities, hospitals, and residential buildings are located close to the main roads; thus, a large percentage of the population is exposed to the high levels of road traffic noise.

- **The awareness of health impacts of traffic noise**

Although the noise emission from traffic in HCM is high and its health impacts can be enormous, the awareness of traffic noise and its health impacts among authorities is relatively low. The government has regulated the maximum noise levels that are allowed in special areas and normal areas (presented in table 4-7). However, reducing the current noise level to the limited value is a big challenge. At first, improving the data related to noise levels is strongly needed to better understand the current situation and its magnitude of impacts. Both public authorities and the population need to be informed of the situation, the harm of exposure to the high level of noise, which contributes to raising awareness and motivation to take actions and improve the situation.

Table 4-7: Noise limited levels according to the Vietnam National Technical Regulation on noise

Noise (dBA)	From 6 am - 21 pm	From 21 pm - 6 am
Special areas (e.g., hospital, kindergartens, schools, ...)	55	45
Normal areas (e.g., residential areas, roadsides, hotels, …)	70	55

4.2.4Transport-related physical activity

- **Physical activity and its health impacts in HCMC**

Some studies were conducted to investigate the situation of physical activity levels and factors influencing physical activity levels among the population in Vietnam and in HCMC. At the national level, the majority (70%) of the Vietnamese population aged 25-64 years met WHO recommendations of physical activity level for their age. The main source of PA was related to work activities and was higher in rural areas (Van Bui et al., 2015). This is an explainable fact because a large proportion of Vietnamese population is working in the agriculture sector, which usually requires high labour intensive.

However, in urban areas, physical inactivity and insufficient physical activity have become a big concern. A study conducted a cross-sectional survey to investigate the prevalence and correlations of physical inactivity among adults (25-64 years old) in HCMC (Trinh, Nguyen, Dibley, Phongsavan, & Bauman, 2008). The result showed that nearly half of these adults were physically inactive or insufficient physical activity, and the main contributors of PA were from working and active commuting. Figure 4-20 presents the percentages of adults being sufficiently active for health by age and gender in the city. The oldest group had the highest percentage of being sufficient active. This can be explained that as they become older, they care more about their health and they also have more free time to participate in exercising and doing leisure physical activities.

Recently, some studies focused on younger population in the city. For example, a study investigating the level of physical activity among fifth-grade (around 10 years old) students in urban districts of HCMC that 82% of students were not active enough, and 52.7% of the total respondents were classified as overweight and obese (To et al., 2018). The most active time of these students was at schools, and the most sedentary activities happened after school time. Another study investigating the correlations of body mass index among children aged 7-9 years in HCMC in urban districts and semi-rural districts showed that 48.2% of these children were classified as overweight and obese, based on their body mass index. The children attending schools located in urban districts have a higher percentage of being overweight and obese than those attending schools in semi-rural districts (N. K. Pham, Sepehri, Le, & Tran, 2020). Similarly, the percentage of overweight and obese among school children in HaNoi was also high. Around 36% of children aged 11-12 years were overweight and obese (T. T. P. Pham et al., 2019). Both studies mentioned that lack of physical activities and increase in time for second sedentary behaviours (e.g. watching television and playing game) were linked with the overweight and obese conditions among school children.

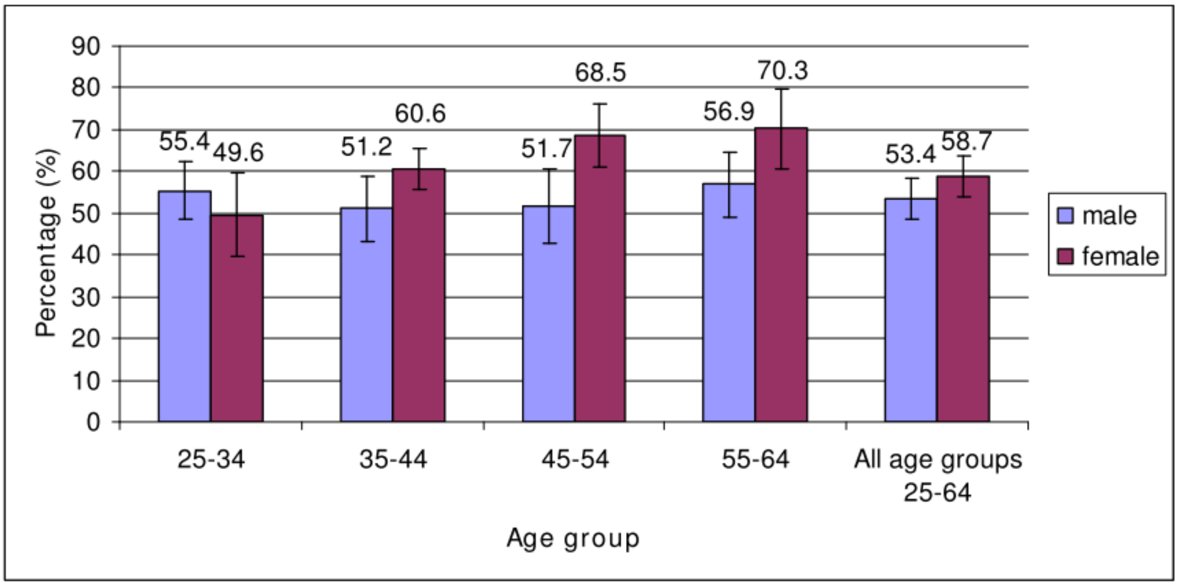

Figure 4-20: The percentages of adults being sufficiently active for health by age and gender in HCMC, Vietnam (Trinh et al., 2008)

Existing evidence notably shows that inactivity and insufficient physical activity have been rising among Vietnamese population, especially among school children in urban areas of big cities. According to the Vietnamese's Ministry of Health report, the lack of physical activities is one of the most concerning risk factors among behavioural and lifestyle factors (e.g. smoking, drug use, abuse of alcohol) affecting population health (MOH, 2016). A study examining the association between metabolic syndrome and physical activity in adolescents in HCMC, found that a more physically active lifestyle is associated with a lower risk of having metabolic syndrome (T. H. Nguyen, Tang, Kelly, Van Der Ploeg, & Dibley, 2010). Pham and Eggleston found that not having enough physical activity level, ageing, and urbanisation were associated with the increasing prevalence of diabetes among Vietnamese adults (N. M. Pham & Eggleston, 2016) . They estimated that around one in 17 and one in seven Vietnamese adults had diabetes and prediabetes, respectively. Another study showed that Vietnamese adults with type 2 diabetes were not active as those without type 2 diabetes and were less likely to meet the recommendation for physical activity level (Van Do et al., 2019).

- **Transport related-physical activity and its health impacts in HCMC**

As mentioned, the primary sources of physical activity among adults in HCMC were from work and active commuting. However, with the development and innovation of technology, labour intensity at work has declined, and work becomes more sedentary. Together with the increase in urbanisation, urban sprawl, motorisation, and lack of facilities for active transport, the active commuting trips in the city have greatly reduced in the last decades. As two principal sources of a person's physical activity level have declined considerably, the level of physical inactivity and insufficient physical activity among adults in HCMC and other cities in Vietnam is predicted to increase significantly unless effective interventions are implemented.

Walking and cycling to/from schools are considered as the main source of physical activity among schoolchildren. However, in HCMC, active commuting among schoolchildren has been declined substantially. A study examining the change of active commuting to school among adolescents in HCMC over the period 2004-2009 found that active commuting in adolescents reduced in this 5-year period from 27.8% in 2004 to 19.6% in 2009 (Trang, Hong, & Dibley, 2012). Nowadays, it is popular that school children in HCMC usually travel to/from school together with one of their parents or other family members. With the fear of traffic accidents, security, air pollution, limited time, and the convenience of motorcycles, Vietnamese parents prefer to bring their kids to school instead of letting them travel alone, leading to increased dependent commuting trips among children. This may be the main reason explaining why active travel has been declining among children in the city.

In HCMC, the transport policies and transport interventions still mainly focus on the movement of motorised traffic. The infrastructure and facilities for cycling are totally missing in the city. The sidewalks are often occupied by street vendors, shops, restaurants, and other residential activities. In 2015, the first walking street was opened in the city centre, with the main purposes are to provide a public open space for HCMC citizens and to attract tourists. This street has attracted a large number of visitors since it was opened and is becoming one of the most attractive places for the population in the city, especially at the weekend. Recently, the city is planning to expand the walking network around the city, also with the main objectives to provide open space for the public and attract more tourists. However, besides these main purposes, walking streets may also encourage walking behaviour in the city, educate citizens about the benefits of having more walkable streets, and gradually change people's travel behaviour towards active transport modes. In addition, public transport is a promising way to improve physical activity since people have to walk to/from bus stops and stations. However, public transport ridership in HCMC is still low.

The studies on the health impacts of transport-related physical activities are not found from the literature review yet.

- **Awareness of the health impacts of transport-related physical activity**

In general, the awareness of authorities and the general population on the health benefits of physical activity is increasing gradually in HCMC. It can be seen by the increase in the number of the sport facilities such as gyms and yoga centres and sport events in the city. However, the awareness of physical activity generated from daily commuting is very low. Many people do not consider that they can gain their physical activity level through walking, cycling, or using public transport for their daily travel

4.2.5Transport accessibility

- **Accessibility of private motorised transport**

In HCMC, motorcycles are considered the most accessible transport mode in terms of spatial, temporal and cost. Due to vehicle characteristics and street network in HCMC, motorcycle users can access nearly all corners in the city. Furthermore, with the economic development, owning a motorcycle is becoming affordable for a large population, around 2.3 motorcycles per household (Minh, Long, Y, & Tu, 2016). This allows people to travel anywhere and whenever they want. A study by Van, Boltze and Tuan found that motorcycle was a major mode for all areas and travel distances in the city, from short trips (less than 5 km) to long trips (more than 10 km) as well as plays a vital role in providing daily travel for people of all ages, especially for people aged between 25 to 60 years (Van, Boltze, & Tuan, 2013).

In contrast, car ownership and car use in HCMC are still relatively low and are not as highly accessible as motorcycles. In terms of costs, including the purchasing and operating costs, owning a car is still not affordable for the large population in the city. Together with the existing road network and lack of parking spaces in the city, cars' spatial and temporal accessibility is significantly lower than motorcycles. However, car ownership and car use are increasing sharply in recent years and are predicted to keep growing unless effective measures are implemented.

- **Accessibility of public transport**

Regarding the public transport system, till now buses are the main public transport mode in the city. In 2016, the city had 142 bus lines with 2,985 vehicles. In general, the bus network in the city is quite reasonable that connects the major locations in the city centre to surrounded areas. Figure 4-21 shows the bus network coverage in HCMC, which is defined as population and land area served by bus service within a radius of 500 m from each bus stop/station. According to Tuan and Son, around 67% of the city's population lived within a walkable distance to bus stop/station, and 27% of the areas were covered by bus network (Tuan & Son, 2015)**.** They also found that the bus service was highly concentrated in urban districts (area 1 and area 2), where the population density is high. Whereas, in the rural area, only 30% of the population and 18% of land areas were covered by the bus network, and bus service was mainly available along the main roads. This means that people living in urban areas are much easier to access public transport than those living in rural areas. Although public transport coverage in rural areas was much lower than that in urban areas, buses plays a vital role in connecting these areas with the urban districts (Van et al., 2013). Thus, improving the public transport coverage in rural areas is strongly needed to ensure accessibility and mobility for the rural population. In addition, improving accessibility of public transport for disabled people, children, and the elderly is also needed. Recently, at some main bus stations, the ramps that allow people with a wheelchair can access have provided. However, the facilities that support disabled people to access public transport in HCMC are considerably missing. This problem had received insignificant attention from service providers and relevant agencies.

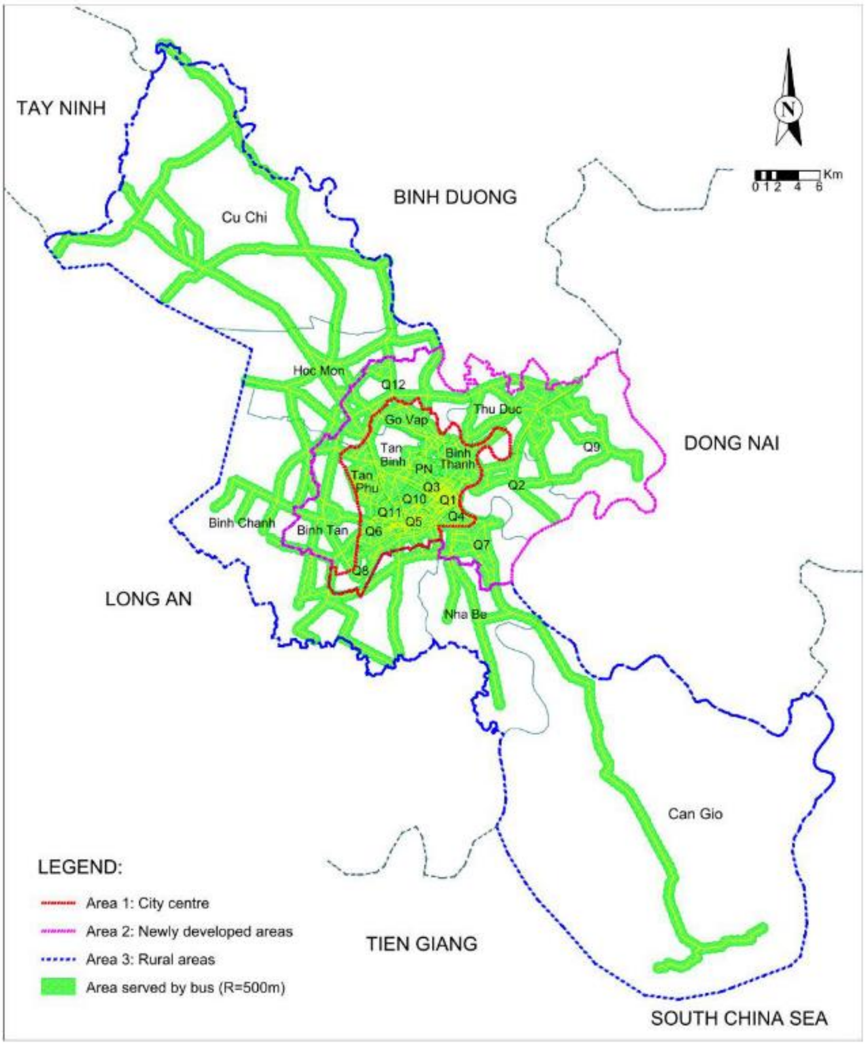

Figure 4-21: Coverage of bus network in Ho Chi Minh city (Tuan & Son, 2015)

Overall, most HCMC populations can access public transport service, especially in urban districts. However, the share of public transport in total transport demand in the city remains low. Due to daily lifestyle and daily behaviours in HCMC, the motorcycle remains a superior transport mode for mobility and accessibility. For example, a family with parents and one child can travel on one motorcycle, parents bring their child to school, then go to their workplaces, and then on the way back, pick up their child and stop along the streets to buy food for their lunch or dinner.

Several studies found that many trips in HCMC were short distance, less than 5 km (Van et al., 2013) (Minh et al., 2016). These trips can be conducted by cycling or walking. However, these transport modes are not popular, and the share of cycling and walking in total transport demand is very small. Cycling and walking are considered essential components of a sustainable urban transport system. However, the city government has no clear goals and visions to develop and promote cycling and walking (Hai, 2018).

4.2.6Others

Studies on the other transport-related health impacts include stress, community severance, security, and exposure to UV radiation, are still unavailable. In this part, brief information of the effects of transport on climate change and land consumption in HCMC is mentioned.

- **Transport and climate change**

HCMC was ranked in the top ten cities in the world whose populations most likely to be severely affected by climate change (ADB, 2010). The result can be seen by the increase in annual average temperature, the number of storms, flood, and extreme weather events. Table 4-8 present the number of regular floods and extreme floods and their impacts in the city in 2009 and projections for 2050.

Table 4-8: Flooding and its impacts in 2009 and projection for 2050 (ADB, 2010)

	2009		2050	
Exposed Areas or Communes	**Regular Flood**	**Extreme Flood**	**Regular Flood**	**Extreme Flood**
Number of communes exposed (Total = 322)	154	235	177	265
Area of HCMC exposed (hectares)	108,309	135,526	123,152	141,885
% of HCMC area exposed	54%	68%	61%	71%

Transport is considered one of the major sources of greenhouse gas emission in HCMC. A study modelled the emission of key sectors in HCMC by using satellite-derived urban land-use data. The result showed that transport has the largest contribution to annual CO_2 emission in the city from 2009 to 2016. Motorcycles contributed to around 50 to 60% of this CO_2 emission. Figure 4-22 presents the annual CO_2 emission of three key sections in HCMC (T. T. Q. Nguyen, Takeuchi, & Misra, 2020). Although studies on the health impacts of climate change are not yet available in HCMC, indirect impacts can be seen through frequent extreme weather events in recent years.

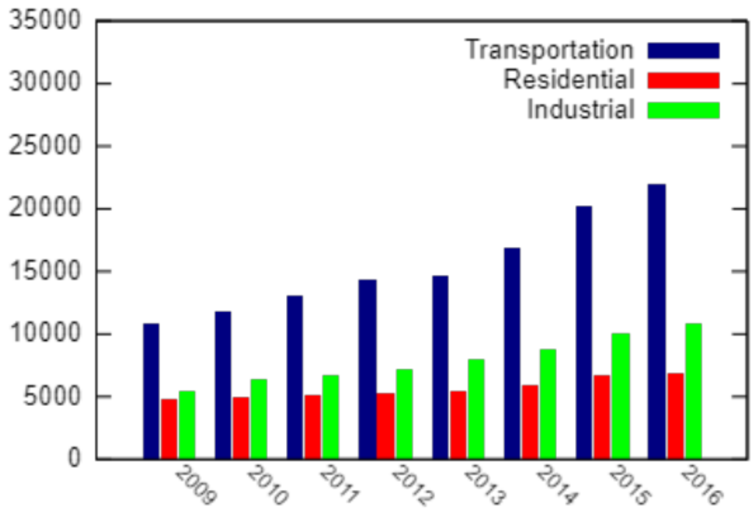

Figure 4-22: Annual CO2 emissions of three key sectors in HCMC (Unit: Gg) (T. T. Q. Nguyen et al., 2020).

- **Transport and land consumption**

As presented in section 4.1.2, the increase in road infrastructure cannot keep up with the increase in travel demand. The city area is unchanged, while transport demand is predicted to increase continuously. Under the current situation, the transport system has already experienced the unbalance between supply and demand, leading to increased traffic congestions and congestion severity. In addition, land areas for public open spaces, green spaces, and parks in HCMC are insufficient, and it accounts for less than 1 m^2 per person. Therefore, high-efficiency transport modes, including public transport, walking, cycling, and high occupancy vehicles, should be prioritised over other individual motorised transport modes.

4.3 Conclusions

In summary, the qualitative assessment of transport-related health impacts, awareness of commuters and the general population and public authorities, and the availability of relevant data are presented in figure 4-23 below.

Overall, the health impacts of traffic accidents and exposure to traffic-related air pollution in HCMC are huge. Therefore, the awareness of commuters, the general population, and public authorities on these issues are also great. Regarding traffic accidents, many interventions have been implemented to reduce the numbers of fatalities and injuries due to traffic accidents. However, the numbers of deaths and injured people remain high and are estimated far higher than the official number. Vulnerable road users, including motorcyclists, cyclists, and pedestrians, are the most affected by traffic accidents. Compared to the other transport-related health impacts, the basic data related to traffic accidents, including the number of accidents, fatalities, and injuries, are widely available. However, the detailed information on the numbers of deaths and injuries classified by road user groups are still missing.

Health impacts of exposure to traffic-related air pollution are estimated higher than impacts from traffic accidents. The awareness of the general population and public authorities on the negative impacts of exposure to air pollution is increasing. However, accurately estimating the magnitude of its impacts remains a challenge due to the lack of relevant data. The situation is similar for estimating the health impacts of exposure to road traffic noise. Improving air and noise quality monitoring systems in HCMC is urgently needed to better understand the problems and develop appropriate mitigating measures.

Health benefits of transport-related physical activity through walking, cycling, and using public transport are expected to be significant in HCMC. However, these health benefits are being neglected among the general population and public authorities. Regarding accessibility, the existing transport system in HCMC provides relatively good accessibility for the majority of the population thanks to the dominance of motorcycles use. However, the accessibility of public transport is still limited in rural and suburban districts. The transport-related health impacts from the other sources including commuting stress, transport-related land consumption, climate change, exposure to UV radiation during travelling, and community severance are largely unknown mainly because of lacking data.

Impacts of transport on health			Expected magnitute of impacts	Awareness of commuters and general population	Awareness of Public authorities	Availability of data
Direct impacts	Negative	Traffic accidents	Very high	High	High	Largely available
		Exposure to air pollution	Very High	High	High	Partly available
		Exposure to noise pollution	High	Medium	Medium	Partly available
		Stress	Medium	Low	Low	Largely unavailable
		Security	Low	Low	Low	Largely unavailable
		Exposure to UV radiation	Low	Medium	Low	Largely unavailable
	Positive	Transport-related physical activity	High	Low	Low	Largely unavailable
		Accessibility	High	Low	Low	Partly available
Indirect impacts		Land consumption	Low	Low	Low	Partly available
		Community severance	Low	Low	Low	Largely unavailable
		Climate change	High	Medium	Medium	Partly available

Largely available Partly available Largely unavailable

Figure 4-23: Overview of transport-related health impacts in HCMC (Source: Author)

5 Health Impact Assessment (HIA) in Transport

Health is an important aspect of everyone life, and it is affected by many factors which go beyond individual lifestyle choices, such as physical environment factors, social and economic factors, and the health care system. The lack of adequate consideration of human health in policy development may result in many unexpected adverse health consequences. Transport is considered one of the main determinants of health that may cause harmful health effects through traffic accidents, air pollution, and noise pollution and bring health benefits such as providing accessibility and increasing physical activity. The integration of health impacts assessment in transport policy development helps to mitigate its negative impacts and promote its positive impacts on human health. Therefore, this chapter focuses on the health impact assessment (HIA) in the transport sector. Firstly, a general introduction of HIA is presented. Secondly, six stages in the HIA are described to provide an overview of how an HIA should be conducted. Thirdly, general information on HIA in the transport sector is examined, and a causal pathway of transport and health is proposed. Fourthly, the health impact assessment of increased active transport and public transport in HCMC is conducted. And finally, a summary of the chapter findings is presented.

5.1 Introduction of health impact assessment (HIA)

This section aims to provide the background information of HIA, which includes the definition, contributions, effectiveness, and challenges and opportunities of HIA.

5.1.1Definition and contributions

- **Definition**

A comprehensive definition of HIA was first developed at the conference of European HIA practitioners that was held in Gothenburg, Sweden, in 1999. This conference was the first in a series that attempted to create a common understanding of HIA. The definitions of Health impact(s) and Health impact assessment (HIA) were stated in the Gothenburg consensus paper as below (WHO, 1999):

"**Health impacts** are the overall effects, direct or indirect, of a policy, strategy, programme or project on the health of a population". (This may include direct effects on the health of the members of the population and more indirect effects through intermediate factors that influence the determinants of the population's health. Such impacts may be felt immediately, in the short term or after a longer period of time).

"**Health impact assessment (HIA)** is a combination of procedures, methods and tools by which a policy, programme or project may be judged as to its potential effects on the health of a population, and the distribution of those effects within the population".

This definition has been widely used in many countries. The International Association for Impact Assessment extended this HIA definition by adding the sentence "HIA identifies appropriate actions to manage those effects" (the effects on health and distribution of health) (R. Quigley et al., 2006). This definition was then adapted by The United State National Research Council as "HIA is a systematic process that uses an array of data sources and analytic methods and considers input from stakeholders to determine the potential effects of a proposed policy, plan, programme, or project on the health of a population and the distribution of those effects within the population. HIA provides recommendations on monitoring and managing those effects" (US National Research Council, 2011).

- **Contributions of HIA**

This is obvious that the major contribution of HIA is to support the decision-making process. HIA aims to inform and influence decision-makers by anticipating how their decisions will affect public health. Therefore, HIA allows decision-makers to choose better health and health equity options and reduces the risk of unexpected adverse health impacts. Identifying the potential health impacts of different options enable decision-makers to make necessary trade-offs when selecting among options and allow them to optimise their decisions (US National Research Council, 2011), (Matthias Wismar, Blau, Ernst, & Figueras, 2007) (Quigley et al., 2006). In addition to the major contribution, HIA also brings at least three important benefits as mentioned by the US National Research Council, including:

Improving the evidence: A systematic HIA will identify data gaps and evidence needed to improve the assessment. This stimulates scientific research more directly, either to improve systematic evaluation and synthesis of available evidences or to conduct new empirical studies. Additionally, monitoring health outcomes of policies or actions after they are implemented could provide valuable evidence that directly addresses questions related to the effectiveness of implemented policies or interventions in terms of health improvements. The result of an HIA also provides a meaningful input for other HIAs.

Raising awareness among decision-makers and the public: HIA contributes to raising the awareness of decision-makers and the general public about potential health effects (both negative and positive) of a policy, plan, or project. HIA provides a better understanding of the cause-effect of the illness and the role of policies, programmes, projects, and plans in shaping health outcomes.

Facilitating the cooperation and collaboration among stakeholders: To assess the health impacts of policies, programmes, projects, and plans effectively requires an interdisciplinary approach with the involvement of many disciplines such as health, social sciences, economics, and policy. HIA serves as a tool to engage authorities, scientists, policy-makers, the community, and other stakeholders in a collaborative decision-making process by acknowledging that health is affected by other factors that go beyond lifestyle choices, genetic predispositions, and medical care. This is fundamental to develop and implement strategies that are needed to improve health effectively.

Some assessments have been incorporated health into assessment, such as Environmental Impact Assessment (EIA) and Strategic Environment Assessment (SEA). For example, there is the legal requirement to integrate health into EIA in European countries and in the United States (EIA directive 2011/92/EU and The US National Environmental Policy Act–NEPA). However, in practice, the consideration of health impacts in EIA is usually inadequate or absent and often limited to those resulting from environmental hazards (Kemm, 2013) (APA, 2016). The lack of assessment or inadequate assessment could lead to many unexpected adverse health and economic impacts. Among the existing assessments, HIA is considered a promising approach to systematically integrate health considerations into the decision-making process because of its applicability to a wide range of policies, programmes, plans, and projects; its consideration of both negative and positive health effects, its ability to consider and incorporate various types of evidence, and its engagement of stakeholders and communities in a deliberative process (US National Research Council, 2011).

The importance of HIA has been recognised throughout the world, and the number of conducted HIA has increased significantly over the last two decades. However, most of the HIAs are found in European countries and in the United States (Hebert, Wendel, Kennedy, & Dannenberg, 2012). HIA could address decisions from small localised programmes or projects on national policies, and is applicable in a wide range of health and non-health sectors, including land use, environment, housing, transportation, employment, education, agriculture, and many others (Matthias Wismar et al., 2007). HIA could be conducted by public health agencies, non-health public agencies, community-based organisations, private companies, academic institutions, state agencies, and community residents, etc.

5.1.2Effectiveness of HIA

In general, the effectiveness of an HIA is evaluated by three types of evaluation including (1) process evaluation examines how the HIA process was carried out and compared it with the objectives established by practitioners or guidelines for HIA practice; (2) impact evaluation examines the impacts of the HIA on the decisions and decision-making process; and (3) outcome evaluation monitors changes in health status or health determinants caused by the HIA, but these evaluations are rarely conducted (R. J. Quigley & Taylor, 2004). They also mentioned that, ideally, all three types of evaluation should be conducted to explore whether an HIA has been successful or not. However, they recommended that typical HIA evaluation should focus on the process and impact evaluation rather than attempting to evaluate long-term health outcomes or whether the predicted impacts actually occurred. Wisma et al. classified the effectiveness of HIA into four groups including direct (leads to changes in the decision), general (raises awareness but no specific changes are made in the decision), opportunistic (favourable decision would have been made anyway), and ineffective (HIA ignored in the decision) (Wismar et al., 2007). Table 5-1 presents a two-way table to analyse the effectiveness of HIA, which is produced in a modified form from Wismar et al.

The main objective of HIA is to inform and influence decision-makers about the health impacts of proposed projects, plans, programmes, and policies to minimise negative and maximise positive impacts on health. Therefore, the direct effectiveness of an HIA is whether it has influenced the decision or not. The decision could be modified, dropped, or postponed as a result of the HIA. In contrast, general effectiveness or indirect effectiveness involves the HIA being considered by decision-makers but not resulting in changing to the proposed decision. The most common benefits of general effectiveness are raising awareness of health among decision-makers and stakeholders, creating and strengthening the engagement of stakeholders and community members, and facilitating the cross-disciplinary and interagency collaborations, and identifying data gaps and questions for future research (A. L. Dannenberg, 2016)(Rhodus et al., 2013). In general, the effectiveness of HIA varies greatly depending on the objectives of HIAs, objectives of the proposed decisions, and expectations of different stakeholders. Existing evidence demonstrated that some HIAs had direct impacts on decisions, but other impacts were found for most HIAs, and these impacts may have been as important as direct impacts. Such other impacts were raising awareness of health issues among decision-makers, engaging community members in problems that affect them, building and strengthening collaboration among stakeholders (A. L. Dannenberg, 2016) (Rhodus et al., 2013) (Harris-Roxas et al., 2012)(Harris-Roxas & Harris, 2013) (Haigh et al., 2015).

Table 5-1: The effectiveness of HIA (Wismar et al., 2007)

<table>
<tr><th colspan="4">The decision changed or modified as a result of HIA</th></tr>
<tr><td rowspan="9">Health adequately acknowledged</td><td rowspan="6">Yes</td><td>Yes</td><td>No</td></tr>
<tr><td>Direct effectiveness</td><td>General effectiveness</td></tr>
<tr><td>Changes in the decision</td><td>Raise awareness among policy-makers</td></tr>
<tr><td>Decision was dropped</td><td>Influence other activities</td></tr>
<tr><td>Decision was postponed</td><td>………………….</td></tr>
<tr><td>…………………</td><td></td></tr>
<tr><td rowspan="3">No</td><td>Opportunistic effectiveness</td><td>No effectiveness</td></tr>
<tr><td rowspan="2">Decision would have been made anyway</td><td>HIA was ignored</td></tr>
<tr><td>HIA was dismissed</td></tr>
</table>

Dannenberg reviewed approximately 200 HIAs conducted in the United States, Europe, Australia, and New Zealand to examine the factors influencing the success of HIA (A. L. Dannenberg, 2016). The result determined seven factors that contribute to the success of an HIA including:

- **Engaging stakeholders:** Engagement of community members, local authorities, researchers, decision-makers, and other relevant stakeholders provide valuable sources of community knowledge, political expertise, and other information related to the proposal. It also increases the consideration and acceptance of HIA recommendations.
- **Timeliness:** HIA must be conducted early enough in the decision-making process to have impacts on the decision.
- **Policy and system support for conducting HIA:** Commonly, HIA is still not a mandatory requirement in many countries. Therefore, having legal requirements or policies that support HIA will increase the probability of conducting HIA and considering HIA results in the decision-making process.
- **Engaging the “right” people on the HIA team:** Conducting HIA requires various skills and expertise such as teamwork skills, knowledge of the subject matter being assessed, knowledge of local context, communication skills, and others. Having direct involvement of the right people on the HIA and ensuring that those people are at the right positions are crucial for the success of the HIA.
- **Engaging and obtaining support of decision-makers:** Involving the decision-makers on board as the key stakeholders or HIA team members enables decision-makers to understand, contribute and use HIA findings and recommendations.
- **Clearly articulated, feasible recommendations:** To increase the possibility of adoption and implementation, HIA recommendations should be technically and politically feasible, specific and actionable, and realistic. Recommendations have to be clear and easy for decision-makers to understand, giving them a clear idea of what to do.
- **Deliver messages to decision-makers and other audiences at the right times:** The HIA should make information accessible to many audiences throughout the HIA process. The

HIA team should consider both contents of the messages and the strategic timing of their dissemination and tailor these to the needs of different audiences.

Besides factors contributing to the success of HIA, conducting HIA is still facing many challenges. The major challenges include (1) insufficient time and resources, (2) lack of expertise and knowledge for conducting HIA, (3) difficulty to engage stakeholders and decision-makers into HIA process, (4) lack of legal requirement for conducting and considering HIA findings, and (5) absence of relevant data (A. L. Dannenberg, 2016) (Bourcier, Charbonneau, Cahill, & Dannenberg, 2015) (McCallum, Ollson, & Stefanovic, 2015).

5.2 HIA process

There is consistency in the basic elements that are generally included in the HIA process from the literature review. Although they may be organised differently in the number of stages or steps that are outlined, the contents are similar. According to Gothenburg consensus, HIA is implemented in five stages: screening, scoping, appraisal or assessment, reporting, monitoring and evaluation (WHO, 1999). While, the US national research council proposed a six stages process, including screening, scoping, assessment, recommendations, reporting, and monitoring and evaluation (US National Research Council, 2011). In this guideline, the reporting stage is divided into two small stages: recommendation and reporting, compared to the Gothenburg consensus paper. A comprehensive review of HIA guidelines among 45 local, national, and international studies found that the six stage HIA is the most popular to use. Therefore, in this study, the author chooses to follow the six-step HIA process, consisting of screening, scoping, assessment, recommendations, reporting, and evaluation and monitoring. In this section, a policy, plan, project, programme, etc. will be named as the proposal.

The detail of the HIA process could be found in the Gothenburg consensus paper titled "Health Impact Assessment: Main concepts and suggested approach" (WHO, 1999)**, the report from the US National Research Council titled "**Improving Health in the United States: The Role of Health Impact Assessment Committee on Health Impact Assessment" (US National Research Council, 2011), a published book by Kemm John titled "Health Impact Assessment: Past Achievement, Current Understanding, and Future Progress" (Kemm, 2013), a report published by US Environmental Protection Agency title "A Review of Health Impact Assessments in the U.S.: Current State-of-Science, Best Practices, and Areas for Improvement" (Rhodus et al., 2013), and a report published by WHO European region titled "The effectiveness of health impact assessment: Scope and limitations of supporting decision-making in Europe" (Matthias Wismar et al., 2007). A short description and objectives of each step in the HIA process are summarised in figure 5-1.

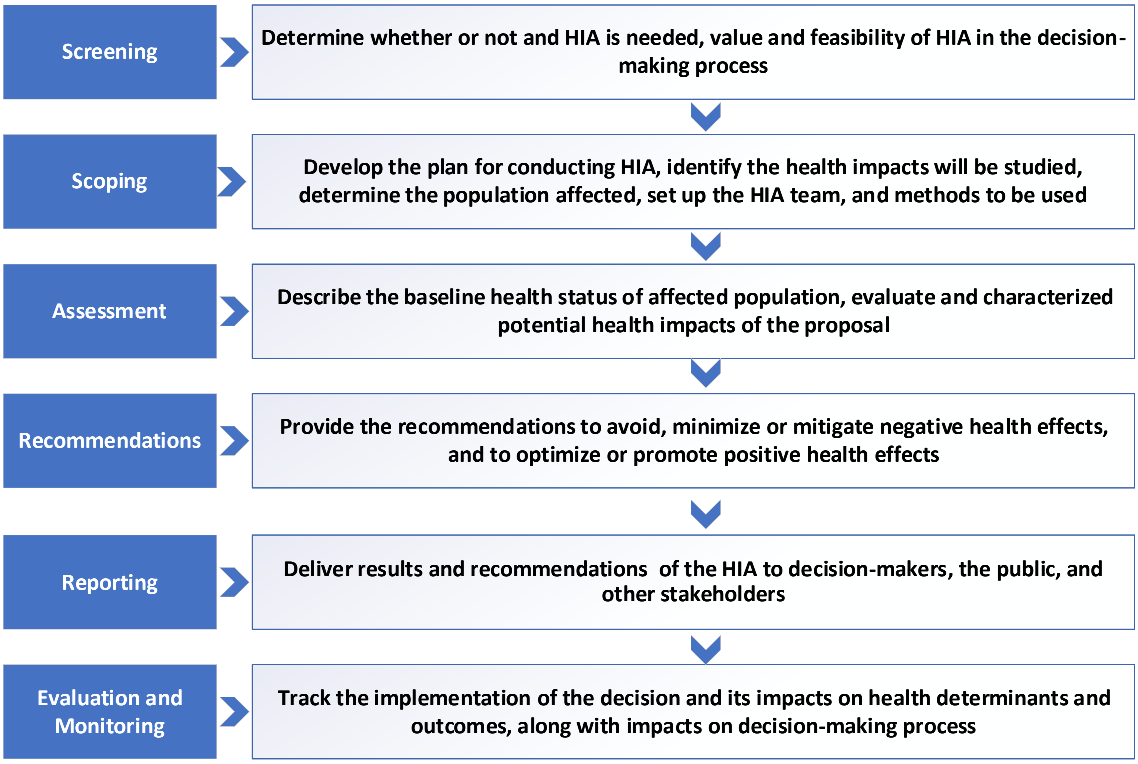

Figure 5-1: Health impact assessment process (adapted from US National Research Council, 2011)

5.2.1Screening

This is the first and essential step in HIA. This step aims to identify whether a proposal needs an HIA and the value of conducting an HIA. According to Kemm, some important questions need to be answered in the screening step, including (Kemm, 2013):

- Is the proposal likely to affect health and well-being or health inequalities?
- Is there an opportunity to influence the proposal?
- Is there anyone who wants an HIA?
- Will the decision makers be influenced by the HIA?
- Are there resources (e.g., finance, staff, data, time) to do the HIA?

If the answers to all of these questions are yes, then HIA is indicated. If an answer to any of these questions is no, then do not do HIA. This step is intended to be quick, stressing the efficient use of resources. Several screening tools are commonly used, such as the checklist of factors to consider, and often focus on health determinants that may be affected by the proposal, screening questions, sequential yes-no query, screening meetings, and some may depend on a specific requirement or mandated procedure. However, regardless of the specific tool used, in most cases, the decision to conduct HIA depends on the practitioners' or decision-makers' judgement regarding the possibility of impacts, time and resources available, and the likelihood that the result produced by the HIA will be a valuable aid to the decision-making process (US National Research Council, 2011). The result of the screening step should be a simple statement that covers the following points:

- A brief overview of the proposal
- A preliminary statement of the potential health impacts of the proposal

- The potential resource requirements for conducting the HIA and the capability to meet them
- A description of the opportunities to influence decision-making
- A screening recommendation such as no further actions required, no HIA, or proceed with HIA

According to Harris et al., the screening should be done by a group rather than one individual. This group should include decision-makers with the ability to change the proposal, the proposal proponents, communities and community representatives who are likely to be affected by the proposal, and key informants with knowledge of the potential health effects (Harris et al., 2007).

5.2.2Scoping

Scoping is the critical step in the HIA process that aims to develop a plan for conducting HIA, identify the health impacts that will be studied, determine the affected population, set up the HIA team and methods to be used. The overall types and categories of questions that should be addressed are defined at this stage of HIA. Well-established scoping at this stage will save time, work, and resources in the remaining stages of the HIA (Harris et al., 2007). Four important tasks need to be addressed in scoping state, including (1) setting an HIA team and plan for stakeholders' involvement throughout the HIA process, (2) defining which impacts will be assessed, (3) selecting the appropriate level for the HIA that needs to be undertaken and developing the working plan for it, and (4) identifying methods, sources of evidence, and data that will be used in the assessment.

- **The HIA team and stakeholder involvement**

The HIA team will conduct the HIA. The team may be the same group that conducted the screening and should include persons who know the topic of the proposal and skills and experience in areas such as public health, communication, stakeholder engagement, and research and analysis. The membership of the HIA team varies, but it is recommended that the HIA team should be small enough to be manageable and also large enough to cover a diverse range of expertises and interests (Kemm, 2013).

The term "stakeholder" is commonly used in HIA, and they are all people who will be affected by or have an interest in the decision. Thus, stakeholders include proposers, decision-makers, politicians, all people who will be affected by the proposal, environmental groups, etc. The stakeholder participant during the scoping could bring significant benefits such as providing local knowledge related to conditions and potential impacts, introducing the mitigation measures to address key concerns, and allowing representative involvement in forming the terms of the HIA by groups affected by the proposal. When developing a plan for stakeholder participation, it is important to define the level of engagement and methods for stakeholder involvement to be used. The methods for stakeholder involvement could include public campaigns, interviews, surveys, meetings, workshops, focus groups, and expert consultations (Rhodus et al., 2013).

- **Identifying health impacts for assessment and affected populations**

The potential health impacts of the proposal could be identified from many sources such as literature researches, public and stakeholder's inputs, and the opinion of experts in topics relevant to the proposal. The causal diagram, pathway diagram, and logical framework are often used to present the relationship between the proposal and its's potential health effects (Rhodus et al., 2013). In reality, it is often not possible to examine all of these potential health effects (e.g., lack of time, resources). Therefore, it is necessary to select which health effects to be assessed. The selection process should consider the health effects that appear most important from a public health perspective and issues that have been raised prominently by stakeholders. Questions related to the severity of the health impacts, the size and likelihood of the impacts, and the potential impact of exacerbating health inequities are important from public-health perspectives (US National Research Council, 2011).

It is crucial to determine who are likely to be affected by the proposal and the geographic and temporal boundaries of these effects. The determination of vulnerable groups such as children, the elderly, disabled people, low-income people, and people who have pre-existing health conditions is also important. In general, the proposal is conducted locally, but its impact could be extensive. For example, a new road will affect those who live close to it and all those who will travel on it or whose business will be made more or less viable by the road. According to Kemm, deciding the area and population for which impacts will be considered and areas and populations which will be out of scope of HIA are needed (Kemm, 2013). Some effects will happen immediately or soon after implementing the proposal. Others will appear some years, decades or centuries later, and the effects may vary, depending on the time period considered. Therefore, the temporal scope is necessary to define in HIA.

- **Deciding what type of HIA is conducted**

In general, HIA is classified into three types reflecting the depth levels of the HIA, namely rapid, intermediate, and comprehensive. The type of HIA selection depends on the scale of the proposal, the size and magnitude of the potential impacts, resource requirement and available capacity (time, staff, finance, etc), and external interest. For example, the more political, professional, and public interest are in the proposal, the more comprehensive the HIA should be, and the more complex these interests are, the more comprehensive the HIA should be. Table 5-2 shows some criteria used to classify types of HIA.

Table 5-2: Criteria used to classify overall types of HIAs (adapted from Waheed et al., 2018)

Criteria	**Rapid**	**Intermediate**	**Comprehensive**
Time	Few days to few months	Few weeks to several months	Several months to years
Resources	Minimal	Moderate	Extensive
Stakeholder engagement	Minimal to non	Moderate	Extensive
New data collection	Non	Moderate	Extensive
Type of data used	Mostly qualitative	Mostly qualitative and some quantitative	Both

- **Identifying data sources and methods to conduct HIA**

The potential data sources, availability of data, sources of evidence, and data gaps are identified. In some cases, the resources and data are available, reliable, and enough for conducting analysis. In others, new data may be needed, which could be collected through measurements, interviews, and modelling.

The outputs of scoping should include a framework for the HIA and a written project plan that covers the following (US National Research Council, 2011):

- The description of the HIA team and approaches for stakeholder involvement.
- A summary of the pathways showing the relationship of the proposal and its potential health effects and identifying which health effects to be addressed, including the reasons for how the impacts are determined and why specific health effects are selected for assessment.
- Identification of affected population and vulnerable groups
- The description of research questions, data sources, methods to be used
- Identification of data gaps and data collection methods could be conducted to address the gaps or reasons for not conducting data collection.

5.2.3Assessment

Two main objectives of the assessment stage are (1) to develop a profile of the existing conditions of the community or population affected by the proposal and (2) to evaluate and characterise the potential health impacts of the proposal. This step is conducted by the HIA project team. Five important tasks should be included in this phase are (Rhodus et al., 2013):

- Gathering existing data and collecting new data if needed by using diverse sources
- Using data and existing tools and methods to profile existing conditions and evaluate potential health impacts of the decision
- Identifying the direction, magnitude, severity, likelihood, and distribution of impacts by qualitative and quantitative analysis
- Describing data sources and methods used, including documentation of stakeholder engagement
- Describing assumptions, strengths, and limitations of data and methods used

- **Development of the baseline profile**

To understand how a proposal will affect health, it is necessary to know the initial state of the population's health status that will be affected when the proposal is implemented. This is called a baseline profile. The profile provides an overview of the population potentially affected by the proposal and identifies groups that could be more vulnerable than the general population. It is important to note that the purpose of the baseline profile is to understand the baseline conditions and to be able to predict changes. Therefore, the indicators might change if the proposal is implemented should be determined and monitored (Kemm, 2013). The information in baseline profile may include data about the demographics (e.g., age, gender, ethnicity), socio-economic status (e.g., income, poverty, education level), the health status of the affected population, including at-risk groups (e.g., children, elderly, disabled people, low-income people), behaviours (e.g., smoking, drinking), and social and environmental conditions (e.g., housing, green space).

Data used in HIA could be collected from a variety of sources, including literature sources (e.g., peer-reviewed research, systematic reviews, and grey literature), government reports or publications that are relevant to the topic (e.g., public health agencies, transport agencies, environmental agencies, hospitals, department of statistic), community expertise (e.g., focus groups), stakeholder participation, and survey data (Rajiv Bhatia et al., 2011).

- **Assessment of the effects**

A wide range of data and analytic methods could be used to evaluate the potential health effects. When the data is not available, expert judgment plays a crucial role in the HIA. The explicit statement of data sources, methods, assumptions, and uncertainties need to be clearly described in this step. It is noted that when the evidence of an effect is uncertain, describe the potential causal pathways that are based on the reasonable interpretation of available data and expert judgement. This evidence could help develop a framework for monitoring and managing any impacts that might occur as the proposal is implemented.

Qualitative and quantitative assessments are both important in HIA. The HIA should focus on the quality of evidence regardless of whether it is quantitative or qualitative (Metcalfe, Higgins, & Lavin, 2009). The key points that are commonly addressed when conducting an assessment of the effects are listed below: (US National Research Council, 2011)

- **The nature:** Describes the nature of the effect (e.g., direct or indirect).
- **The direction:** Indicates whether the effect is beneficial, adverse, or unknown.
- **The severity:** Indicates the severity of the effect (e.g., fatal, disability, or no disability).
- **Magnitude:** Determines how widely the effects would be spread within a population or across a geographical area (e.g., the number of people affected).
- **The distribution:** Determines the spatial (localised or community-wide) and temporal (permanent, temporal) boundaries of the effects and identifies groups or communities likely to bear differential effects to ensure that the health equity is addressed.
- **Likelihood**: Refers to the probability that the effects will occur.
- **Confidence or certainty**: Describes the effects according to the level of confidence or certainty in prediction, which is mainly based on the strength of the evidence of the effect.

The output of the assessment should include (US National Research Council, 2011)

- Describe the baseline health status of the affected population with appropriate indicators, including prevalent health problems, health disparities, and social, economic, and environmental factors that affect health. The baseline should be focused on the problems that are likely to be affected by the proposal.
- Analyse beneficial and adverse health effects and characterises the changes in the indicators selected, to the extent possible, in terms of nature, direction, severity, magnitude, distribution, and likelihood.
- Integrate stakeholder inputs into the analysis of the effects.
- Describe explicitly data sources, assumptions, uncertainties, and analytics methods and methods used to engage stakeholders.

5.2.4Recommendations

The main objective of this phase is to provide recommendations to avoid, minimise or mitigate adverse health effects, and to optimise or promote positive health effects. The results of recommendations could be supported for a specific decision alternative, modifications in the proposed proposal, or providing measures to mitigate negative health impacts and/or to enhance positive health impacts of the proposal (Rhodus et al., 2013). In some case, the recommendations may not be indicated if there were no identified adverse health impacts.

Three considerations are particularly important for developing the effective and workable recommendations including (US National Research Council, 2011), (Rajiv Bhatia et al., 2011), (Rhodus et al., 2013), (R Bhatia et al., 2014) :

- The input of the affected community is essential during the development of recommendation to ensure that the recommendations are responsive to community needs and address community concerns in an acceptable manner.
- Recommendations are effective only if they are adopted and implemented. Thus, input and involvement of decision-makers when developing the recommendations are needed to make sure that the recommendations are translated into actionable measures. The decision-makers must balance health considerations with many other technical, social, political, and economic concerns related to the proposal. These concerns should be taken into account when developing recommendations.
- Where possible, the plan of implementing recommendations should be developed that includes information such as timeline, who will be responsible for implementation, and indicators that could be monitored.

To make sure the recommendations are implemented, a list of criteria should be used when developing recommendations, including being responsive to predicted impacts, specific and actionable, evidence-based and effective, enforceable, could be monitored, technically feasible, politically feasible, economically efficient, and relative to the authority of decision-makers (Rajiv Bhatia et al., 2011)

5.2.5Reporting

Two primary objectives of this stage are to write a final report and communicate the results of the HIA to decision-makers, the public, and other stakeholders. The final report is important in HIA. This is the first way to present the result of HIA to decision-makers, the public, and other stakeholders. The HIA should describe the project, plan, or policy that is the subject of the HIA, data sources, analytic methods used, participants involved in HIA, process and finding of each step of the HIA, and overall conclusions and recommendations. The HIA conclusions and recommendations should be documented in a transparent, concede manner and easy to understand (US National Research Council, 2011). The HIA report should be accessible to all stakeholders.

Only providing and disseminating the HIA report may not be sufficient to secure the adoption and implementation of HIA recommendations. A good communicating strategy is essential for the success of an HIA. Five main factors of an effective communication plan include developing key messages, targeting messages to specific audiences (e.g., public, decision-makers, other stakeholders), developing communication materials (e.g., letters, fact sheets, testimony, video), identifying spokespeople, and identifying methods of communication (e.g., dissemination of HIA report, presentations, press releases, public and/or stakeholder meetings, conferences) (Rajiv Bhatia et al., 2011). It is important to note that the purpose of HIA is to support decision-makers. Therefore, the involvement of decision-makers throughout the HIA process is vital for the effectiveness of HIA (Kemm, 2013).

5.2.6 Evaluation and monitoring

Monitoring can be conducted by tracking the adoption and implementation of HIA recommendations or tracking changes in health indicators as a new policy, programme, plan or project is implemented.

Some types of evaluations may be conducted on an HIA, including (1) process evaluation attempting to determine whether the HIA was conducted according to the plan of action and applicable standards; (2) impact evaluation aiming to understand the impact of the HIA itself on the decision-making process; and (3) outcome evaluation focusing on the changes of health status resulting from the implementation of the proposal. The evaluation is necessary for field development and practice improvement. However, in practice, it is not an essential element of HIA and often not conducted due to lack of interest, time, and resources (US National Research Council, 2011)(R Bhatia et al., 2014).

5.3 HIA in transport

5.3.1 Existing situation

In transport planning and development, the intervention proposals are usually assessed by estimating the costs and benefits known as cost-benefit analyses. Although human health is one of the aspects that has been considered in transport planning, policy development, and interventions for decades, these tools often do not consider the health impacts of the proposal in their assessment.

In practice, health impacts of transport policies, plans, projects, and interventions can be assessed in association with other forms of impact assessments such as environmental impact assessment (EIA), strategic environmental impact assessment (SEA), sustainable impact assessment (SIA), and social impact assessment (SIA) or conducted separately through HIA. EIA is the first widely-used impact assessment process and is obligatory in many countries. EIA is defined as "the process of identifying, predicting, evaluating and mitigating the biophysical, social, and other relevant effects of development proposals prior to major decisions being taken and commitments made" (IAIA, 1999). In many countries, health is considered an integral part of EIA. However, the health assessment is often limited to some environmental risk factors or totally ignored (Wismar et al., 2007), (Dora & Hosking, 2011). For example, a study analysing the inclusion of health in EIA of four major transport infrastructure projects in Vietnam, including the Hanoi Metro rail project (line 3), Ho Chi Minh City Metro Rail project (line 2), and two Expressway projects (T. Pham, Riley, & Harris, 2018), found that health was inadequately considered in all four EIAs, and there was no direct health assessment within these EIAs. The HIA is generally not legally mandated; however, it offers opportunities to assess the potential health effects of proposals, helping decision-makers select better options for the health.

- **Effectiveness of transport HIAs**

Given the concerns related to health impacts of transport are growing, HIAs are increasingly being conducted in the transport sector, especially in European countries, the United States, and New Zealand. Waheed et al. conducted a systematic review of worldwide HIA on transport projects, plans, and policies (Waheed et al., 2018). They reported that the most common transport areas for which HIAs have been used include community active transport plan, community transport plan, public transit development, road and bridge (re)development, and corridor (re)development. They also found that the major funding for conducting transport HIAs worldwide was from public agencies (especially public health agencies) and non-governmental organisations, and not-for-profits (NGOs/NP). McAndrews and Deakin analysed 59 HIAs on transport issues in 2005-2016 in the United States (McAndrews & Deakin, 2018). They found a similar conclusion that most HIAs were led and funded by public health organisations, suggesting that the transport professional has not often internalised the HIA and relied on external influences to take health considerations into the policy process. They also found that these transport HIAs have been implemented for several purposes, including influencing decisions, providing information, expressing community support, building capacity, or serving as a planning tool. However, most transport HIAs have conducted counselling by public health professionals, health advocacy groups, universities, with little initial engagement with the transport planners who make the decisions about these projects and policies (Dannenberg et al., 2014). Therefore, the questions regarding the effectiveness of these HIAs remain largely unknown. In literature, document related to the effectiveness of transport HIAs is very limited.

The engagement of transport agencies and transport decision-makers in the HIA process is vital to ensure the effectiveness of HIA, which has mentioned in the US National Research Council report on HIAs that *"recommendations are effective only if they are adopted and implemented. Adoption of recommendations depends partly on the involvement of decision-makers in the HIA process….Collaboration with decision-makers or consultation with experts familiar with the legal or regulatory context may be the most effective way to ensure that recommendations are pragmatic and can be practically incorporated into the decision-making process."*(US National Research Council, 2011). For example, a study analysing five HIAs in which substantial interactions between transport and public health professionals took place during and after HIA in the United States, found that these HIAs helped raise awareness of health issues by transport decision-makers in all cases, and recommendation from the HIAs led to changes in decisions in some cases (A. Dannenberg et al., 2014).

- **Types of HIA and assessment methods**

Qualitative and quantitative approaches both play essential roles in transport HIAs. Some of the transport-related health impacts can be quantified or estimated, such as fatalities and injuries due to traffic accidents; these health impacts can be evaluated by using a quantitative approach. However, other transport-related health impacts such as stress due to traffic congestions and health impacts of transport-related community severance cannot be or are difficult to be quantified. According to the practical evidence, rapid HIAs were the most common type of transport-related HIAs because of limitation in funding and resources. Therefore, qualitative analyses were also more common (Waheed et al., 2018). Some common qualitative assessment methods are focus groups, expert consultations, interviews, and strengths-weakness-opportunities-threat (SWOT) analysis.

Although the use of quantitative data and quantitative assessment methods are not common in transport HIAs, using these quantitative assessments may improve the effectiveness of HIA by adding depth and defensibility to the HIAs and allowing estimates of the scale and magnitude of potential impacts (US National Research Council, 2011), (Kemm, 2013). Quantitative assessments of health impacts are based on the combination of exposure data and exposure-response relationship (Nieuwenhuijsen, Khreis, Mueller, & Rojas-Rueda, 2020).

The exposure data of transport-related health impacts could be collected by monitoring, measuring, and modelling. The exposure-response relationships are often obtained from the systematic review of the epidemiology and scientific evidences to select the most robust evidence to quantify the attributable health impacts. However, the quantitative assessment has some limitations because not all health impacts could be quantified, and it may require considerable effort to collect the necessary data. In addition, it may be difficult to conduct and understand, especially for non-health practitioners such as transport planners and decision-makers. Figure 5-2 presents a framework for conducting the quantitative health impact assessment.

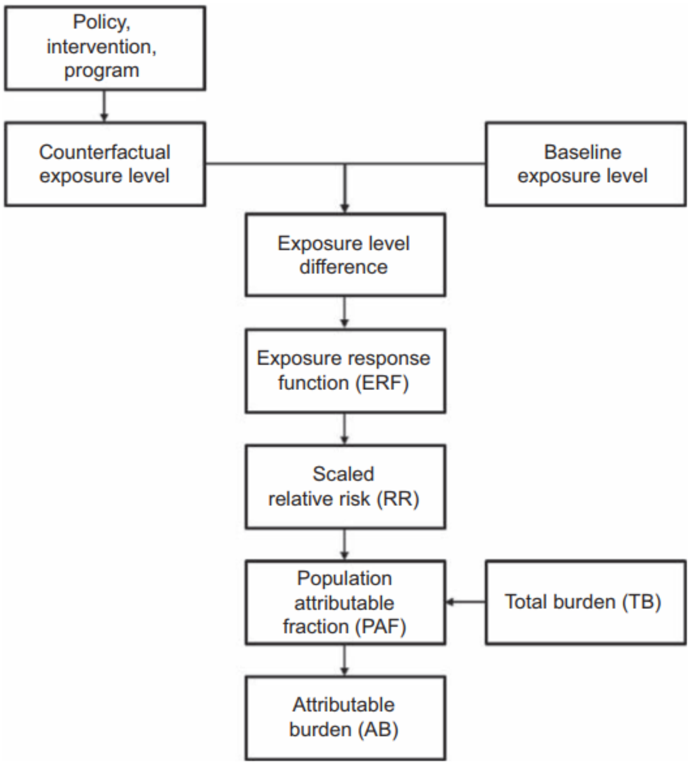

Figure 5-2: The framework of quantitative health impact assessment (Nieuwenhuijsen et al., 2020)

From the literature review, there are some integrated assessment tools and models that have been developed and used in specific case studies. Three common tools have been used in transport HIAs are the Health Economic Assessment Tool (HEAT) for walking and cycling, the Integrated Transport and Health Impact Model (ITHIM), and the Urban and Transport Planning Health Impact Assessment (UTOPHIA) model. These tools/models have combined different quantitative assessment methods within a modelling framework to provide a more comprehensive and definite measure of impacts (Dora & Hosking, 2011). A brief description of these tools/models is introduced below. In general, except for HEAT, other tools/models still tend to be research tools that need to be further developed and improved but show the potential to be applied in practice (Nieuwenhuijsen, Khreis, Verlinghieri, Mueller, & Rojas-Rueda, 2017). Each of the approaches has both advantages and disadvantages; the combination of these approaches will provide comprehensive HIAs as this gathers all available evidence on the health impacts of transport. However, depending on available resources, including time, budget, data requirement, and staff, appropriate methods could be selected for assessments.

- **Health Economic Assessment Tool (HEAT)**

HEAT which is developed by WHO is a harmonised method for the economic evaluation of health effects of cycling and walking (WHO, 2017). HEAT aims to estimate the economic value of health benefits of reduction in mortality that results from increased physical activity; answering the question *"If x people regularly walk or cycle an amount of y, what is the economic value of the health benefits resulting from the reduction in mortality caused by their physical activity?".* HEAT is developed based on the best available evidence and transparent assumptions that are adaptable to local contexts. Currently, HEAT also takes the health effects of road crashes, air pollution, and carbon emissions into account. More detail of HEAT could be found on the website: https://www.heatwalkingcycling.org/.

- **Integrated Transport and Health Impact Model (ITHIM)**

The health impacts of transport policies are modelled through the changes in physical activity, air pollution, and road traffic injury risk. ITHIM models physical activity exposure by comparing the distribution of weekly physical activity under various scenarios. The changes in population physical activity and air pollution exposure resulting from the changes in health outcomes are estimated by a comparative risk assessment method. Road traffic injuries are modelled by using a risk, distance, and speed-based model (Woodcock, Givoni, & Morgan, 2013). More detail of ITHIM could be found on the website: http://cal-ithim.org/ithim/.

- **Urban and Transport Planning Health Impact Assessment (UTOPHIA) model**

UTOPHIA have been developed and applied by Mueller et al. to estimate the number of premature deaths that could be prevented by following the international exposure recommendations for physical activities, air pollution, noise, heat, and access to green spaces (Mueller et al., 2017b). Firstly, the recommended exposure levels and current exposure levels have been collected. Secondly, exposure differences between recommended levels and current level are estimated. Thirdly, the exposure-response functions quantifying the association between exposure and mortality have been obtained from the literature. Then, relative risks and population attributable fractions corresponding to each exposure difference are calculated. Finally, the number of preventable mortalities is estimated.

According to existing evidence, traffic injury risk, exposure to air pollution and noise pollution, and transport-related physical activities are the most common transport-related health impacts that have been selected in HIAs. The other health impacts, such as health effects caused by transport-related community severance and stress due to traffic congestions, have gained little attention and been often not mentioned in transport HIAs. As a result, the opportunities to improve public health may be missed.

- **Opportunities and challenges of HIA in transport**

Overall, relationships of transport and health are gaining substantial attention at local, regional, and international levels, together with the increase in the awareness among individuals and communities of having good health to ensure happy lives and promote sustainable development. Therefore, HIA is a promising approach to facilitate health considerations into the transport decision-making process, supporting transport decision-makers to select the alternatives that are better for health and raise the awareness of their decisions on health. Transport HIA also facilitates the collaboration among stakeholders, including the general public, health professionals, transport planners and decision-makers, academic researchers, and others. Thus, city planners and decision-makers should consider HIA as a useful supplement to the current planning process rather than a burdensome additional requirement (Forsyth, Slotterback, & Krizek, 2010). Based on existing evidence, HIA in transport is growing rapidly; however, applying and conducting transport HIA in practice is still facing many challenges that need to be addressed to promote transport HIA and its effectiveness. Some major challenges are reported by (Waheed et al., 2018), (Nieuwenhuijsen et al., 2017), (Nieuwenhuijsen et al., 2020) and summarised as below:

- Lack of legal requirements for conducting HIA in practice, therefore, lack of the interest among transport decision-makers to integrate health considerations into their decision-making process routinely.
- Lack of data, especially quantitative data such as levels of exposure and health impacts of these exposures. For conducting quantitative, assumptions may contain uncertainties.
- Lack of standardised methods for assessing health impacts, and the complicated of quantitative HIA, which often makes it difficult for practitioners and policy-makers to conduct, resulting in the limited of quantitative HIA.
- Lack of relevant skills, expertise, and resources for conducting HIA.
- Incomplete inclusion of decision-makers as key stakeholders to increase the effectiveness and impacts of HIA.
- Difficulty to access the HIA report, the document related to HIA is often published as grey literature and not widely published in peer-reviewed literature.
- Lack of comprehensive HIA transport affects health in many aspects, but only some major health effects have been selected for assessment; the knowledge of many other health impacts of transport remains limited and is often ignored in HIA.

The majority of HIA in transport have been conducted in developed countries so far. In developing countries, health is still largely ignored in transport decision-making due to lack of relevant data, knowledge, expertise, and resources for conducting HIA, which may have immense impacts on population health, reduce the quality of life, and generate significant costs to solve the related-health problems. By institutionalising HIA in decision-making progress, these countries could avoid the mistakes and learn experiences from developed countries to mitigate adverse transport-related health impacts, which have long-term benefits for society in terms of overall well-being, productivity, prosperity, and reduction in healthcare costs. Therefore, spending in this area should be considered as societal investments rather than societal costs (Khreis et al., 2016).

5.3.2Propose a health impact pathway of transport

The negative health impacts of the transport system are highly related to private motorised transport, especially with individual combustion vehicles. Researchers, academics, and policy-makers have been trying to estimate the health impacts of transport for decades. However, due to the limitation of data and research methods, the estimation is still limited at some major direct health impacts such as fatalities and injuries due to traffic accidents, exposure to vehicle emissions, and exposure to traffic noise. The other indirect health impacts such as the threat of catastrophic environmental damage through climate change, to which vehicle emissions are a key contributor, effects of sedentary lifestyles resulting from frequent use of motorised vehicles are largely unknown. Therefore, the magnitude of the health impacts related to private motorised transport is predicted significantly higher than existing estimations.

Despite the negative health effects associated with private motorised vehicles, the number of motorised vehicles is still increasing due to the increase in travel demand and lack of travel alternatives (e.g., inadequate public transport system). The travel demand is predicted to increase continuously due to economic development, population growth and urbanisation, particularly in urban areas where the current transport system has already experienced an imbalance between supply and demand. The increase in travel demand creates pressures to increase the number of private motorised vehicles, energy consumption, transport infrastructure, land consumption, climate change, noise pollution, and air pollution. As a result, if no effective solution is implemented, the negative health effects of the transport system will become worse.

The author reviewed the all-potential health impacts of the transport system that was described in chapter 2 and chapter 3. Based on the findings from these chapters, a health impact pathway of transport is developed and presented in figure 5-3. Transport policies affect the transport modal share in an urban transport system, which turns out to affect commuters' health and the general population' health. The proposed framework provides the fundamental background for transport planners, decision-makers, and other stakeholders an overview of how a transport policy could affect health. This also enables them to initially predict or estimate the health impacts of a proposed policy, programme, or project and decide whether an HIA should be implemented.

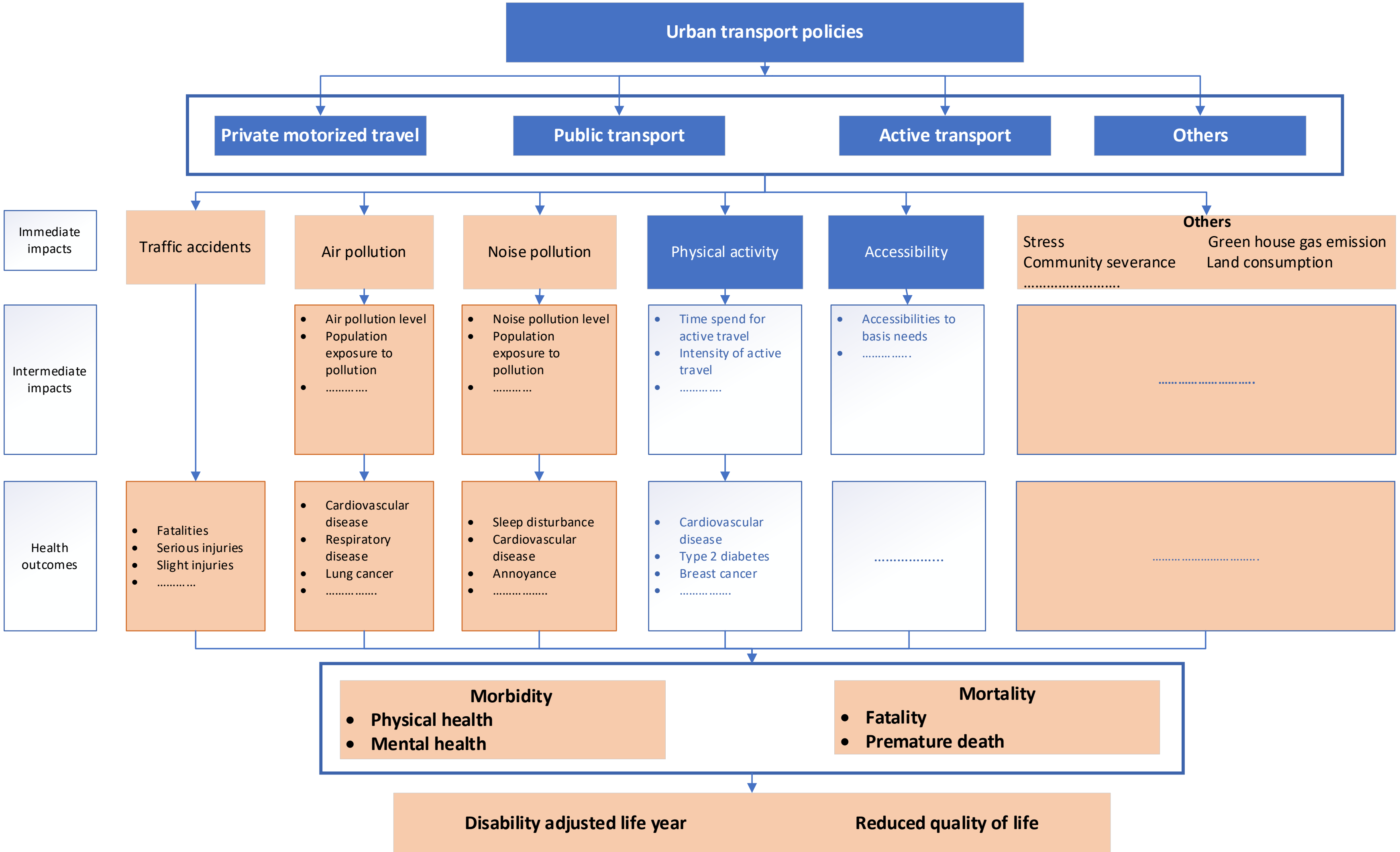

Figure 5-3: Health impact pathway of transport (Source: Author)

5.4 HIA of increasing active transport and public transport use in HCMC

The awareness of public authorities and the general population about the negative health impacts of transport such as traffic accidents and exposure to traffic-related air and noise pollution is increasing in HCMC. Active transport and public transport are an instrumental factor in promoting health and addressing other urban transport problems in the city. However, the awareness of these benefits of active transport and public transport remains low in HCMC, especially among commuters. This section aims to conduct an HIA of increasing active transport and public transport use in HCMC. Three main objectives of this HIA are (1) investigating the association between transport mode use and its health impacts on commuters, (2) examining the health impacts of increased active transport and public transport in HCMC, and (3) providing knowledge and raising the awareness of general population and public authorities about the benefits of promoting active transport and public transport.

Increased walking, cycling, and using public transport have potential impacts on health, both on commuters and the general population. As presented in chapter 3, among different transport modes, active transport and public transport have the least impacts on the general population's health. However, they may experience higher negative impacts on their health, compared to private motorised transport commuters. Therefore, this HIA focuses mainly on the health impacts of new active commuters and new public transport passengers, who shift from cars and motorcycles to walking, cycling, and travelling by buses. The health impacts of this proposal on the general population will be discussed to some extent. This HIA also focuses on four major transport-related health impacts including traffic accidents, exposure to traffic-related air pollution, exposure to traffic-related noise pollution, and transport-related physical activity. Figure 5-4 presents a causal pathway showing the health impacts of increased active transport and public transport in HCMC. This is an advocacy HIA and conducted alone by the author; together with lack of time and finance, the author will focus only on the assessment stage in the HIA process. Two major tasks in the assessment stage are (1) to develop a baseline profile of population who affected by the proposal and (2) to assess and characterise the potential health impacts of the proposal.

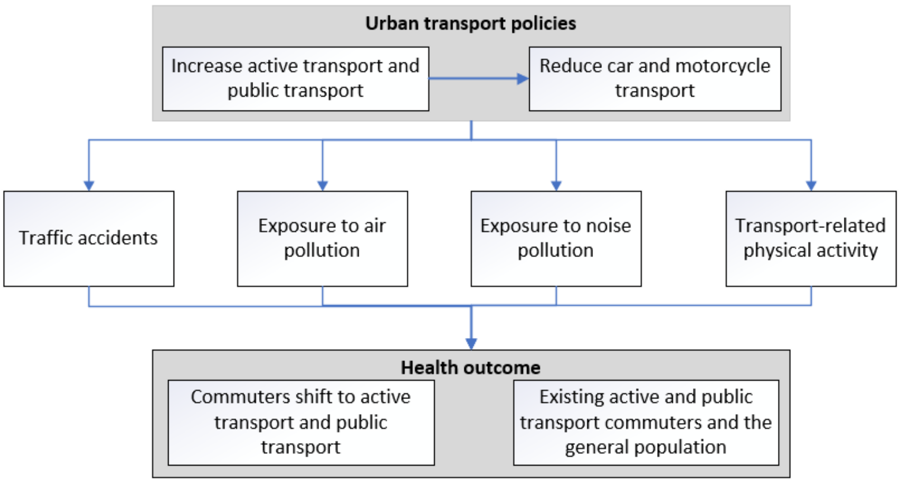

Figure 5-4: Causal pathway of the health impacts of increased active transport and public transport use in HCMC (Source: Author)

The objective of developing a baseline profile is to investigate the health impacts of transport mode use on its commuters, highlighting the health benefits and health drawbacks of walking, cycling, and using buses. As presented in chapter 4, the data on transport-related health impacts in HCMC is limited and largely unavailable. Therefore, two surveys were conducted to establish the baseline profile, including the measurement survey and interview survey. These two surveys aim to collect primary data to explore the level of exposure to air pollution and noise pollution and the health status of different road users, based on their transport mode use. Additionally, other methods such as literature review and observation were also carried out to present the baseline profile comprehensively. The following parts will explain briefly how two surveys were conducted, primarily focusing on the results of surveys. The detail of survey designs, route selections, measurement devices, minute ventilation rate estimation, interview questionnaires, and some descriptive results are presented in the appendix B and C.

5.4.1Measurement survey

A: Survey description

The measurement survey aims to measure levels of exposure to air pollution and noise pollution during commuting for different road user groups in HCMC. Then, the dose of inhaled pollutants during commuting are calculated for each commuter group by taking into account travel time and minute ventilation rate.

The measurement survey was conducted in HCMC, Vietnam. The survey period was 4 weeks, starting from 4th October to 31st October in 2019, on weekdays only to avoid irregular traffic conditions, and no measurements were taken in rainy conditions.

- **Measuring times and routes**

The measurements were carried out for five transport modes, including car, bus, motorcycle, bicycle, and walking on two selected routes. Due to the limited number of measurement devices (only one set of devices), the measurement cannot simultaneously be conducted for different transport modes. Therefore, there were around 2 to 4 days of measurement for each transport mode during the measurement campaign. On each measurement day, a person carried real-time air pollution and noise measurement devices in specified route and commuting mode during both heavy-traffic times (06:30-9:00 and 16:30-19:00) and light-traffic times (10:00-12:00 or/and 14:00-16:00). A trip was defined as from the starting point to the endpoint through the specified route.

Two routes were selected for the measurement survey and described in figure 5-5. Route 1 is one of the main routes, connecting districts 2, 9 and Thu Duc to the city centre. And route 2 is one of the main routes, connecting the city centre to district 2,9, Thu Duc, Binh Duong province, and Dong Nai province. These two routes had nearly the same origins and destinations. Route 1 starts from a bus stop located in front of HUTECH university (HUTECH bus stop) and end at Ham Nghi Bus station. Route 2 starts from Hang Xanh bus stop (around 500 metres far away from HUTECH bus stop) and also end at Ham Nghi bus station. Ham Nghi bus station is the largest bus station in the city centre (serving more than 30 bus lines). Many universities, schools, companies are located along these two routes. Therefore, the travel demand on these two routes is relatively high, and congestion happens relatively often. These two routes also represented as an example of typical commuting route of HCM citizens, which covers a representative range of microenvironments existing in the transport network in the city including large roads (multiple lanes, two directions), small roads (1 lane, 2 lanes, one and two directions). The length of two routes were both approximately 5.4 km.

Since the whole route was too long for walking (5.4 km), four road sections along two routes were selected to measure the level of exposure to air pollution and noise pollution for pedestrians. The walking distances were around 500 to 1000 metres.

Section 1 is located in front of HUTECH university; this section has high density of street vendors who cook and sell their foods and drinks at the same time. Gas and coal are used by street vendors for their cooking activities. The cooking activities happened for whole day at this road section, more in the morning and afternoon time. Section 2 also has some cooking activities, which, however, was much less than section 1. And cooking activities happened only in the morning time. But in section 2, the sidewalk is quite small, and pedestrians walked close to traffic. Section 3 is located along Le Duan street, there were no cooking activities along this section, and there was a small median between road and sidewalk. This section has higher traffic volume in the morning peak hours than in the afternoon peak hours. Section 4 is located along Dien Bien Phu street, there were no cooking activities along the select sections, one side of this section is buildings, and the other side is a park. The locations of four sections were marked in the figure 5-6.

Apart from mobile measurement, five bus stops located along two specified routes were also selected for measuring the exposure levels of air pollution and noise during waiting time for the trips using public transport as this happened to be inherently associated with public transport trips.

Figure 5-5: Study area (Map source: Google maps)

Figure 5-6: Selected sections for walking trips (Source: Author)

- **Transport modes**

Five transport modes were selected for measurement including car, bus, motorcycle, bicycle, and walk.

For measurement in car, different taxis were rented by using car sharing services (Grabcar), the instruments were placed on the front passenger seat, nearby the surveyor. The information of vehicle was answered by the taxi drivers during commuting time. All of vehicles are under 3 years old and powered by gasoline. Because of the hot weather in Ho Chi Minh city, all taxis were operated with air conditioning on and closed windows.

When measuring on buses, the surveyor chose a random seat (if available) or stood and wore the instruments that were tied to their backpacks. Measurements were conducted on bus line number 19 on route 1 and bus line number 93 on route 2. These two bus lines have similar vehicles' characteristics; buses are relatively new, powered by compressed natural gas (CNG), all windows were closed, and air conditioning was turned on when operating.

When measuring on motorcycles and bicycles, the instruments were tied in the backpack of the surveyor. The surveyor also tied the devices in her backpack and walked along four selected road sections for walking trips, with walking distances around 500 to 1000 metres long.

The average temperature and humidity during the measuring period were 28.2 degrees and 70.9%, respectively. There was only one set of measuring devices; therefore, there is no spare equipment's available to set up a background site during the measuring campaign. However, the author did several measurements at the park (Le Van Tam Park) located along route 2. The result showed only small differences in the level of air pollution concentrations between measuring times. This could be assumed that the air pollution concentrations during the measuring campaign did not vary much.

- **Estimate the inhaled doses of air pollutants**

The inhaled doses of air pollutants for each transport mode were calculated by multiplying trip averaged concentration of air pollutants and trip duration and minute ventilation value. This method was used in many studies to compare the inhaled doses of pollutants (such as $PM_{2.5}$, CO, PM_{10}, UFP) for different transport modes (J. Huang, Deng, Wu, & Guo, 2012), (de Nazelle et al., 2012), (Ham et al., 2017),(Apparicio, Gelb, Carrier, Mathieu, & Kingham, 2018),(Zuurbier et al., 2010), (Okokon et al., 2017b).

The formulas below were used to calculate the average amount of UFP number concentration and UFP mass concentration commuters inhaled during their commuting trips. The first formula (Eq 1) was used to calculate the inhaled dose of commuters travelling by car, bus (in the vehicle only), motorcycle, bicycle, and on foot. However, bus users generally have to walk from their origins to the bus stops and/or from the bus stops to their destinations and wait at the bus stops. Therefore, bus users also exposed to air pollution while they were walking and waiting. The second formula (Eq 2) was used to calculate the bus users' inhaled dose per bus trip. The walking time and waiting time were taken from the result of the interview survey, assuming that all bus users have to wait for one time for their bus trip. The average concentrations of UFP number and UFP mass were taken from the measurement survey. The values of minute ventilation, also called inhalation rate (amount of air inhaled per minute) was estimated based on the literature.

$$Inhaled\ Dose_{trip} = UFP_{average,i} * VR_i * T_i \quad \textbf{(Eq 1)}$$

$$Inhaled\ Dose_{whole\ bus\ trip} = UFP_{average,i} * VR_i * T_i + UFP_{average,wait} * VR_{wait} * T_{wait} + UFP_{average,walk} * VR_{walk} * T_{walk} \quad \textbf{(Eq 2)}$$

With: $UFP_{average,i}$: average UFP concentration of transport mode i (#/cm^3 or µg/m^3)

$UFP_{average,wait}$: average UFP concentration during waiting time (#/cm^3 or µg/m^3)

$UFP_{average,walk}$: average UFP concentration during the walking time (#/cm^3 or µg/m^3)

VR_i: minute ventilation rate of transport mode i (L/min)

VR_{wait}: minute ventilation rate during waiting time (L/min)

VR_{walk}: minute ventilation rate during the walking time (L/min)

T_i: travel time of transport mode i (minute)

T_{wait}: *Average* waiting time of bus users at the bus stop (minute)

T_{walk}: Average walking time of bus users, including walking from origin to bus stop and from bus stop to destination (minutes)

- **Estimate ventilation rate**

Ventilation rate also called as minute ventilation or respiratory minute volume is the volume of air inhaled or exhaled from a person's lungs per minute (Source: https://en.wikipedia.org/wiki/Minute_ventilation). In general, minute ventilation is associated with the metabolic oxygen needs of the body mostly depending on individual characteristics (e.g., age, gender, health situation), type of activities (e.g., working, siting, cycling), and environmental conditions (e.g., temperature). To estimate minute ventilation, five common methods were used: (1) methods using (physical) activity types, (2) methods based on energy expenditure, METs (metabolic equivalents of task), and oxygen consumption, (3) methods based on heart rate or (4) breathing rate, and (5) methods that combine heart and breathing rate (Dons et al., 2017).

Differences in minute ventilation between commuter groups influence their inhaled doses of air pollution and affect their health differently. Several studies measured minute ventilation of different activities, including commuting with different transport modes. However, the results of minute ventilation varied across these studies because of differences in measurement design, used devices, personal characteristics, and environmental conditions. In HCMC, studies that measured minute ventilation are not available yet. Therefore, for in this study, the author did review the studies that measured minute ventilation when commuting with different transport modes. The reviewed studies are described in appendix B. Then, the average ventilation rate was calculated, based on the results from previous studies, and these values were used to estimate the inhaled doses of air pollutants for different commuter groups. Table 5-3 presents average ventilation rate estimated for this study.

Table 5-3: Ventilation rate of commuters

Activities	Ventilation rate (L/min)	Remark
Car driving	12.5	
Bus travelling (in vehicle only)	13.7	
Motorcycle driving	13.7	Same value as commuting by bus
Bicycle driving	37.3	
Walking	25.6	
Waiting at bus stop	9.0	Average value between siting and standing

There were no studies measuring minute ventilation while travelling by motorcycles. Due to the hot weather condition and frequent stop-and-go traffic, the minute ventilation while riding motorcycles should be higher than travelling by cars. In this study, the author assumed that minute ventilation while riding motorcycles was similar as that while commuting by buses. Minute ventilation for waiting time at a bus stop is the average value of minute ventilation while standing and sitting, because the bus users may seat and stand during their waiting time.

- **Measurement devices and measured indicators**
  - **Air pollution measurement device: Partector 2**

For air pollution, a portable device named Naneos Partector 2 manufactured by Naneos Particle Solutions GmbH in Switzerland was used. The Partector 2 is in conformity with the provisions of the two European Directives (2011/65/EU and 2014/53/EU). This device is characterised by small size, low weight and long battery lifetime; thus, it is well suited for mobile measurement. The device measures numbers of particle concentration (UFP), average UFP diameter, and lung-deposited surface area (LDSA) simultaneously. In addition, ultrafine particle (UFP) surface and ultrafine particle mass concentrations are calculated and displayed by using the measured diameter of the particles. The detail of specification of the device is presented in appendix B**.** Because of the nature of the work and unavailability of laboratory equipment for this device, the calibration of device was done by the supplier itself with the error range in the industry standards. Calibration certification was provided by the supplier.

Ultrafine particles (UFPs)

Ultrafine particles (UFPs) are particles with diameter less than 100 nm, and the emission from motorised vehicles has been considered the leading source of ambient UFPs concentrations and of human exposure (Kumar et al., 2014) (HEI, 2013) (Schraufnagel, 2020). From the literature review, extensive evidence showed that exposure to $PM_{2.5}$ and PM_{10} have been associated with many adverse health effects, including cardiovascular diseases and respiratory diseases. Limit values of these air pollutants have been widely regulated and measured across the world. Recently, many researchers have been focused on investigating health impacts of exposure to UFP. However, the results of studies are still limited and inconsistent mainly because lack of routinely monitored data for UFP. Worldwide, the air quality regulations for UFP are not available yet, therefore, they have not received due attention of public authorities. Despite the limited evidence, there is strong suggestion that exposure to UFP is suspected to exacerbate harmful health effects (HEI, 2013) (Hennig et al., 2018) (Schraufnagel, 2020). Due to small size, UFPs could easily enter to human lungs and translocate into the blood and other organs.

Lung deposit surface area (LDSA)

LDSA is defined as the concentration of particle surface area per unit volume of air, weighted by the deposition probability in the lung (Fierz, Houle, Steigmeier, & Burtscher, 2011). Traditionally, the particle mass per unit of air volume is used to estimate the health effects caused by particles. However, this indicator may be not good enough for estimating health impacts because only those particles that end up in the human body could cause health effects and that is what should be measured (naneos particle solutions gmbh, 2016). With particle size from 200 to 300 nm, only about 10 % of the particles present in the air are deposited in human body, while at 40 nm diameter, about half the particles end up in our body. Thus, measure the LDSA is possibly be the most relevant metric for quantifying exposure to particles.

Based on the instruction of the manufacturer, measuring the LDSA requires the measurement of the entire particle size distribution, followed by a summation of particle surface in each size weighted by its lung-deposition probability. However, by a coincidence, LDSA could be also be measured directly by diffusion charging. Diffusion chargers impart a size-dependent charge q on particles passing through them, which could be well described by formula:

$$q \cong const \cdot d^{1.1}$$

Where d is the particle diameter. LDSA is approximately proportional to the diffusion charger signal:

$$LDSA = surface\ area \cdot deposition\ probability \cong d^2 \cdot d^{-1} = d^1 \approx q$$

Source: (naneos particle solutions gmbh, 2016)

Particle number concentration (PNC) total number of particles in one cubic centimetre of air

- **Noise measurement device: Sound level metre PCE 432**

For measuring level of noise exposure, a decibel metre PCE 432 manufacture by PCE Instruments Gmbh in Germany was used. The device complies with ICE 61672-1:2013, ANSI S1.4-1983, and ANSI S1.43-1997. The device has three measurement modes including level metre, 1/1 octave, 1/3 octave. For the purpose of this study (measuring the average sound pressure levels while commuting by different transport modes), the level metre mode was selected, which measuring sound pressure level with A frequency weighting and the data-logging interval was set 1 second. The measuring range was from 22 to 136 db (A), at a frequency of 3 Hz - 20 kHz.

Given that noise was measured on a logarithmic scale, the average value was calculated using the following formula:

$$\textit{Average noise level}\,(dBA) = 10 \times \log \frac{\left(\sum 10^{\frac{Leq}{10}}\right)}{n}$$

Where:

L_{eq}= Equivalent continuous noise level for each second
n = total number of the one-second measurements per trip

(User manual of PCE432)

<u>B: Survey results</u>

- **Descriptive statistics**

In total, 145 trips were conducted during the survey period, representing approximately 783 km of travel. However, due to weather condition (rainy) and device problem (out of batteries), 4 trips were stopped during measuring time and thus excluded from data analysis. Therefore, only 141 trips were used for data analysis, including 29 by taxi, 36 by bus, 38 by motorcycle, and 38 by bicycle. Among these trips, 71 and 70 trips were measured on route 1 and route 2, respectively, and 42, 54, and 45 trips were monitored during morning peak hours, off-peak hours, and afternoon peak hours, respectively. In addition, 53 short walking trips (around 10 to 15 minutes each trip) and 54 waiting times were measured at 4 selected sections, and 5 bus stops along route 1 route 2. The detail of this information is presented in appendix B.

Under the same routes and similar traffic conditions, the motorcycle is the fastest transport mode with an average travel duration is 22 minute per trip. While travelling by car, bus (time on the vehicle only), and bicycle have the same travel duration (29 minutes). Among three measuring times, travelling in the afternoon rush hours was longer for all transport modes, with the longest travel time for car (average 43 minutes per trip). The detail of travel duration for each transport mode is presented in appendix B.

- **Level of exposure to air pollution during commuting for different commuter groups**

Figure 5-7 presents the average levels of LDSA, UFP number concentrations, UFP mass concentrations, average UFP size when commuting with different transport modes. Overall, car and bus commuters were exposed to the lowest concentrations of LDSA, UFP number, and UFP mass. In contrast, motorcyclists and cyclists were exposed to the highest LDSA, UFP number, and UFP mass concentrations. People who were wating at the bus stops also exposed to relatively high level of air pollution due the close proximity to emissions from bypass vehicles and from idling and accelerating of buses.

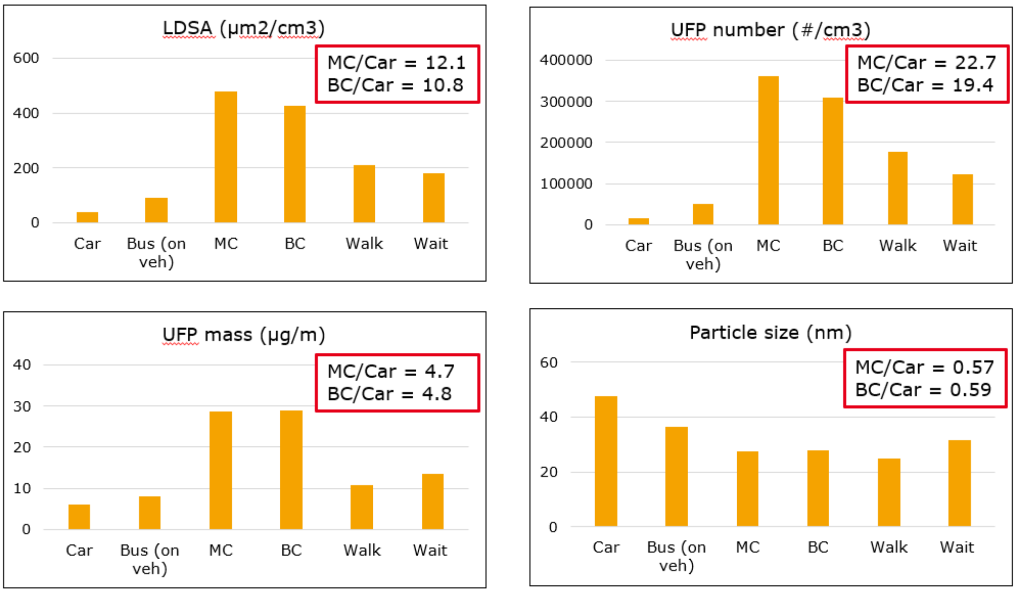

Figure 5-7: Average commuter's exposure to LDSA, UFP number concentration, UFP mass concentration, and UFP size (MC state for motorcycle, BC state for bicycle)

- **Commuters exposed to LDSA, UFP number concentration, UFP mass concentration**

Commuters exposed to LDSA concentrations

Even though LDSA is considered an appropriate indicator for estimating the health impacts of ultrafine particles, the studies that measured commuters' exposure to LDSA are very limited in the literature. The result from this measurement survey could contribute to this scarce database of LDSA.

The average LDSA concentration was 39.55 $\mu m^2/cm^3$ when commuting by cars. Commuting by bus, motorcycle, bicycle, walking, and waiting at bus stops were exposed 2.3, 12, 11, 5, and 4,6 times higher level of LDSA than commuting by car, respectively. Ham et al. measured the levels of LDSA concentration while commuting by different transport modes in Sacramento, California. Their result showed that people travelling by car and light-rail exposed to the lowest level of LDSA concentration,11 and 14 $\mu m^2/cm^3$ respectively while commuting by bus, train and bicycle ranged between 36 to 45 $\mu m^2/cm^3$ (Ham et al., 2017). These figures were significantly lower than those measured in Ho Chi Minh city. Cyclists and motorcyclists exposed to average LDSA concentration of over 400 $\mu m^2/cm^3$.

Commuters exposed to UFP number concentrations

Motorcyclists and cyclists were exposed to the highest UFP number concentrations during their commuting trips, $3.6*10^5$ and $3.1*10^5$ particles/cm^3, respectively. These figures were 23 and 19 times higher than those for travelling by car. Bus passengers exposed to a relatively low level of UFP number concentrations when travelling on buses, at around

$0.5*10^5$ particles/cm^3. Pedestrian exposed to 3.4 times higher number of UFP concentrations compared to bus users.

Compared to other studies, cyclists in HCMC exposed to a much higher number of UFP concentrations. For example, cyclists in HCMC were exposed to more than 13 times higher in UFP concentration than cyclists in Frankfurt (Germany) (Menges, 2019).

Commuters exposed to UFP mass concentrations

People who travelled by cars and buses exposed to the lowest level of UFP mass concentration, 6.06 µg/m^3 and 8.00 µg/m^3, respectively, followed by pedestrians, 10.86 µg/m^3. People commuting by motorcycles and bicycles were exposed to a similar level of UFP mass concentration, which was approximately 5 times higher than car commuters.

Buses and cars were relatively new and operated with closed windows and air conditioners on in the measurement survey. Thus, car users and bus passengers were protected from traffic pollutants by vehicle shield, which may explain why the levels of LDSA, UFP number concentration, and UFP mass concentration were considerably lower in cars and buses, compared to those on motorcycles and bicycles. The LDSA and UFP number, UFP mass tend to be higher in buses than that in cars. A possible reason for this difference is those car's windows remain closed for the whole trip, leading to reduced infiltration of particles from the ambient environment into vehicles. The filter in the air conditioning system may also contribute to preventing further ingress of particles. While, buses had to open the doors at bus stops, which may facilitate the infiltration of air pollutants from the outside environment into buses.

The levels of LDSA, UFP number and mass concentration were markedly higher while commuting by motorcycles and bicycles than by cars and buses. The main reason for this difference is that cyclists and motorcycles travel closer to tailpipe emissions, as they are often surrounded by other vehicles (buses, cars, other motorcycles). They are directly exposed to the emissions from other vehicles and road dust, air pollutants from cooking activities along the road, and pollution from smoking behaviours of other commuters while commuting without any physical protection from vehicles. In HCMC, there are no separated lane or paths for bicycles, and cyclists have to use the same road space with other motorised vehicles, explaining why they were exposed to a similar level of air pollutants as motorcyclists. However, levels of LDSA and UFP number concentrations while commuting by bicycle were slightly lower than those by motorcycle. This may be explained by the cyclists' travel behaviours. They tend to travel in the right lane closest to the sidewalk that often has less traffic than other road lanes.

Average UFP size exposure

The average particle size while travelling by different transport modes ranged from 25 to 48 nm. The average UFP diameters have an opposite trend with the number of UFP concentrations; larger average particle sizes were for transport modes with lower UFP concentrations and vice-versa. This result is similar to the study from (Ragettli et al., 2013) (Ham et al., 2017) (Menges, 2019). Motorcyclists and cyclists exposed to smaller particle sizes, compared to car and bus commuters. This is explained by the proximity of cyclists and motorcyclists to traffic, and due to small sizes, UFP could easily disperse into the air before it could enter cars or buses.

Several studies showed that smaller particles caused more adverse health effects than larger ones. The smaller particles are easier to go into cells and transcytosis across epithelial and endothelial cells into the blood and lymph circulation to reach potentially sensitive target sites such as bone marrow, lymph nodes, spleen, and heart. They retain longer in the lung compared to larger particles (Oberdorster, Ferin, & Lehnert, 1994), (Oberdörster, Oberdörster, & Oberdörster, 2005), (Tsuda, Henry, & Butler, 2013), (Meng et al., 2013), (Hennig et al., 2018), (Schraufnagel, 2020). Figure 5-8 illustrates the deposition of inhaled particles in the human body, based on particle sizes.

In HCMC, cyclists, motorcyclists, and pedestrians were exposed to a significantly higher number of UFP concentrations that have smaller average particle sizes during their commuting trips than people travelled by cars and buses. As a result, the health impacts of exposure to air pollution on cyclists, motorcyclists and pedestrian may be much higher than those on car and bus users.

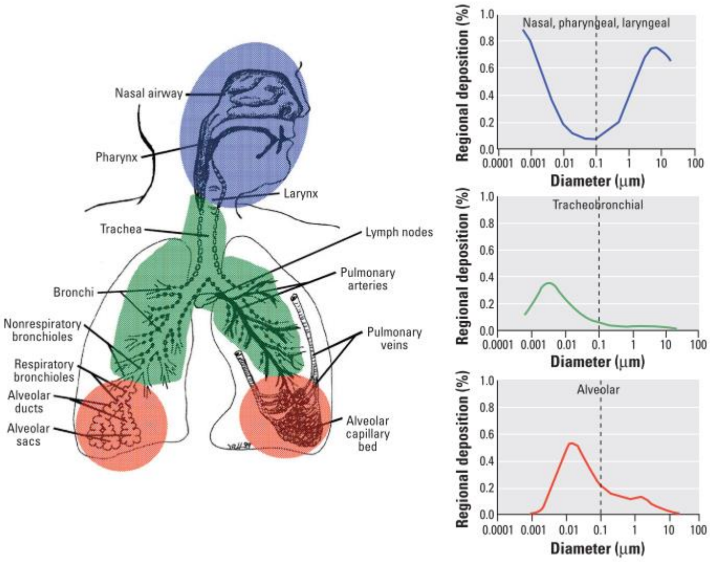

Figure 5-8: Illustration of the deposition of inhaled particles in the nasopharyngeal, tracheobronchial, and alveolar region of the human respiratory tract during nose breathing (Oberdörster et al., 2005)

- **Commuters exposed to air pollution by measuring time**

Figure 5-9 presents the level of LDSA, number of UFP concentration, UFP mass concentration, and average particle sizes by transport modes and measuring periods. From observation during the measuring campaign, traffic volume in the peak hours was considerably higher than in off-peak hours. However, car and bus commuters were exposed to relatively similar air pollution levels regardless of peak hours or off-peak hours, meaning that their levels of exposure to air pollution were only slightly affected by traffic conditions. A similar situation was also found for pedestrians and people who were waiting at the bus stops. In contrast, motorcyclists and cyclists were exposed to a significantly higher level of air pollution during peak hours than off-peak hours, showing that their exposure to air pollution was highly affected by traffic conditions.

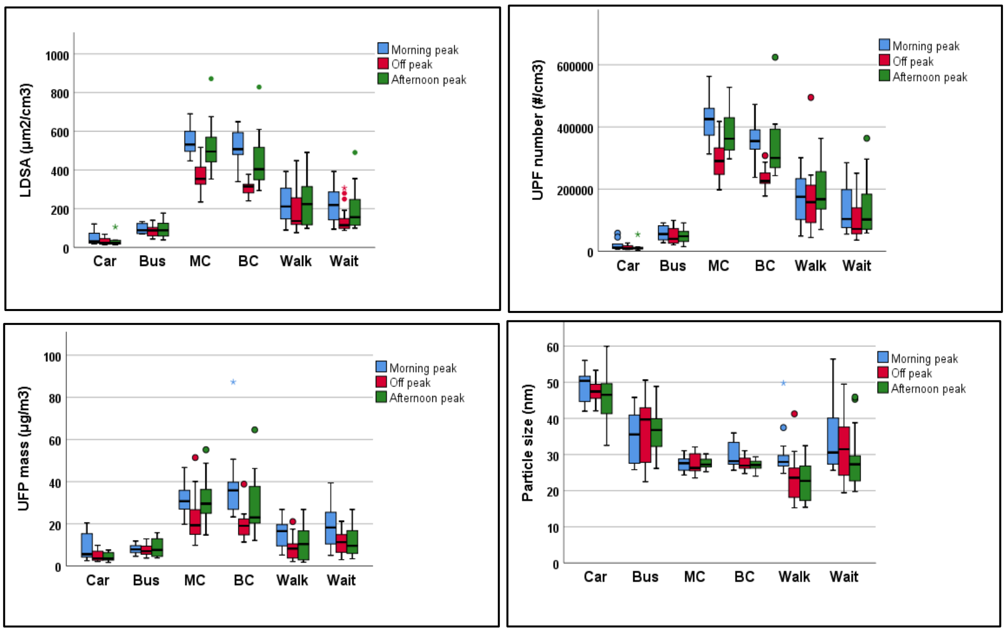

Figure 5-9: Levels of LDSA, number of UFP concentration, UFP mass concentration, and average particle sizes by transport modes and measuring periods

In addition, the values of LDSA and the number of UFP concentrations fluctuated markedly while commuting by motorcycles and bicycles. In contrast, these values inside the cars and buses were more stable. Figure 5-10 shows an example of fluctuation of UFP number concentration while commuting by car, bus, motorcycle, and bicycle.

Motorcyclists and cyclists were exposed to more frequent peak-values of UFP number concentration, with peak values were frequently above 1.000.000 particles/cm^3. This further reinforced that air pollution levels of motorcyclists and cyclists were highly influenced by traffic conditions because they were often surrounded by other vehicles with different characteristics. Other studies also found a similar trend; however, their frequented peak values were significantly lower than this study (Boogaard et al., 2009), (Int Panis et al., 2010).

In order to find out the reasons that caused high frequent peak air pollution values during motorcycle and bicycle trips, the traffic data recorded during trips and air pollution data with GPS file were checked. As results showed, these peak values often happened in the following situations: waiting for the traffic light at intersections, travelling close to old vehicles, passing cooking vehicles, moving in the stop-and-go traffic, travelling close to trucks and big buses. Bus users are sometimes also exposed to peak air pollution values mainly caused by long waiting time at bus stops with opened bus doors.

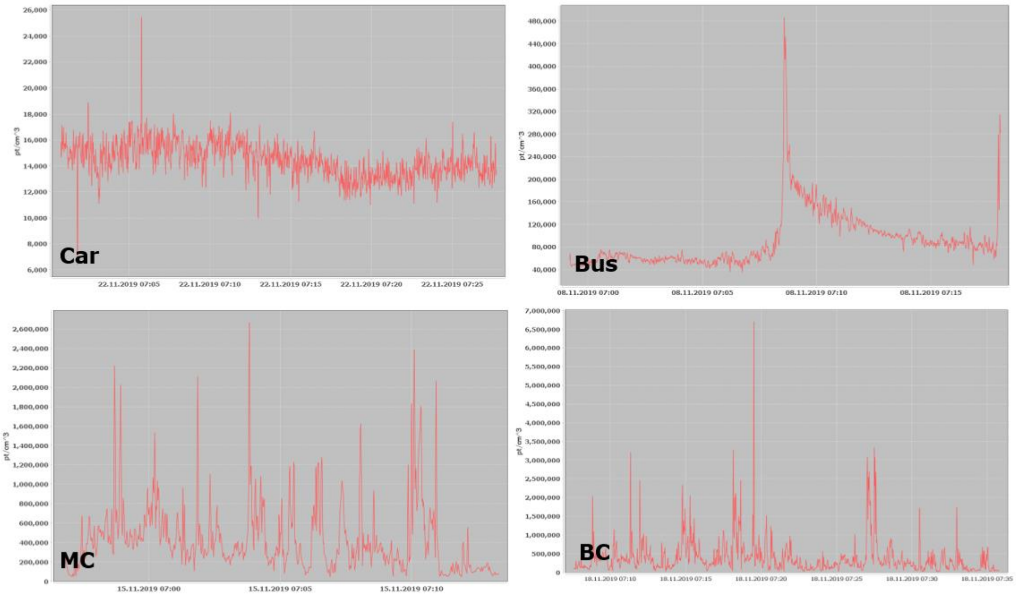

Figure 5-10: Examples of the fluctuation of UFP number concentration during commuting by different transport modes (note: the figure used for illustration purpose only)

- **Pedestrians exposed to air pollution at different road sections**

Figure 5-11 presents average exposure levels of pedestrians to LDSA, UFP number, UFP mass, UFP size at four different road sections measured in morning peak hours, afternoon peak hours and off-peak hours. The result showed that the highest concentration of LDSA, UFP number and UFP mass concentrations were at road section 1, following is section 2 and 4. Pedestrians walking at the road section 3 were exposed to the lowest level of air pollution. Traffic conditions, cooking activities and distance between sidewalk and streets had strongly influenced the levels of pedestrians exposed to air pollution.

In section 1, pedestrians had to walk along a big street (two directions, three lanes each direction) and pass a large intersection (Hang Xanh intersection). The traffic volume in this street is usually high in the morning peak hours and afternoon peak hours because it is one of the main streets to connect suburban areas to the city centre. At the intersection, there are often long queues and stop-and-go traffic in all directions. In addition, section 1 is located in front of HUTECH university; this section has a high density of street vendors who cook and sell their foods and drinks along the sidewalk simultaneously. Street vendors often use gas and coal for their cooking activities. The cooking activities happened for the whole day at this road sections but happened more often in the morning and afternoon peak hours. This explains the high level of LDSA and UFP number concentrations in the morning and afternoon hours than in the off-peak hours.

Section 2 also has some cooking activities, but much less than section 1. And cooking activities happened only in the morning time. But in section 2, the sidewalk is relatively small, and pedestrians walk closed to traffic. Traffic volume in the morning peak hours in section 2 is also higher than in the afternoon peak hours. Therefore, the levels of air pollution concentrations in the morning peak hours were considerably higher than in the off-peak hour and afternoon peak hours.

Section 3 is located along Le Duan street, there were no cooking activities along this section, and there was a small median between the road and sidewalk. This section has higher traffic volume in the morning peak hours than in the afternoon peak hours. Thus, air pollution concentrations measured in the morning peak hours were higher than the other measuring times. Section 4 is located along Dien Bien Phu Street. This is the one-way direction street, and there were no cooking activities along this section. Traffic volume in this road section was very high in the afternoon peak hours, and stop-and-go traffics happened frequently, explaining the high air pollution concentrations in the afternoon peak hours.

Previous studies described factors affecting near-road air pollution concentrations such as vehicle density, traffic flow composition, street geometry, building structures, wind speed, and wind direction (Ragettli et al., 2013), (Boarnet et al., 2011). However, there were no studies that investigated the impacts of street vender business- cooking activities, which is the case in HCMC. In this study, the result showed that cooking activities along with the sidewalk significantly influence the level of air pollution concentrations.

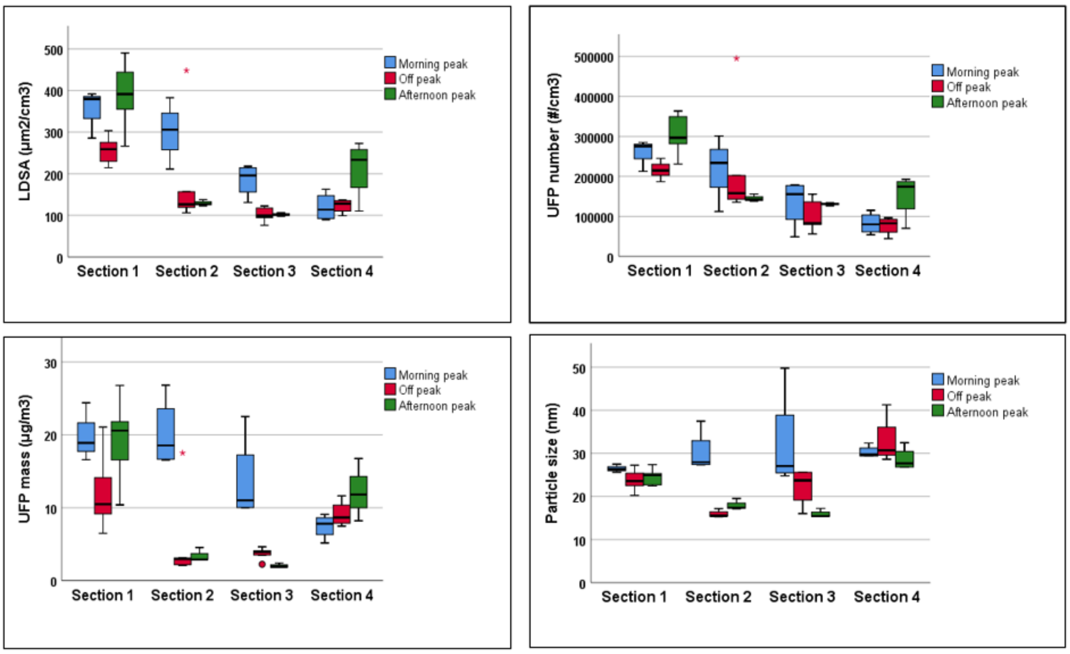

Figure 5-11: Average exposure of pedestrians to LDSA, UFP number, UFP mass, UFP size by road sections and by measuring time

- **Commuters exposed to road traffic noise according to their transport modes**

Overall, all road users in HCMC were exposed to substantially high noise pollution levels, ranging from 80.6 dB(A) to 93.2 dB(A). Figure 5-12 presents the level of exposure to road traffic noise of different road user groups. Based on the author survey result, commuters in HCMC exposed to the average noise level at 88.6 dB(A) during their commuting time. This value is much higher than the Vietnamese national regulation value (70 dB for daytime) and WHO recommendation thresholds (55 dB for daytime). Motorcyclists and cyclists were exposed to the highest noise level during their trips. Therefore, in terms of health impacts due to exposure to road traffic noise, they are the most affected.

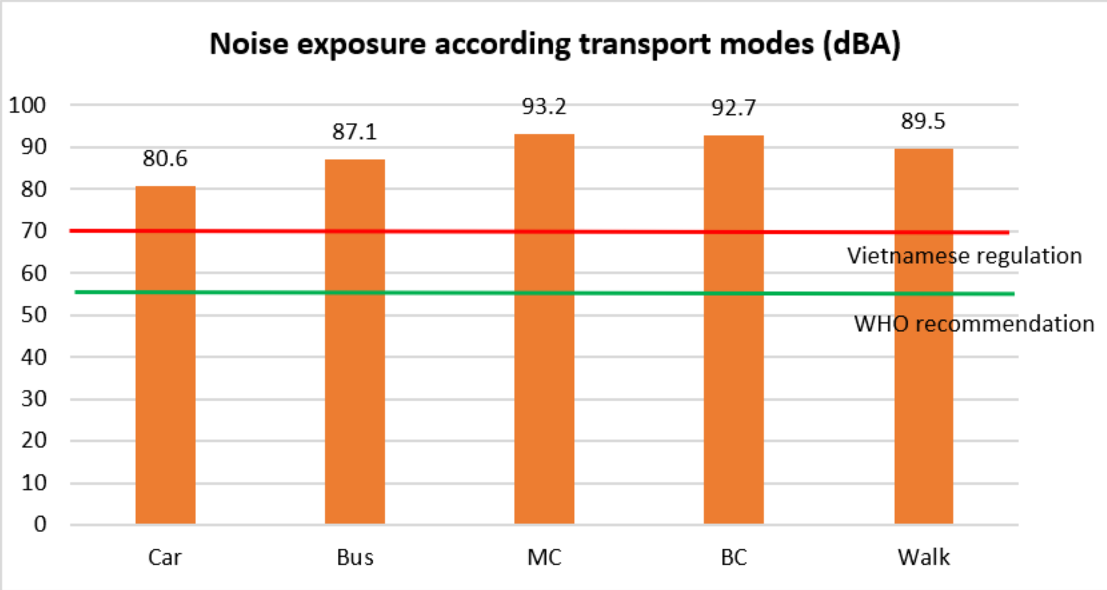

Figure 5-12: Noise exposure according to transport modes

- **Inhaled dose of UFP number and UFP mass for different commuter groups**

Figure 5-13 presents the average amount of UFP numbers and UFP mass that different commuter groups inhaled during their trips. To calculate the inhaled dose of the whole bus trip, walking time from origin to bus stop, and bus stop to destination and waiting time at the bus stop is taken into account. These numbers are taken from the interview survey, assuming that bus passengers take only one bus for their trip. In the interview survey, 209 bus users were interviewed. On average, a passenger spent 12 minutes walking and 10 minutes waiting. The UFP number and UFP mass concentration levels that passengers exposed to during waiting time at bus stops are average values measured at five bus stops. For walking, an assumption of average walking speed is 5 km/hour. With a distance of 5.4 km, it is 65 minutes to walk. And the average UFP number concentration and UFP mass concentration during the walking trip (53 trips) is calculated by average values measured at four road sections. The methods for calculating the inhaled dose of pollutants for different commuter groups were presented in the previous section.

When commuting time and minute ventilation were taken into account, cyclists inhaled the highest amount of air pollutants because they had the longest travel time and the highest minute ventilation. The number of UFP numbers and UFP mass that cyclists inhaled were 65 and 16 times higher than car commuters, respectively. The following were pedestrians, they inhaled nearly 53 and 9 times higher UFP numbers and UFP mass than car users. People who commuted by cars inhaled the lowest amount of air pollutants. Bus passengers and motorcyclists inhaled roughly the same amount of air pollutants.

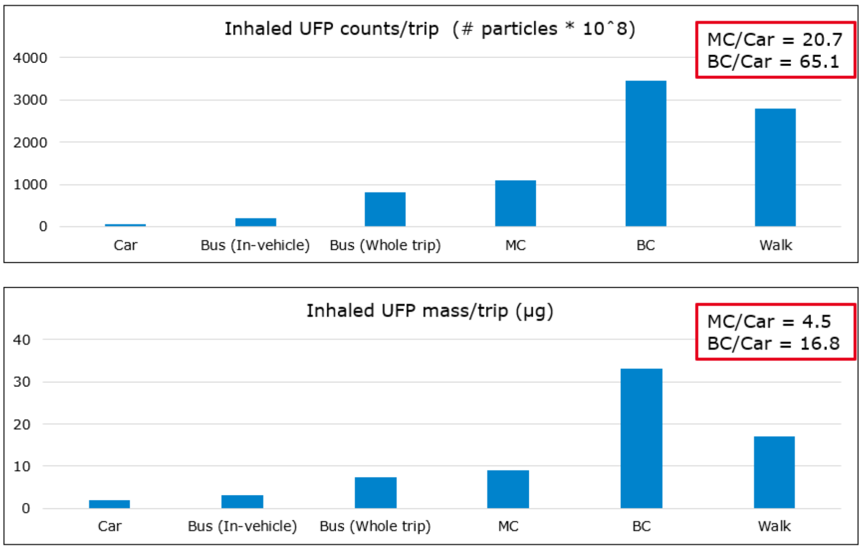

Figure 5-13: Average dose of inhaled pollution per trip by commuter groups

5.4.2Interview survey

A: Survey description

Interview survey aims to (1) investigate the health impacts of transport mode use on commuters, (2) understand the perception of commuters about health impact factors when selecting their daily transport modes, and (3) investigate the willingness to change to healthier transport modes of commuters. A questionnaire was developed, based on the findings from chapter 2 and 3 in this study.

- **Questionnaire design**

The questionnaire has six parts and presented in the appendix C. Part 1 includes the questions related to vehicle ownership and transport mode use, focusing on the most frequent and regular transport mode use for daily commuting. Part 2 focuses on the health status of interviewees, covering both physical health and mental health and self-evaluation of their health status. In Vietnam, the majority of people did not take regular health check and often go directly to pharmacies buying medicines without prescriptions from health professionals. Therefore, the interviewees will be asked two questions regarding the health issues, including (1) health problems if they have been told by any health professionals and (2) health problems based on their personal feelings. The health problems asked in this part were identified based on the health impacts of transport mentioned in chapter 2 and 3. The questions related to evaluating the importance of health impact factors and other factors such as travel time and travel cost when selecting the daily transport mode are presented in part 3. In this part, the questions of the willingness to change to healthier transport modes are also asked. Part 4 includes the questions related to outdoor activities. This interview survey was partly funded by the Institute of Transport Planning and Technology at the Technical University of Darmstadt. The purpose of part 4 in the questionnaire is used for the project for "Sustainable and Health-Oriented Traffic and Urban Planning (SHOTUP)". Therefore, the result of part 4 will not be discussed within the scope of this study. The general information of interviewees is mentioned in part 5. And finally, the smoking and drinking behaviours of commuters are asked in part 6.

As mentioned in chapter 5, health is affected by a large number of factors, and transport mode use is only one of these factors. Among factors influencing health, smoking and drinking behaviours are strongly associated with cardiovascular and respiratory diseases, and these diseases are also resulted from exposure to air and noise pollution. In addition, the daily commuting modes may also affect the daily habit of commuters and vice versa. Therefore, smoking and drinking behaviours were included in the questionnaire.

- **Interview methods**

The survey was conducted through face-to-face interviews and online interviews. A group of surveyors were trained to do face-to-face interviews. A small pilot survey was conducted before starting the main survey to ensure that the surveyors understood the questionnaire well. The online interview was carried out by using Google form.

<u>B: Survey results</u>

- **Characteristics of the interviewees**

In total, 1105 people were interviewed. However, 24 interview samples were excluded from the analysis because they used other transport modes, and some samples were missing information. Therefore, the data from 1081 interview samples were used for analysis, including 206 pedestrians, 203 cyclists, 255 motorcyclist, 208 car users, and 209 bus passengers.

Their socio-economic characteristics are presented in figure 5-14. Overall, 56% of respondents were male, and 44% of respondents were female. People under 15 years old were not included in the interview samples because they were considered the dependent travel group. Their daily travel and their transport mode choice still highly depended on their parents.

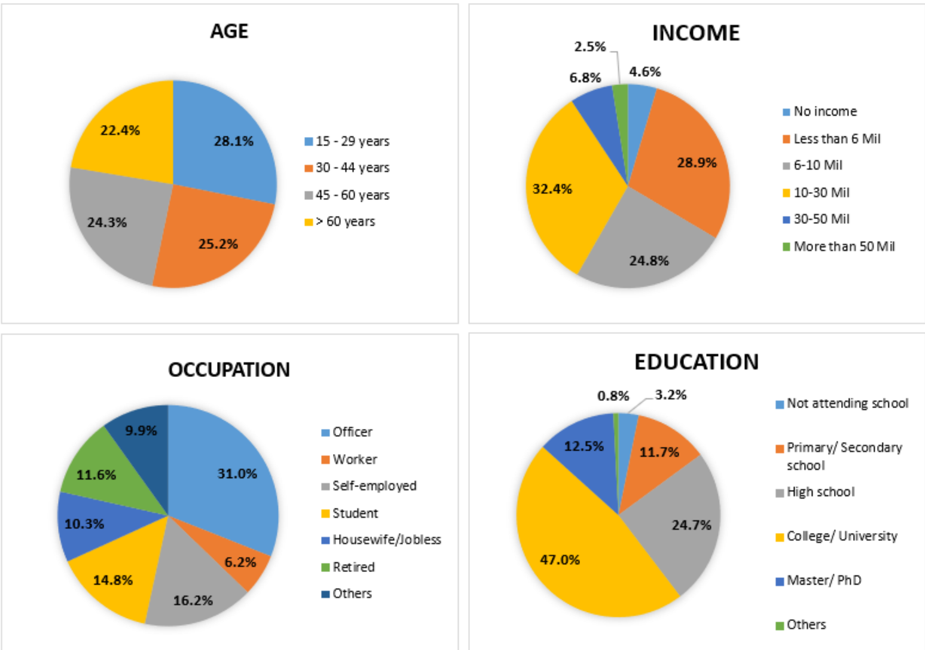

Figure 5-14: Characteristics of respondents

- **Distribution of transport mode use and trip purposes and income**

The survey revealed that the majority of car users (48%) used their vehicles for work purposes, as opposed to 18% for meeting friend and family. Meanwhile, 37% of motorcyclists used their vehicles for work, and 20% used them for shopping trips. It is interesting to find that 37% of bus users also used buses for working trips, meaning that many people were not considered buses a transport mode for students and low-income people. This is different from the common belief that buses are for students and low-income people. Around 19% of bus passengers used buses for study trips. People who walk and cycle used their vehicles for all purposes; there were no big differences between the frequency of walk and cycle and trip purposes. The distribution of transport mode use and trip purposes is presented in figure 5-15.

More than 75% of bus passengers, cyclists, and pedestrians had a monthly income below 10 million VND (equal to 435 USD/month or 358 EUR/month). Meanwhile, around 52% of motorcyclists earned less than 10 million VND a month, and more than 88% of car users were paid above 10 million VND.

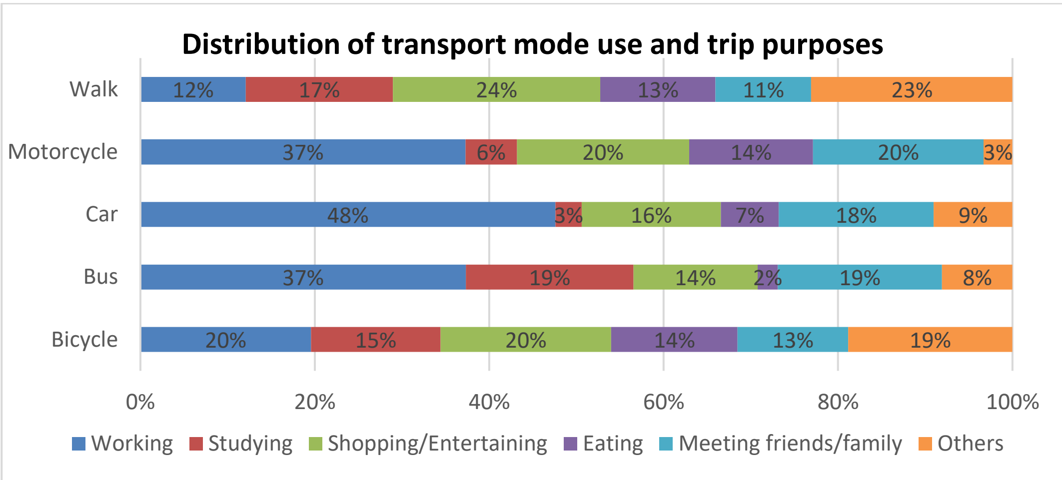

Figure 5-15: Transport mode use and trip purposes

- **Transport mode use and health status**
  - **Self-evaluation health status and satisfaction with health status among different commuter groups**

Figure 5-16 shows the self-evaluation of the health status of different commuter groups. Overall, only 5% of commuters thought their health was poor, and 10% thought they were in good health conditions. Nearly half of the respondents graded their health as good, and around 37% categorised it a in normal condition.

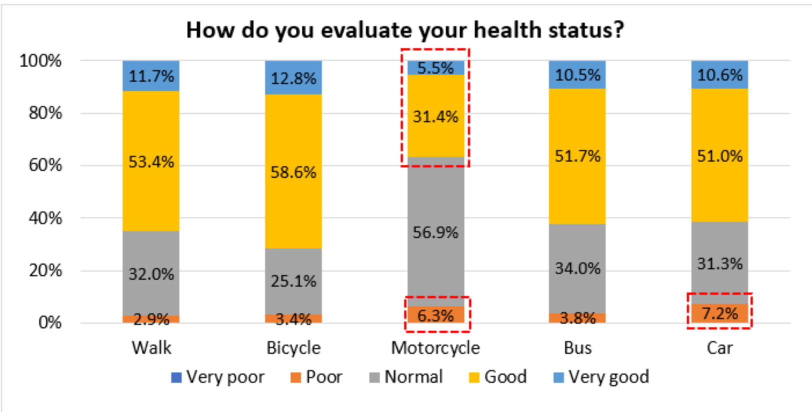

Figure 5-16: Commuters evaluated their health status

However, when taking a deeper look into different commuter groups, cyclists had the highest percentage of respondents regarded their health conditions as good and very good, around 70%, followed by 65% of pedestrians. In contrast, motorcycle and car commuters had the highest percentage of respondents who thought they were in poor health conditions, 6.3 % and 7.2 %, respectively. Only 36.9% of motorcyclists grouped their health in good and very good conditions.

A similar trend was also found when interviewees were asked about their satisfaction with their health status. Generally, the majority of commuters in HCMC were satisfied with their health status, with around 77% of interviewees who replied that they were satisfied and completely satisfied with their health conditions. Pedestrians and cyclists were the most satisfied and completely satisfied with their health status (more than 80% for each group). People commuting by motorcycle and car had the highest percentages of interviewees who responded that they were dissatisfied with their health status,7.5% and 8.7%, respectively.

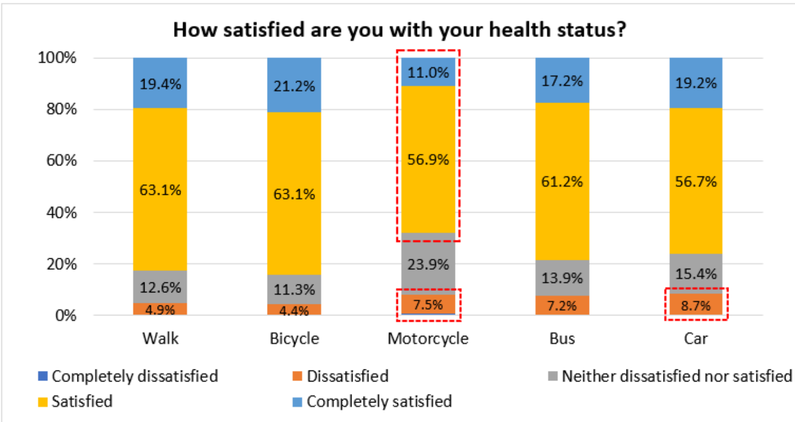

Figure 5-17: Level of satisfaction of the health status of different commuter groups

In this study, the author suggested that daily commuting transport mode may affect commuters' social and family relationships. Therefore, interviewees were also asked to evaluate their satisfaction levels with their social and family relationships. The result showed that 75% of commuters were satisfied or completely satisfied with their social relationship, and more than 90% of commuters were satisfied or completely satisfied with their family relationship. There were no big differences in the levels of satisfaction with family and social relationship among pedestrians, cyclists, motorcyclists, and car users. Only the bus commuter group had a slightly higher number of respondents dissatisfied with their social and family relationships than other groups. Therefore, it is not clear that commuting mode affects commuters' social and family relationships or not; further studies on this issue are desirable.

- **Health issues of different commuter groups**

Health problems reported by health professionals

Commuters were asked about their health problems that were reported by health professionals for the last 12 months because the health impacts of transport mode use may not happen within a short period of time, and most of the harmful traffic-related air pollutants (e.g., $PM_{2.5}$, PM_{10}, ...) used in examined association transport-related health impacts are annual values.

The result showed that respiratory diseases, cardiovascular diseases, and sleep problems were the most common health issues reported in all commuter groups. Overall, 28% of all commuters had respiratory diseases (e.g., asthma, throat irritation, bronchoconstriction, chronic obstructive pulmonary). Around 17% of commuters had cardiovascular diseases (e.g., hypertension, heart failure, stroke, arrhythmia, heart attack), and 21% of respondents had sleeping problems (e.g., sleepiness, sleep disorder, insomnia). Next come health issues related to skin problems (e.g., acne, skin ageing, atopic dermatitis, skin cancer), eye problems (e.g., eye irritation, dry eye, redness, watery eyes, sore eyes), hearing problems (e.g., tinnitus, hearing loss), and mental health problems (e.g., depression, bipolar affective disorder), with 13%, 15%, 7%, and 6%, respectively.

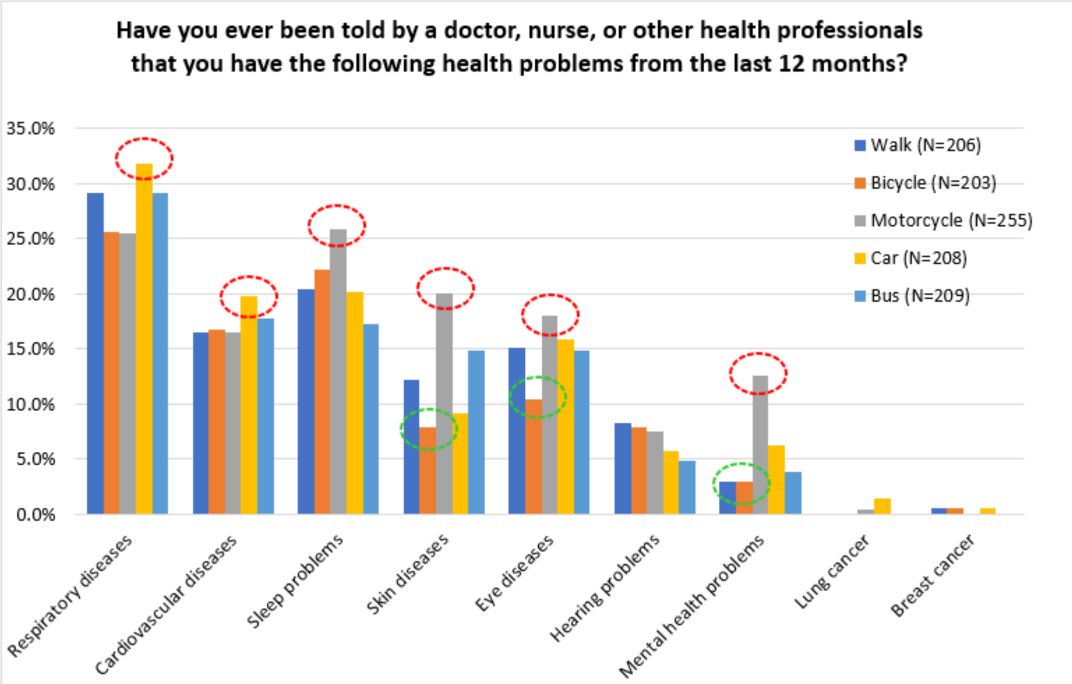

Figure 5-18: Health issues of different commuter groups (note N: total interviewed samples for each commuter group)

There were differences in health problems among various commuter groups. Figure 5-18 shows the health problems of various road user groups. Car users had the highest percentages of respondents with respiratory (31.7%) and cardiovascular diseases (19.7%). Meanwhile, motorcyclists had the highest percentages of respondents with sleep problems, skin problems, eye problems, and mental health problems, with 25.9%, 20.0%, 18.0%, 12.5%, respectively. Especially for skin diseases and mental health problems, motorcyclists had a significantly higher number of people having these diseases than other traveler groups. Compared to car and motorcycle users, cyclists had lower percentages of respondents who reported having health issues. The biggest differences were found between motorcyclists and cyclists in the number of people who reported with skin diseases, eye diseases, and mental health problems.

The proportions of pedestrians and bus passengers who had respiratory diseases were also relatively high, more than 29% for each group. However, for the other health issues, including sleep problems, skin and eye diseases, and mental health problems, the number of pedestrians and bus passengers who had these health issues, they were lower than those of motorcyclists.

Health problems based on commuters' feelings

The regular health check is still not common among the population in HCMC. Many people often go directly to pharmacies to buy medicines without prescriptions from health professionals. Therefore, the interviewees were also asked about their health problems based on their personal feelings. Commuters were asked how often they feel that they have health problems in a given list for the last 12 months. Five levels of frequency were never, rarely, sometimes, often, and very often. People who responded that they sometimes, often, and very often had problem with a specific disease were assumed to have this health issue. The result showed that the figures for those who reported having health problems based on their feelings was significantly higher than that reported by health professionals. These differences are presented in table 5-4 For example, only 28% of commuters were said by health professionals that they had respiratory diseases; however, 54% of commuters responded that they had respiratory diseases based on their feelings.

Table 5-4: Differences in health in commuters' health problems based on reported from health professionals and commuters' feelings (Note: one commuter could select many health issues)

Health issues	Health problems reported by health professionals	Health problems based on commuter feelings
Respiratory diseases	**28%**	**54%**
Cardiovascular diseases	17%	31%
Sleep problems	**21%**	**46%**
Skin diseases	**13%**	**28%**
Eye diseases	15%	21%
Hearing problems	7%	12%
Mental health problems	6%	25%

Overall, when asking people about health issues based on their feeling, there were no big differences among car users, bus passengers, pedestrians, and cyclists. However, the rate of motorcyclists who reported having sleep problems, skin diseases, and mental health problems were higher than the other commuter groups. Figure 5-19 shows mental health problems and sleep problems of different commuter groups, based on their frequency of having these issues.

Regarding mental health problems, commuters were asked how often they felt stress, sadness, loneliness, angry, and difficulty to think and/or concentrate. The result revealed that the percentage of motorcyclists that had nervousness or anxiety, stress, and sadness higher than that in other commuter groups.

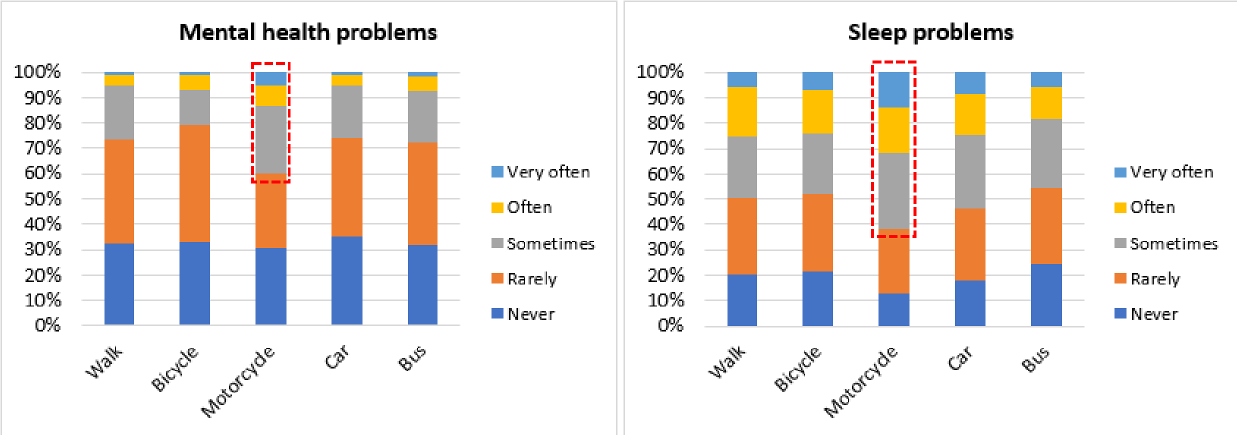

Figure 5-19: Frequency of having mental health problems and sleep problems of different commuter groups

Among commuter groups, car and bus users had the highest proportions of people who reported that they often and very often had issues related to cardiovascular and respiratory problems. The figures commuters who had eye problems and hearing problems were similar for all groups.

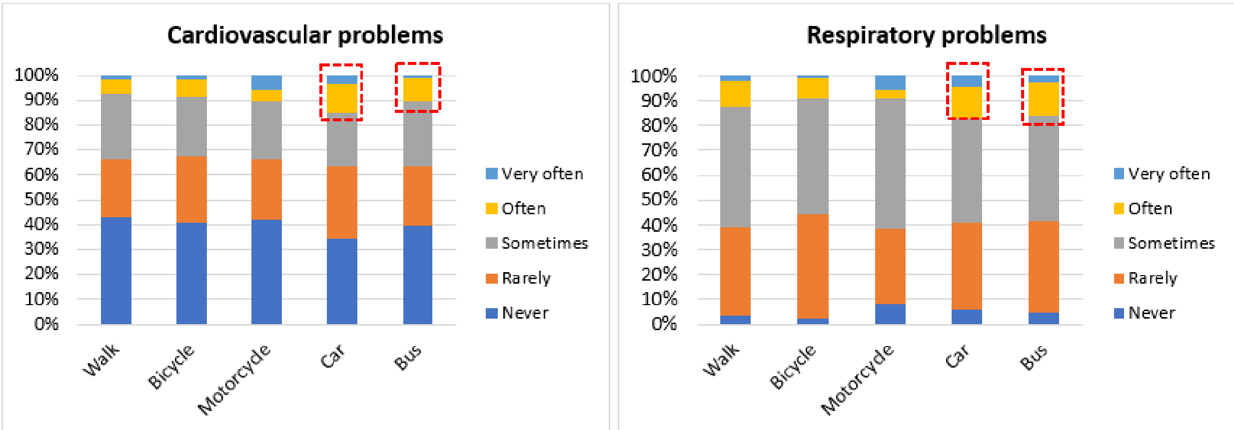

Figure 5-20: Frequency of having cardiovascular problems and respiratory problems of different commuter groups

Feeling of stress and annoyance when commuting with your daily transport modes

Commuters were asked about the frequency of having stress, annoyance due to traffic-related problems (congestions, air pollution, noise pollution) and safety when using their daily transport modes. Nearly half of the interviewees responded that they sometimes, often, and very often have stress when travelling with their transport modes. People who travelled by cars and motorcycles more often had stress than the other commuter groups.

Regarding the level of annoyance due to general traffic problems, traffic noise, and traffic-related air pollution during daily commuting, roughly 50% of all commuters reported that they were quite a lot and extremely annoyed with these problems. Motorcycle users had the highest number of people who had quite a lot and were extremely annoyed by traffic-related air and noise pollution during their daily travels. Related to the safety issue, commuters were asked about their sense of safety when using their transport modes for daily commuting. Interestingly, there was no big differences in the feeling of safety among pedestrians, cyclists, bus passengers, and car users. In general, most commuters in these groups reported that they felt normal, safe, and very safe when commuting. Whereas the percentages of motorcyclists who had the feeling of unsafe and very unsafe were significantly higher than those of other groups.

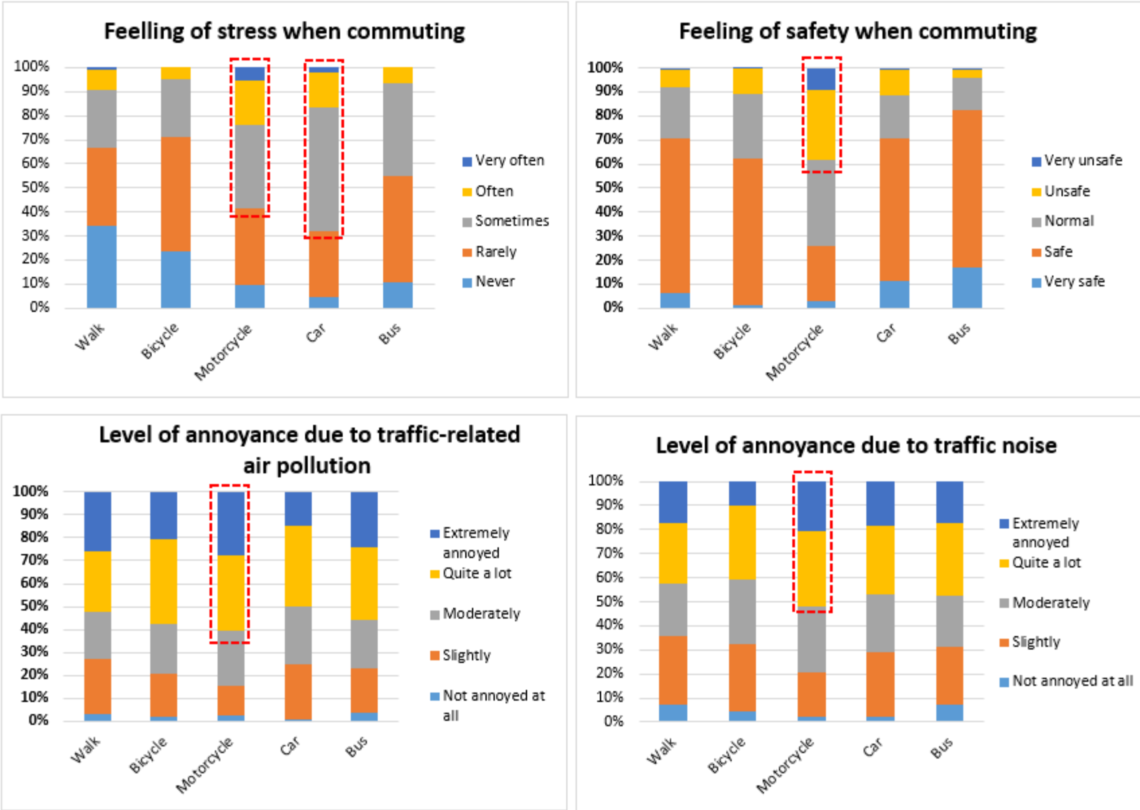

Figure 5-21: Level of stress, feeling of safety, level of annoyance due to traffic-related air and noise pollution during daily commuting of different road user groups

Body Mass Index (BMI) of different commuter groups

Commuters were asked about their height and weight, and then the author calculated their BMI based on the formula: BMI = Weight (kg)/high*height (m^2). The BMI for different commuter groups is presented in figure 5-22. The classification of BMI was based on the WHO recommendation of BMI for the Asian Population. Car and motorcycle groups had a higher percentage of being overweight and obese, compared to other groups. Meanwhile, bus users and pedestrians had higher percentages of being underweight. Cyclists and pedestrians had the lowest percentage of people being overweight and obese, compared to other commuter groups.

Commuters were asked about their average daily travel time. The result showed that cyclists spent 24 minutes on average for their daily trips, while pedestrians spent 18 minutes. The average travel time of motorcyclists, car users and bus passengers (only time spent on buses) were 42 minutes, 53 minutes, and 37 minutes, respectively. Bus passengers spent an average of 12 minutes walking to and from bus stops. Among commuter groups, cyclists and pedestrians were more likely to meet WHO recommendation of physical activity level (150 minutes of moderate-intensity physical activity per week) than other groups by their commuting time only. Therefore, they may be less likely to be overweight and obese than other road user groups. However, to have a precise conclusion on this issue, further studies are needed, which should consider other non-transport-related physical activities (e.g., exercising, sports), eating habits, and different daily lifestyles of commuters as well.

Regarding smoking and drinking behaviours, car users often smoked and drank more than other groups. Nearly 30% of car commuters were self-employed; their occupations may be related to these smoking and drinking habits rather than their travel mode. Thus, further studies to examine the relationship between transport mode use and smoking and drinking behaviours are also required.

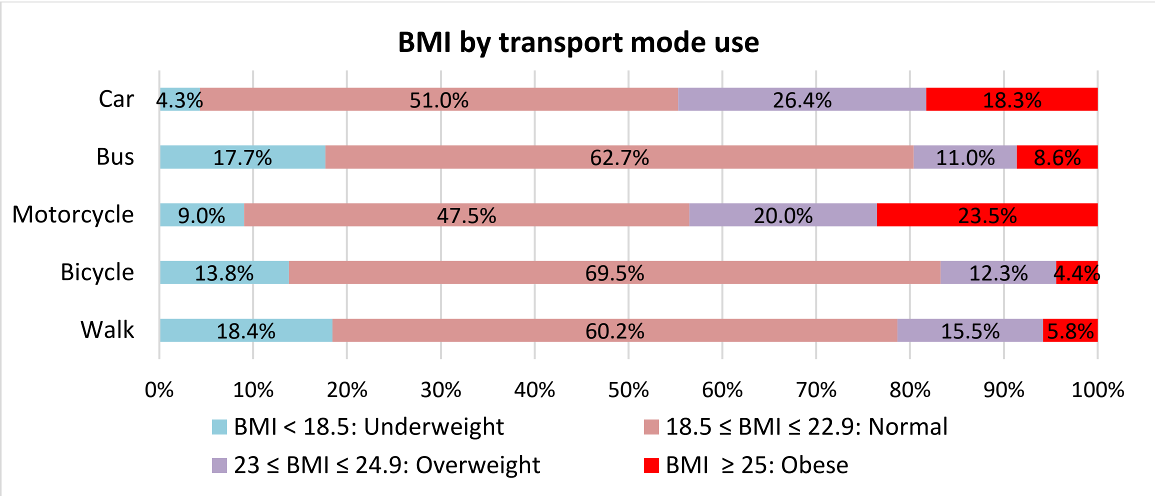

Figure 5-22: BMI of different commuter groups

5.4.3Summary key findings of surveys and develop the baseline profile

This section summarises key findings from measurement survey and interview survey aiming to understand the health status of different road users, based on their transport mode use.

- **Commuters exposed to air pollution**

Figure 5-23 shows the ratio of UFP exposure levels and UFP inhaled doses of different commuter groups, compared to cars and motorcycles. Some key findings related to the level of exposure to air pollution of different road user groups are:

- Cyclists and motorcyclists exposed to the highest level of LDSA, UFP number and UFP mass concentrations.
- Car and bus users were exposed to the lowest level of LDSA, UFP number and UFP mass concentrations.
- The level of air pollution exposed when commuting by motorcycles and bicycles are highly influenced by traffic conditions.
- Cooking activities are significantly influenced by the level of air pollution exposed by pedestrians.
- Cyclists and motorcyclists often exposed to high frequent peak air pollutant values.
- When travel time and minute ventilation are considered, cyclists inhaled significant higher level of air pollutants than other commuter groups.
- Pedestrians, cyclists, and motorcyclists were exposed to smaller particles than car and bus users, which may cause more adverse health impacts.

Therefore, regarding the health impacts of exposure to air pollution, cyclists are predicted to be the most affected, followed by pedestrians, motorcyclists, and bus passengers. Car users are the least affected by exposure to air pollution.

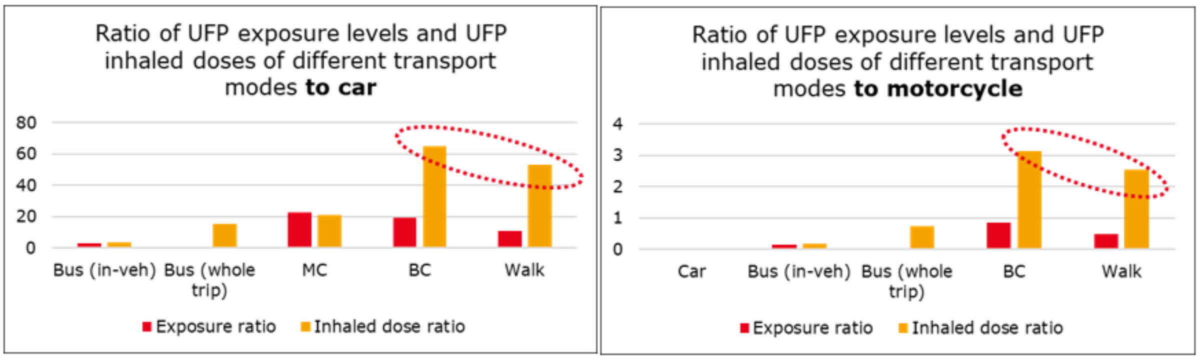

Figure 5-23: Exposure ratio and inhaled dose ratio of commuter groups compared to car and motorcycle users

- **Level of exposure to traffic-related noise pollution**

Overall, all commuters in HCMC exposed to a considerably high level of the noise level that is much higher than the national limited noise value and WHO noise recommendation threshold. Therefore, the health impacts of exposure to road traffic noise in HCMC are estimated relatively high. Among commuter groups, cyclists and motorcyclists exposed to the greatest noise level. Therefore, the impacts of exposure to road traffic noise may be more significant for cyclists and motorcyclists, compared to other groups.

- **Transport mode use and health issues**

Cardiovascular diseases, respiratory diseases, sleep problems, skin diseases, and eye disease were among the most common health issues in all commuter groups. Health problems reported based on commuters' feelings were significantly higher than those reported by health professionals. More than 50% of all commuters were quite a lot and extremely annoyed by traffic-related air and noise pollution during their daily commuting trips. The major differences in health status among commuter groups are summarised in the table below:

Table 5-5: Health issues related to different commuter groups

Health issues related to commuting	**Key findings**
Self-evaluate health status	▪ The percentage of cyclists who graded their health as good and very good was highest among commuter groups. Next come pedestrians and bus passengers. In contrast, the figure for motorcyclists was the lowest. ▪ The proportion of motorcyclists and car users who categorised their health status in poor condition was higher than that in other groups.
Satisfaction with health status	▪ The proportions of cyclists and pedestrians who reported they satisfied and completely satisfied with their health status were higher than those of other groups. ▪ Motorcyclists were the least satisfied with their health status.

	▪ The percentage of people who reported dissatisfaction with their health status was higher among motorcycle, bus, and car commuters.
Health issues based on the statement of health professionals	▪ The percentages of car users who had cardiovascular and respiratory diseases was higher those that in other groups. ▪ The percentages of motorcyclists who had sleep problems, skin diseases, eye diseases, and mental health problems were higher than those of other groups. ▪ The percentages of cyclists who had skin diseases, eye diseases, mental health problems were lower than those in other groups.
Health issues based on commuters' feeling	▪ The percentages of motorcyclists who often and very often had mental health problems and sleep problems were highest among commuter groups. ▪ The percentages of car users and bus passengers who often and very often had respiratory and cardiovascular problems were higher than those of other groups.
Feeling of stress, safety, and annoyance during daily commuting	▪ The percentages of motorcycles and car users who often and very often had the feeling of stress during daily trips were higher than those in other groups. ▪ The percentages of motorcyclists who felt unsafe and very unsafe were highest among commuter groups. ▪ The percentages of motorcyclists who reported quite a lot and extremely annoyed due to traffic-related noise and air pollution were highest among commuter groups.
Transport-related physical activities	▪ Cyclists spent 24 minutes on their daily travelling with their bicycles on average. ▪ Pedestrians walked on average 18 minutes per day. ▪ Bus passengers walked around 12 minutes to and from bus stops. ▪ Motorcyclists and car users spent 42 and 53 minutes on average on their daily commuting, respectively

- **Traffic safety of different commuter groups**

As mentioned in chapter 4, the data related to the number of deaths and injuries due to traffic accidents classified by road user groups are not available. However, existing evidence has shown that cyclists, pedestrians, and motorcyclists are the most affected by traffic accidents in terms of the number of fatalities, injuries, and severity of injuries.

The infrastructure for cyclists is not yet provided in HCMC. Cyclists have used the same road infrastructure with other motorised transport. However, when asking about safety feeling, 70% of cyclists responded that they feel safe and very safe during their daily trips. Whereas only 25% of motorcyclists responded that they feel safe and very safe when commuting with their motorcycles.

In summary, under current traffic conditions in HCMC, cyclists were exposed to the highest level of noise and air pollution among commuter groups. Therefore, the health impacts of exposure to traffic related-air and noise pollution among cyclists are predicted much more significant than other groups. However, when being asked about health status and health issues, cyclists had less health issues than other road user groups. The percentages of cyclists who graded their health as good and very good were also higher than those of other groups. In addition, cyclists spent on average 24 minutes on their daily commuting, equal to 120 minutes/5 weekdays. By everyday cycling only, cyclists approximately met WHO physical recommendation for adults (150 minutes per week). Therefore, it is suggested that the health benefits of cycling-related physical activity among cyclists may be greater than the negative impacts of exposure to the high level of noise and air pollution.

In contrast, motorcyclists exposed to a similar noise and air pollution level during their daily commuting as cyclists was suffering. They also inhaled much less amount of air pollutants compared to cyclists. However, they were the least satisfied with their health status, and they had the highest percentages of respondents who reported with sleep problems, skin and eye problems, and mental health issues. Compared to cyclists, motorcyclists had no health benefits from transport-related physical activity, although they spent average 42 minutes travelling with their motorcycles. This may explain why they have more health issues than cyclists and other road user groups.

Despite the large difference between health status among cyclists and motorcyclists, there were no big differences among pedestrians, car users and bus passengers. Although pedestrians and bus passengers were exposed and inhaled to significantly higher air and noise pollution levels than car commuters, the negative impacts of exposure to high noise and air pollution among these groups may offset by benefits from their transport-related physical activity. On average, a pedestrian walked for 18 minutes per day (equal to 90 minutes/5 weekdays), and bus passengers walked at around 12 minutes per day to access to and from bus stops (equivalent to 60 minutes/5 weekdays).

5.4.4Qualitative HIA of increase active transport and public transport in HCMC

Based on the baseline situation, health benefits related to transport-physical activity among cyclists, pedestrians, and bus passengers are predicted greater than their negative health impacts due to high exposure level of air and noise pollution. However, it is still unclear for cyclists and pedestrians if these health benefits still outweigh its negative health impacts if traffic safety is considered. Therefore, to assess the health benefits of increased walking, cycling, and using buses in HCMC, there was an assumption that the basic safety level for cyclists and pedestrians will be provided, such as a marked bicycle lane and safe crossing for pedestrians.

In general, increasing walking, cycling, and using buses in HCMC will bring benefits for many people, including both existing and new pedestrians, cyclists, bus passengers, and the general population. The qualitative assessment of major health impacts of promoting active transport and public transport in the city is presented in table 5-6. The affected population is divided into two groups including (1) commuters who shift from cars and motorcycles to walk, cycle, and buses and (2) existing pedestrians, cyclists, bus passengers, and the general population. The direction of impacts indicates whether the effect is positive, negative, or unknown. The likelihood of impacts refers to the probabilities that impacts will occur (e.g., unlikely, likely, very likely). The magnitude of impact indicates the degree of health impacts on the affected population (e.g., low, medium, high, non). And the strength of evidence describes the effects according to the level of certainty in prediction, mainly based on the result of surveys and literature review.

Regarding commuters who shift from cars and motorcycles to walk, cycle, and use buses, the magnitude of the benefits depends on which transport mode they shift to and safety measures provided for cyclists and pedestrians. For example, people who shift to cycling may gain more health benefits than those who shift to walking and using buses because they may have higher physical activity. Or bicycle lane that is physically separated from other motorised traffic offers better safety levels for cyclists.

Increased active transport and public transport leads to reduced motorcycle and car use in HCMC. As a result, air and noise emissions from motorised traffic are decreased, which reduces the level of noise and air pollution exposed by the general population in the city. In general, the overall health impacts on the general population are predicted positive. However, the magnitude of benefits depends on the number of people who shifted from cars and motorcycles to walking, cycling, and buses.

In summary, it is recommended that car and motorcycle commuters should change their transport modes to active and public transport to improve their health and the others' as well. The city government in HCMC should promote active transport and public transport by investing in infrastructures, policies, and interventions to support these transport modes.

Table 5-6: Qualitative health impact assessment of increase walking, cycling, and using buses in HCMC

Affected population	**Health impacts**	**Direction of the impacts**	**Likelihood of the impacts**	**Severity of impacts**	**Strength of evidence**
Commuters shift to walking, cycling, and using buses	Traffic safety	Positive	Likely	Low/Medium/High	Medium/Strong
	Exposure to traffic-related air pollution	Negative	Very likely	High	Strong
	Exposure to traffic-related noise pollution	Negative	Very likely	High	Strong
	Transport-related physical activity	Positive	Very likely	High	Strong
Summary: Overall, positive health impacts are estimated higher than its negative impacts. However, the magnitude of benefits depending on which transport modes that an individual shift to. And depending on the safety measures provided for cycling and walking					
Existing cyclists, pedestrians, bus passengers and the general population	Traffic safety	Positive	Likely	Low/Medium/High	Medium/Strong
	Exposure to traffic-related air pollution	Positive	Very likely	Low/Medium	Strong
	Exposure to traffic-related noise pollution	Positive	Very likely	Low/Medium	Strong
	Transport-related physical activity	Positive/Unclear	Possible	Low/Medium	Strong
Summary: Overall, the general population will benefit from increased walking, cycling, and using public transport by lower traffic-related air and noise pollution. The magnitude of benefits depends on how many people shift to walking, cycling, and using buses					

It is important to note that there are some limitations of this health impact assessment in HCMC, listed as below:

- The study only focuses on the adult population (above 15 years old). Therefore, the health impact assessment results in this study may not be reasonable for people under 15 years old. Studies that examine the health impacts of transport mode use on children and adolescents are highly recommended. In addition, analysis of the transport mode use and its health impacts among the elderly group (more than 60 years old) should be investigated in more detail to have appropriate recommendations. The recommendation for shifting to active transport and public transport may not apply to people with adverse pre-existing health problems.
- An individual's health is affected by many factors, and daily commuting mode is only one of these factors. In this study, the author only focused on general health problems of different commuter groups. Therefore, it strongly recommends considering other factors such as age, gender, income, and daily habits of commuters when examining the health impacts of daily commuting modes.

5.5 Conclusions

The chapter has reviewed the health impact assessment in general, which includes its definition and contributions, its effectiveness, and standard stages in a HIA process. Then, health impact assessment in transport sector has been also reviewed. It is clear that transport causes many harmful health impacts through traffic accidents, air pollutants, and noise pollutants, but it also brings huge benefits by providing accessibility and increasing physical activity. HIA is a promising approach to facilitate health considerations into the transport decision-making process, supporting transport decision-makers to select the alternatives that are better for health and raise the awareness of their decisions on health. Therefore, it is highly recommended that transport planners and transport decision-makers should integrate HIA into their current decision-making process. To achieve it, the legal requirements for conducting HIA are needed.

Several tools have been developed to assess the health impacts of transport policies. However, these tools are still limited at some major transport-related health impacts such as traffic accidents, exposure to noise and air pollution, and transport-related physical activity. The major reasons for this are lack of relevant data, resources (including time, budget, staff), and methods for conducting HIA. In addition, the lack of legal requirements for conducting HIA in practice leads to the lack of the interest among transport decision-makers to support for conducing HIA. In this chapter, the author proposed a health impact pathway of transport policies, providing an overview of how transport policies could affect health. Based on this causal relationship, transport planners, decision-makers are able to initially predict potential impacts of their policies on health. If the health impacts are predicted to be large, the HIA should be implemented.

Then the assessment of health impacts of increased active transport and public transport in HCMC was implemented. Two surveys were conducted to collect primary data on transport mode use and its health impacts on commuter. The result showed that the health benefits of transport-related physical activity among pedestrians, cyclists, and bus commuters were probably outweigh the negative health impacts of exposure to high level of noise and air pollution. A qualitative assessment of health impacts of increased active transport and public transport in HCMC was carried out with an assumption that the basic safety level for cyclists and pedestrians will be provided. Overall, increasing walking, cycling, and using buses in HCMC provides benefits for many people, including both existing and new pedestrians, cyclists, bus passengers, and the general population. Regarding commuters who shift from cars and motorcycles to walk, cycle, and buses, positive health impacts are estimated greater than its negative impacts. However, the magnitude of benefits depends on which transport modes that an individual shift to and the safety measures provided for cycling and walking. The general population will benefit from increased walking, cycling, and using public transport by lower traffic-related air and noise pollution. The magnitude of benefits depends how many people shift to walking, cycling, and using buses.

6 Development of an Health-Oriented Transport Policy

Health is always an important aspect of every individual's life and every community to ensure a happy life, a happy community, to increase productivity, well-being, and to save health care costs. However, in the 21st century, the world is facing many health challenges, including physical inactivity, obesity, unhealthy diets, road injuries, health pandemic, and climate change. The main objective of this chapter is to develop a health-oriented transport policy that public authorities, transport planners, traffic engineers, the general population, and other stakeholders should aim to achieve and optimise the health effects of the transport system. Firstly, the concept of a healthy-oriented transport policy is introduced, highlighting the importance of good health and the role of the transport system in promoting health. Secondly, goals and objectives of a health-oriented transport policy are proposed. Thirdly, the importance of active transport and public transport in terms of improving health and addressing transport-related issues are discussed. Then, the application of the health-oriented transport policy is proposed for Ho Chi Minh City. Finally, a summary of this chapter is presented.

6.1 Introduction the concept of health-oriented transport policy

6.1.1Health and importance of good health

Health, as defined by the World Health Organization (WHO), is "a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity" (WHO constitution, 1948). Health is one of the most important aspects of every human's life to ensure their happiness and well-being. It is also important for every community, contributing to economic development as a healthy population lives longer, is more productive, and reduces expenditure on sickness. Health is one of the fundamental human rights, as stated in the Declaration of Alma-Ata: "Health is a fundamental human right and attainment of the highest possible level of health is a most important worldwide social goal whose realization requires the action of many other social and economic sectors in addition to the health sector" (WHO, 1978).

In the first International Conference on Health Promotion, there was a statement that "Good health is a major resource for social, economic and personal development and an important dimension of quality of life" (WHO,1986). Poor health may cause large impacts on quality of life, reduce productivity, and increase healthcare costs. Therefore, good health is one of the main goals for every individual and community and is vital in achieving the other goals.

- **The costs of poor health**

Poor health generates significant impacts both on personal life and the country's economy. For example, being in poor health could reduce work productivity and increase the probabilities of being unemployed. Poor health increases the risk of poverty, especially in many low-income countries. In these countries, health is a vitally important economic asset of many people, and their living depends on it. When these people become ill or injured, the whole family will be affected by the loss of income and increased expenditure on medical treatment. A person with better health can learn better, have higher work productivity, make better decisions ang gets higher chance to get a job, . Health is also a precondition and a driving force to provide economic opportunities. Countries with poorer health conditions have more challenges to reach sustained economic development than countries with better health (WHO, 2019a). In 2016, there was an estimation that the world spent US$ 7.5 trillion on health, equivalent to 10% of global gross domestic product (Xu et al., 2018). Global health spending is increasing faster than gross domestic product (GDP) and is growing more rapidly in low- and middle-income countries than in high-income countries.

- **Health and sustainable development**

The relationship between health and sustainable development has well-known for decades. The term "sustainable development" is commonly used and becomes the key goal of many sectors, including agriculture, economy, and the environment. This term initially originated in 1987 in the landmark report of the World Commission on Environment and Development, "Our Common Future", also called Brundtland Report. Sustainable development was defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987). And the first principle of the Rio Declaration reported in the report of the United Nations Conference on Environment and development in 1992 stated that "Human beings are at the centre of concerns for sustainable development. They are entitled to a healthy and productive life in harmony with nature" (UN, 1992). Health and sustainable development inseparably interact with each other. The United Nations Conference on Sustainable Development (known as Rio+20) indicated in its outcome document titled The Future We Want that "health is a precondition for and an outcome and indicator of all three dimensions of sustainable development, including the social, environmental, and economic dimensions"; and "the goals of sustainable development can only be achieved in the absence of a high prevalence of debilitating communicable and non-communicable diseases, and where populations can reach a stage of physical, mental and social well-being" (United Nations, 2013). Therefore, health is an important input for sustainable development, and sustainable development will produce more health (PAHO, 2013).

Figure 6-1 shows 17 Sustainable Development Goals (SDGs) adopted by the United Nations and the Member States in 2015, also known as the Global Goals, which are an urgent call for actions by all countries to achieve a better and more sustainable future for all (UN, 2015). These SDGs and its targets are presented in the report "Transforming our world: The 2030 Agenda for Sustainable Development". Health is a central place in SDG 3, "Ensure healthy lives and promote well-being for all at all ages", and all of the other 16 goals are also related to health either directly or indirectly. Good health and well-being contribute both directly and indirectly to the attainment of other SDGs. Ensure healthy lives and promoting well-being for all are the foundation for healthy communities and healthy economies. The healthier population have higher productivity, which, in turn, creates incentives for investment and attracts foreign investment. Similarly, economic growth contributes to improving the living conditions and health care system, improving the population's health.

Figure 6-1: Sustainable development goals adopted by United Nations General Assembly, 2015 (source: (United Nations Department of Global Communications, 2020)

6.1.2Health challenges

Global health has improved over time as a result of the development of the economy and healthcare services. For example, the development of vaccines has profound effects on preventing many infectious diseases such as measles, mumps, rubella, and others. Despite improvement, global health is still facing many challenges, including non-communicable diseases, unpredicted health pandemics, climate change, health inequities, and many others. Some major health challenges are described below.

- **Non-communicable diseases (NCDs)**

The development of vaccines has great impacts on controlling many infectious diseases. Whereas the progress in preventing and controlling premature death from NCDs has remained low or even increased in many countries, and NCDs are becoming the leading causes of death worldwide (WHO, 2018c). In 2019, there was an estimation that NCDs caused 41 million deaths, equivalent to 74% of all deaths globally (WHO, 2020) . The major NCDs, including cardiovascular diseases, cancers, chronic respiratory diseases, and diabetes, were responsible for more than 80% of these deaths. The population in low-and middle-income countries was most affected. According to the World Economic Forum and the Harvard School of Public health report, NCDs have already posed a significant economic burden that will continue to increase substantially over the next two decades. They estimated that over the next 20 years, NCDs would cost more than 30 trillion USD, representing 48% of the global GDP in 2010 (Bloom, Cafiero, Jané-Llopis, Abrahams-Gessel, & Fathima, 2011). Thus, NCDs are one of the major global health challenges of the 21st century, which not only affect human health but also to affect development and economic growth.

- **Health pandemics**

Recently, global health is facing with coronavirus pandemic (also known as the Covid-19 pandemic) that has been declared by WHO “the outbreak a public health emergency of international concern” in January 2020 and a pandemic in March 2020. In May 2021, there have been more than 163 million confirmed cases of covid-19, including more than 3.3 million deaths (source: https://covid19.who.int/). This outbreak has strongly shown the vulnerability of the global population and the healthcare system's weakness when facing a health crisis. In the Covid-19 pandemic, patients with pre-existing NCD conditions such as diabetes, obesity, and hypertension, become more vulnerable with a higher risk of dying or having adverse effects (Zheng et al., 2020) (Simonnet et al., 2020). For example, a report described characteristics of 25,452 patients who have died in hospitals from covid-19 in Italy. It reported that the majority of these deaths had comorbidities, mainly NCDs. The most common NCDs among these patients were hypertension (69.2%), type 2 diabetes (31.8%), ischemic heart disease (28.2%), chronic obstructive pulmonary disease (16.9%), and cancer (16.3%) (Palmieri et al., 2020). The situation further requires urgent actions to address risk factors to prevent NCD, improve the population's health, and protect them from future unpredicted pandemics.

- **Climate change and health**

Climate change is potentially the greatest global health threat of the 21st century (Costello et al., 2009). The major impacts of climate change include increases in temperatures, rising sea levels, and increases in the frequency and intensity of extreme weather events, which affect health either directly or indirectly, such as food and water insecurity, heat waves, and human settlements (IPCC, 2014). Although climate change may have some positive impacts on human health, strong evidence supports that negative health impacts of climate change are extremely higher than its positive impacts (K. R. Smith et al., 2014), (WHO, 2014b).

The World Health Organisation has estimated that climate change will cause approximately 250,000 additional deaths per year between 2030 and 2050 (WHO, 2014b). This number only represents some associated health risks that can be quantified and does not represent the overall impacts of climate change on health since many other impacts cannot be quantified. In addition, the impacts of climate change are distributed unequally; the poorest countries will suffer the largest consequences of climate change even though they contributed the least to emissions (Costello et al., 2009). The most vulnerable population is the most affected by future disruptions of climate change.

- **Health inequities**

"The enjoyment of the highest attainable standard of health is one of the fundamental rights of every human being without distinction of race, religion, political belief, economic and social condition", and "health inequities between and within countries are politically, socially and economically unacceptable, as well as unfair and avoidable" were stated in the 8th Global Conference on Health Promotion (WHO, 2014a). Although there are significant improvements in population's health, life expectancy and infant mortality, health inequities between countries and within countries still persist, and progress to reduce health inequities has not been as fast as expected (WHO, 2019b). There is strong relationship between socio-economic status and health. For example, people with higher incomes live longer and have lower rate of diseases than those with low incomes. People with poor health are more likely to lose their jobs, stay out of work longer than healthy people, and the wealthy are more likely to have fewer health problems. Health inequities arise through exposure to multiple risks and exposure to adverse conditions such as poor housing, unsafe neighbourhoods, poor accessibilities to services, education and employment opportunities, and poor working conditions. Countries where inequalities in income, health, education, employment, etc. are high has slower growth.

Therefore, improving health and ensuring no one is left behind in terms of health will contribute to economic growth and sustainable development (WHO, 2019a).

6.1.3Factors influencing health

Health is a complex issue and is influenced by social, physical, and economic environments, which are referred as "social determinants of health". Figure 6-2 presents the main determinants of population health, defined as conditions in which people were born, grow, live, work and age (Dahlgren & Whitehead, 1991). For individuals, factors described in the centre of this figure, such as age, gender, and constitutional characteristics, definitely influence their health, however, these factors are largely fixed, and they have little control over them. However, the other factors surrounding them, such as working and living conditions and individual lifestyle, can be influenced and modified by individuals and policies. These factors mutually interact with others. For example, individual lifestyles are influenced by social norms and networks in their community and their working and living conditions, which, in turn, are related to the wider socio-economic and cultural and environmental conditions (Dahlgren & Whitehead, 2006).

As presented in figure 6-2, many sectors such as agriculture, housing, industry, and transport affect population health considerably through environmental risks and conditions. The health impacts of many environmental risk factors have been well-documented for many decades. The health impacts of these sectors distribute unequally across countries and also across social groups. Health and health inequities are affected and shaped by many policies outside the health care sectors**.** Thus, promoting health and well-being cannot be achieved by the health sector alone, the benefits of a healthy population are multispectral, and investments need to be made by all sectors. Therefore, to improve health, co-ordinating and acting across all sectors are needed, requiring collaboration across many different sectors and strong commitments from government at all levels, from local to national and international levels (Prüss-Ustün, Wolf, Corvalán, Bos, & Neira, 2016), (WHO, 2018d).

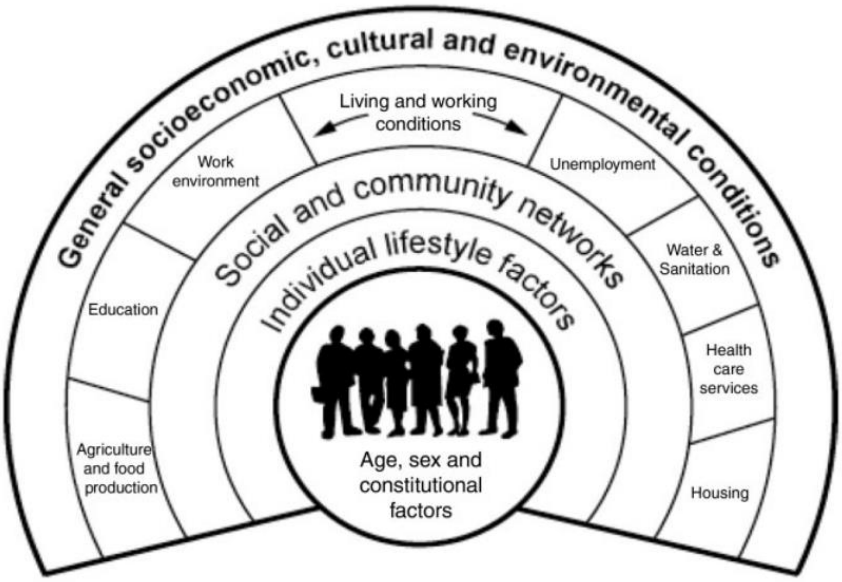

Figure 6-2: The main determinants of health (Dahlgren & Whitehead, 1991)

6.1.4Health-oriented transport policy

- **Health in All Policies (HiAP)**

As mentioned, health and health equity are human rights, and they are important prerequisites for attaining other goals. However, health and health equity are influenced by many sectors that originate from social, environmental, and economic sectors beyond the direct influence of the health sector. Public policies in all sectors at different levels of governance can affect health and health equity significantly. Therefore, the HiAP approach is necessary to protect and promote health and health equity. The approach has been built on a rich heritage of ideas, evidence, and actions that originated from the Alma Ata Declaration on Primary Health Care (WHO, 1978) and the Ottawa Charter for Health Promotion (1986). Recently, this approach has been reinforced in the 2011 Rio Political Declaration on Social Determinants of Health (WHO 2011a) and the UN General Assembly Resolution on the Prevention and Control of Non-Communicable Diseases (United Nations 2011). The HiAP approach has been adopted in many countries such as Australia, England, and Thailand, and it is still a growing field (Baum et al., 2014). A global status report on HiAP stated that HiAP provides a sustainable model for working across sectors to improve health and contributes to achieving the goals of other sectors, but the progress and development are different across countries (GNHiAP, 2019).

There are different definitions of HiAP; however, the most common definition is defined in the 8th Global Conference on Health Promotion in Helsinki in 2013, as *"an approach to public policies across sectors that systematically takes into account the health implications of decisions, seeks synergies, and avoids harmful health impacts in order to improve population health and health equity"* (WHO, 2013c). This approach facilitates the consideration of health, health equity, and sustainability as part of the decision-making process in all sectors. HiAP improves the collaboration of many sectors, improving efficiency by determining problems addressed by multiple agencies and fostering discussion of how agencies can share resources and reduce redundancies. Global health is facing many challenges that require actions from all sectors and at all levels of governments. By institutionalising the consideration of health into decision-making across sectors and policy areas, HiAP is a systematic approach to address health challenges and ensure sustainable development.

- **Urban planning, transport, and population health**

In 2018, 55% of the world's population has lived in urban areas, and it is projected to grow to 68% by 2050. Almost 90% of this growth will happen in low- and middle-income countries (UN, 2018). Cities are engines of wealth creation and innovation, offering many opportunities for employment, education, social interactions, cultural exchanges, and services, which influences health in many positive ways. However, cities have also posed many adverse health effects through air pollution, noise pollution, injuries, inadequate housing, slums, inequities, lack of green spaces, physical inactivity and others, resulting in increased morbidity and premature deaths (Kleinert & Horton, 2016) (Giles-Corti et al., 2016b) (Carmichael et al., 2019) (Nieuwenhuijsen, 2016). The increase in the urban population, demographic change, and climate change are predicted to generate further impacts on human health (WHO, 2010b)(Watts et al., 2015). A large proportion of these burdens are in the cities, as this is where people live and where the higher exposure levels are (Nieuwenhuijsen, 2020).

Although cities are facing and generating many health challenges, they are also providing opportunities for better health. The Lancet series on urban design, transport and health have been highlighted the possible health impacts of urban and transport planning and how city planning and transport planning can address these health impacts, environmental, and economic burdens (Giles-Corti et al., 2016a), (Stevenson et al., 2016a), (Sallis et al., 2016b). Figure 6-3 presents direct and indirect pathways through which urban and transport planning and design decisions affect health and well-being. Public authorities, urban planners, and decision-makers can improve population health by placing health consideration into their decision-making process. Therefore, it is vital for them to understand that health is a crucial asset to foster city development sustainably. The health benefits of land-use changes, reduction in car dependency, and increase in public and active transport have been well-documented. For example, a study estimating the health benefits of compact cities in which land-use density and diversity increased, distance to public transport decreased, and walking and cycling were promoted, showed that health gains were observed in all of six selected cities. Overall, there were 420-826 disability-adjusted life-years (DALYs) gained per 100,000 population under the compact cities modal (Stevenson et al., 2016a). Nieuwenhuijsen reviewed the evidence of how cities can become healthier through better urban and transport planning (Nieuwenhuijsen, 2020). He reported that better urban and transport planning through land-use changes, reduction in car dependency and shift towards public and active transport, greening cities, visioning, citizen involvement, collaboration, leadership and investment, and systematic approaches are pathways to carbon-neutral, liveable and healthy cities. City planners, policymakers, health professionals, and citizens must work together to maximise the opportunities of cities to promote health and well-being alongside economic and business developments by making people-centred, livable, equitable, sociable, and enjoyable (Kleinert & Horton, 2016).

- **Health-oriented transport policy**

Transport is a fundamental component of every community that brings enormous benefits to the development of economic, social, cultural, and human civilisation. However, transport also generates many adverse health effects presented in detail in chapters 2 and 3. The negative health impacts of the transport system are highly related to private motorised transport, which are consequences of transport infrastructure and transport policies that focus on the movement of motor vehicles. The extensive literature has been documented the negative health effects of automobile-oriented build environments on non-communicable diseases, such as traffic injuries, respiratory diseases, cardiovascular diseases, stress, and other health outcomes (J. Mindell, Rutter, & Watkins, 2011),(Sallis, 2016), (Giles-Corti et al., 2016b), (Khreis et al., 2016)(Nieuwenhuijsen & Haneen, 2020). It is concluded that transport is also one of the major sources of greenhouse gas emissions, causing climate change threatening human health.

Despite the adverse health effects of private motorised vehicles, the number of motorised vehicles is still increasing due to increased travel demand. The travel demand is predicted to increase continuously due to economic development, population growth and urbanisation. The world's population is predicted to continue to grow, 1.1% per year, resulting in additional 83 million people annually and reaching 9.8 billion in 2050; the largest growth is expected in Africa and Asia (UN, 2017). The same trend can be seen for urbanisation. Around 55% of the world's population is living in urban areas in 2018 worldwide, and it is projected to grow to 68% by 2050. Almost 90% of this growth is happening in Asia and Africa (UN, 2018). The increase in travel demand creates pressures to increase private motorised vehicles, energy consumption, transport infrastructure, land consumption, climate change, noise pollution, and air pollution. Consequently, the negative health impacts of transport will continue to increase, and the population in developing countries will continue to face the greatest health burden related to transport. Transport is the one sector where the reduction in energy use and emission is extremely difficult to achieve. Banister argued that the current situation is unsustainable, and transport must contribute fully to achieving carbon reduction targets (Banister, 2011). As a result, if no effective solution is implemented, the negative health effects of the transport system will become worse.

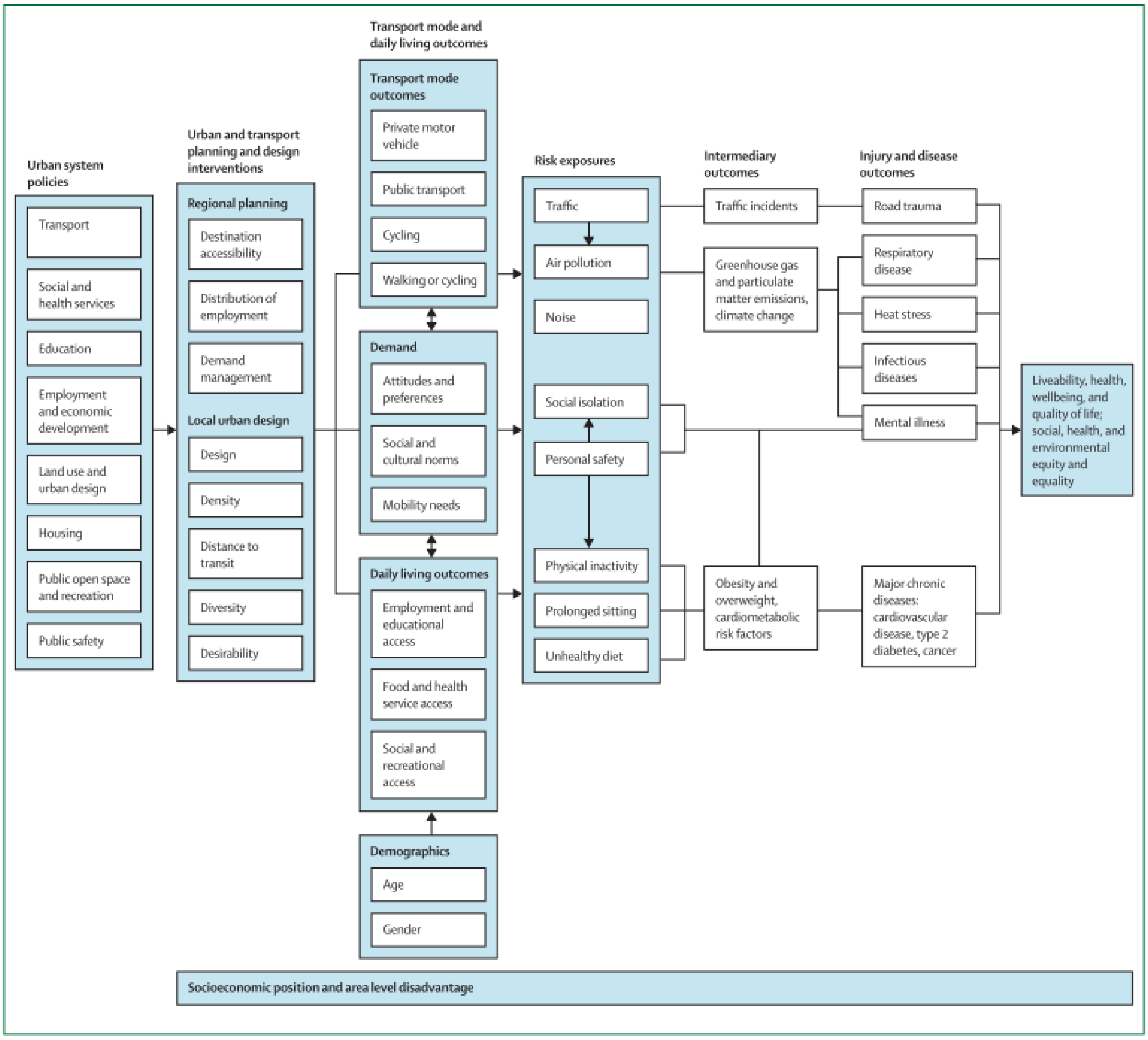

Figure 6-3: Direct and indirect pathways through which urban and transport planning and design decisions affect health and well-being (Giles-Corti et al., 2016b)

Fortunately, the transport system can be changed and re-designed to mitigate its negative health impacts and promote its positive impacts. Many interventions have been implemented in many cities, including a limited number of private motorised vehicles, encouraging active transport and public transport, shifting to electric vehicles, and controlling motorised transport demand. Recently, the evidence of health benefits of these interventions is increasing and widely reported, especially in developed countries. For example, there was an estimation that 7,332 and 12,516 disability-adjusted life-years could be reduced per year by the increase in active travel and less use of motor vehicles in London and Delhi, respectively (Woodcock et al., 2009).

Transport systems that place health as a central goal of policy development can address transport-related health problems, promote health, and support achieving other sustainable development goals. The transport policies that aim to optimise the health impacts of transport by maximising positive health impacts and minimising negative health impacts are considered health-oriented transport policies. Section 6.2 will present the proposed goals and objectives of the health-oriented transport policy.

6.2 Proposed goals and objectives of the health-oriented transport policy

Traditionally, human health is not sufficiently considered and often neglected in transport planning. The transport planning and interventions in many cities are still mainly focusing on the movement of vehicles instead of people. However, the understanding about associations of private motorised transport and its negative health impacts is increasing rapidly. The awareness of the importance of good health in terms of ensuring a good life, promoting economic development, and attaining sustainable development is also growing both in every individual and every community. Therefore, the major purpose of this part is to propose a goal system with specific objectives that public authorities, transport planners, decision-makers, and other related stakeholders should aim to achieve to optimise the positive and negative health impacts of the transport system. The proposed goals and objectives are described in figure 6-4. The detail of these goals and objectives is presented in the following sections.

The goals and objectives are primarily developed based on the outputs of chapter 2 and chapter 3. It is important to note that the transport system is changing that may generate other health issues. For example, the development of autonomous vehicles may cause others health issues that link to security problems. In this situation, this proposed goal system should be modified with changes. In addition, the urban transport development includes other goals, not only health, such as to ensure economic development, which may generate conflicts among goals and objectives. Therefore, it is highly recommended that the local contexts should be taken into account when applying these proposed goals and objectives. Depending on local situations, some goals and objectives can be selected and integrated into the existing urban transport development goal system.

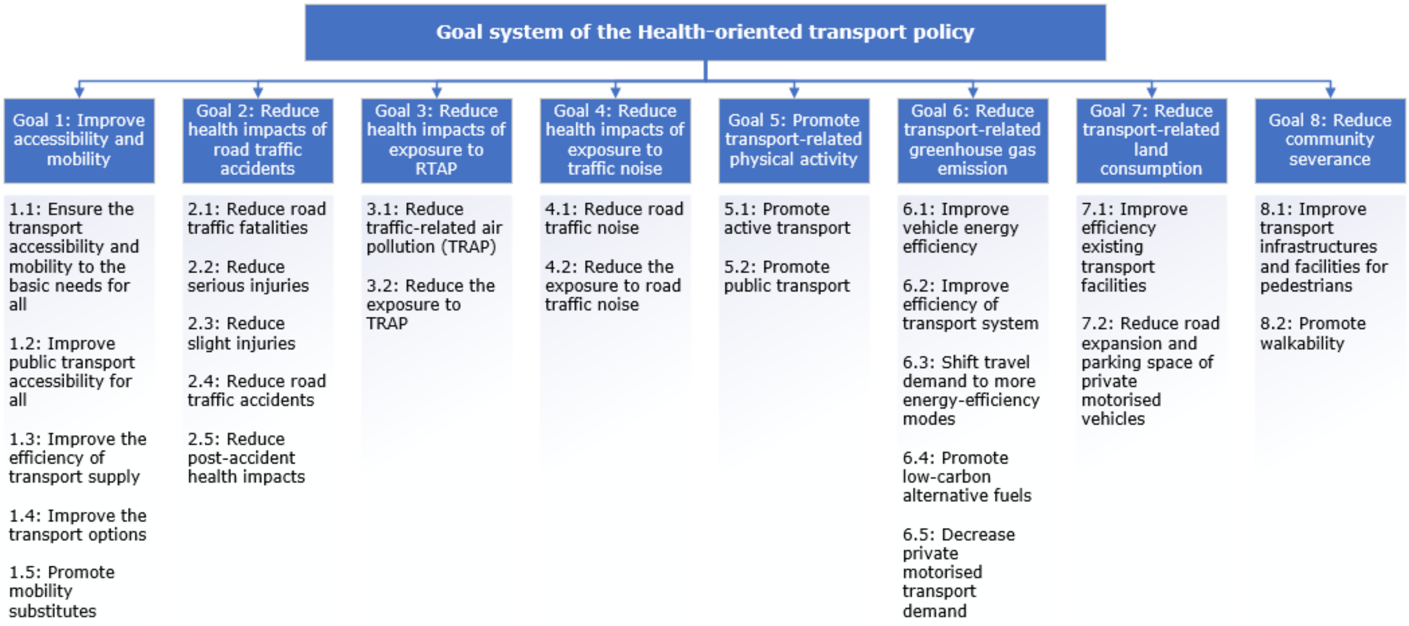

Figure 6-4: Goals and objectives of the health-oriented transport policy (Source: Author)

- **Goal 1: Improve accessibility and mobility**

Accessibility is considered one of the ultimate goals of the transport system. Transport provides accessibility to people's basic needs such as health care services, foods, education, and employment opportunities that either directly or indirectly affect health. Many of these services, activities and opportunities take place over space, and accessibility cannot be achieved without some mobility. Demands for accessibility and mobility vary across groups varying by age, income, education, physical conditions, and other factors. Therefore, ensuring accessibility and mobility for all transport demands is the key goal of transport policy. Improving accessibility and mobility not only improves health but also helps achieve other economic, social, and environmental goals as well as reduce social inequities. The transport system, accessibility, and land use are linked closely; transport and land use both affect accessibility. Due to the scope of the study, this goal only focuses on transport and accessibility. This goal is divided into five specific objectives.

  - **Objective 1: Ensure the transport accessibility and mobility to the basic needs for all**

  Transport provides accessibility to a wide range of services and activities for people. However, some of these services and activities are crucially important for human health; without having accessibility to these services and activities, human health can be threatened, such as accessibility to foods, water, and health care services. Therefore, the transport system has to provide access to these basic needs for all people. The percentage of the population that can access basic needs by a given transport mode in a given travel time can be used to measure this objective.

  - **Objective 2: Improve public transport accessibility for all**

  Public transport is an important component of the sustainable urban transport system. The effective public transport system provides an alternative mean of travel to private vehicles and helps reduce transport-related issues, such as congestions, air pollution, noise pollution, making cities more livable and sustainable. Public transport should be inclusive and accessible for people with all levels of abilities. For many people, such as the elderly, people who do not have access to private vehicles, disable people, children, and low-income people, public transport is important for their lives. Thus, improving access to public transport for these captive riders should be given priority. The enhancement of public transport accessibility should not only focus on accessibility to vehicles but also its affordability, accessible information, accessible ticketing system, and the built environment. The accessible public transport system also contributes to reducing travel inequality. Several indicators can be used to measure this objective, such as the percentage of the population who can access public transport within a given time period or given a walking distance, service frequency, network coverage, distance to stops/stations, the average time to access and leave public transport, operating duration, vehicle capacity, and facilities to support disabled people, elderly, children, etc.

- **Objective 3: Improve the efficiency of transport supply**

This objective aims to maximise the performance of the existing transport system, including roads, parking facilities, walkways, bicycle lanes, and public transport infrastructure. These infrastructure and facilities should be operated efficiently to increase the capacity of the transport system and avoid unnecessary expansion of road or parking facilities. For example, by a well-organised traffic signal program or well-connected transport network, road users can travel to their destinations more smoothly and freely, which leads to reduced travel time, travel costs, and congestion levels. This objective is measured by some conventional indicators such as congestion levels, travel times, average travel speeds, level of services, and travel cost.

- **Objective 4: Improve the transport options**

Travel demands vary among user groups, based on their conditions and individual preferences. Their travel demand can be met by using a single mode or by a combination of several modes. In addition, each transport mode has its own characteristics and specific requirements. Therefore, improving the effectiveness of offered travel options requires a detailed understanding of users' needs, their abilities, and travel mode constraints. The improvement should not only focus on the increase in the number of travel options but also the quality of these options, such as increased convenience, speed, comfort, affordability, security, and information. The enhancement both in quantity and quality of travel options allows people to choose the most appropriate travel option, which can save their travel time, travel cost or increase their travel satisfaction. The priority of improvement should be given to more effective and sustainable transport modes such as public transport, walking, and cycling. These options should be designed as the most attractive travel options for the majority of travel demands to avoid negative consequences related to private motorised vehicles. The transport system is evolving with new types of vehicles (e.g., e-scooters, e-bikes, autonomous vehicles) and new services (e.g. rideshare, bike-share), effective integration of these new travel options into the current transport system can potentially improve accessibility for people. The number of modal choices per trip for different purposes, service quality of various transport modes (e.g., public transport service quality, sidewalk quality, bicycle path quality), park and ride facilities, and integrated ticketing system can be used to measure this objective.

- **Objective 5: Promote mobility substitutes**

The potential of telecommunication and delivery services has been considered to substitute for travel for a long time. However, this is not common till recently when the Covid-19 pandemic happened, terms as “online learning”, “online meeting”, or “home office” are becoming popular in many countries. With the rapid development of information and communication technologies (e.g., high-speed internet, Zoom, Google meeting, Microsoft Team, Cisco Webex, Skype), nowadays, many people can work or learn from home without travelling. In addition, delivery services are also emerging that allow people to access many services without travelling or access by walking, cycling, or public transport instead of driving. These mobility substitutes are potential approaches to provide accessibility for people while decreasing travel needs. To ensure the effectiveness and avoid unintended consequences of these travel substitutes, careful consideration of these substitutes in the transport planning and mobility management program is necessary.

- **Goal 2: Reduce health impacts of road traffic accidents**

Road traffic accidents tremendously affect health of not only the victims but also of their family members, friends, and society. Many victims have experienced adverse social, physical, and psychological effects, either short-term or long-term. Therefore, improve road safety is a crucial goal of the health-oriented transport policy. Improving safety for all road users by reducing transport-related fatalities and serious injuries are two key objectives of this goal. The existing situation has shown that vulnerable road user groups (pedestrians, cyclists, and motorcyclists) have been suffered the greatest health effects of traffic accidents. Therefore, improving the road safety of these vulnerable road users should gain more attention, especially in developing countries. Furthermore, traffic accidents generate a huge economic burden through health care costs and productivity losses associated with occupant injuries and deaths. Thus, improving road safety also reduces the economic burden of traffic accidents significantly.

- **Objective 2.1: Reduce road traffic fatalities**

Death is the most tragic health consequence of traffic accidents, this objective aims to reduce the number of road traffic fatalities across all commuter groups. Some indicators can be used to measure this objective; depending on the availability of the data and purpose of each study, specific indicators will be selected for measuring and monitoring. The most popular measured indicators are the number of road fatalities per year, the number of road fatalities per 100,000 inhabitants, and the number of road fatalities per 100,000 registered vehicles. These indicators have been widely used for measuring the progress of road safety improvement and for international comparison. The other indicators can also be used to measure this objective, including the number of road fatalities per billion vehicle-kilometres travelled, the number of road fatalities per billion passenger-kilometres travelled, and the number of road fatalities by road user groups, number of road fatalities by road types, etc.

- **Objectives 2.2: Reduce serious injuries due to road traffic accidents**

Traditionally, road safety improvement has mainly focused on reducing the number of road deaths, and good progress can be seen in reducing road fatalities. Whereas serious but non-fatal accidents also cause substantial health effects on victims, which is also costly and problematic for society, but the number of seriously injures seems not to have decreased as quickly as the number of fatalities. Seriously injured people may suffer physical sequelae, psychological distress and various socio-economic consequences a long time after accidents. Therefore, it is necessary to reduce the number of severe injuries due to road traffic accidents. Although the health impacts of serious injuries are significant, the ability to account for or accurately estimate these injuries remains challenging in many countries because of the missing a clear definition of injury severity and underreporting and misreporting issues. To effectively reduce the number of serious injuries, clear definition of injury severity and improving data collection is needed. Some indicators can be used to measure the progress of reducing serious injuries, including the number of serious injuries per year, the number of serious injuries per unit of population, the number of serious injuries by road user groups, the number of serious injuries type of roads, etc.

- **Objective 2.3: Reduce slight injuries due to road traffic accidents**

This objective aims to reduce the number of slight injuries due to road traffic accidents. The existing evidence has shown that the psychological and social consequences of road traffic accidents are not always linked positively with the severity of injuries. Even minor injuries can have profound psychological effects on injured people, such as anxiety when travelling, reducing outdoor activities or changing their travel behaviours. However, a significant proportion of these slight injuries are not reported, that if fully collected, the health effects could be substantial. The vulnerable road users, the elderly, and children may be affected by these slight injuries most. For example, children may not be allowed to walk or cycle to school alone, which increases their travel dependence on their parents. This objective can be measured by the number of slight injuries per year, the number of slight injuries per unit of population and the number of slight injuries by transport modes.

- **Objective 2.4: Reduce road traffic accidents**

This objective focuses on reducing the possibility and occurrence of traffic accidents for all road user groups. Road traffic accidents affect health directly through fatalities and injuries that can be seen immediately after an accident. However, road traffic accidents also lead to property damage such as vehicles, which may indirectly influence the health of people involved in accidents, especially the poor people. For example, in many developing countries, the vehicle is a mean of daily earning (e.g., motorcycle or taxi drivers in Vietnam), damaged vehicles mean loss of daily income which affects their health in different aspects (e.g., not enough money for food, cannot afford to pay tuition fee for their children). Indicators can measure this objective, including the number of accidents per year, the number of accidents per unit of population, the number of accidents per unit of registered vehicles, and the number of accidents per road user group.

- **Objective 2.5: Reduce post-accident health impacts**

Road traffic accidents may affect injured people a long time after their accidents. Many people suffer physical disabilities and psychological disorders, change their jobs or change their way of life. To reduce post-accident health consequences, the collaboration among transport sectors, health sectors, and social programmes is essential to provide adequate medical treatments and psychological and social consulting to rehabilitate injured people. Long-term health impacts of road traffic injuries are still poorly documented in many countries. Still, this objective can be measured by the number of disabilities due to road traffic accidents or the number of people suffering from post-traumatic disorders.

- **Goal 3: Reduce health impacts of the exposure to traffic-related air pollution (TRAP)**

The evidence from epidemiological studies on the negative health impacts of exposure to TRAP is growing rapidly. Short-term and long-term exposure to TRAP both cause adverse health effects. The common diseases linked to exposure to TRAP are cardiovascular diseases, respiratory diseases, lung diseases, and premature deaths. The urban population growth and increase in income level lead to increased private motorised vehicles and travel demand. Thus, the adverse health impacts of exposure to TRAP could continue to increase. Reducing TRAP and its negative health consequences is an important goal of health-oriented transport policies. This goal is divided into two objectives consisting reducing the TRAP and reducing exposure to TRAP.

  - **Objective 3.1: Reduce traffic-related air pollution (TRAP)**

  This objective focuses on reducing TRAP sources, including exhaust emissions, non-exhaust emissions, and evaporate emissions. Motor vehicles emit a wide range of air pollutants, consisting of black carbon (BC), carbon dioxide (CO_2), carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NO_x), particulate matter (PM), ultra-fine particles (UFP). However, based on the literature review, particulate matter with a diameter less than 10 microns (PM_{10}) and less than 2.5 microns ($PM_{2.5}$), nitrogen oxides (NO_x), and ozone (O_3) have been considered the most health-harmful air pollutants caused by traffic activities. Therefore, decreasing the amount of these air pollutants should be given priority. Several indicators can be used to measure this objective, such as the annual mean concentrations of TRAP at traffic monitoring stations, the average concentration of TRAP per passenger kilometre travelled by transport modes, the number of days TRAP concentration exceed the limited value or threshold values per year, total TRAP emission from road transport per year. Depending on the available data, air quality monitoring system, national air quality guidelines, purpose of studies and specific indicators can be selected for measuring this objective. These indicators can be estimated by modelling or directly measure at the roadside stations and mobile measurements.

  - **Objective 3.2. Reduce the exposure to TRAP**

  Human exposure is people's contact with a pollutant, and this is a necessary condition for the occurrence of health effects. Thus, reducing exposure to TRAP will reduce its adverse health effects. The magnitude of the exposure and the extent of the health effects of TRAP are defined by the number of exposed people, the duration of contact with TRAP, and the TRAP concentration in the place where the contact happens. Therefore, reducing the number of people exposed to high TRAP, duration of exposure, and level of TRAP concentration leads to reducing the magnitude of health impacts of exposure to TRAP. This objective can be measured by the number of people exposed to TRAP that above-limited values, the number of population living along the major roads, the average travel time of road users along the major roads, the number of people who had diseases related to exposure to TRAP per year, and the number of premature deaths due to exposure to TRAP.

- **Goal 4: Reduce health impacts of exposure to road traffic noise**

Road traffic noise is a primary noise source in urban areas, and evidence and concerns of its adverse health effects are growing. In many cities, both developed and developing, a large proportion of the urban population has been exposed to a high traffic noise level that exceeds threshold values. Exposure to the persistent or high traffic noise level has been associated with many health problems, including cardiovascular diseases, metabolic diseases, cognitive impairment, sleep disturbance, annoyance, hearing impairment, etc. Therefore, decreasing road traffic noise and exposure levels is needed to improve population health. Like goal 3, two major objectives of this goal are to reduce road traffic noise and reduce the exposure to road traffic noise.

- **Objective 4.1: Reduce road traffic noise**

  This objective focuses on decreasing noise generated from road traffic. Usually, road traffic noise results from the combination of rolling noise, propulsion noise and aerodynamic noise that are influenced by many factors such as vehicle factors, road factors, traffic situation, driving behaviours, and weather factors. All these factors should be taken into account to reduce road traffic noise effectively. The most common indicators used to measure this objective are the annual average sound pressure level of all days, evenings, and nights (L_{den}) and the annual average sound pressure level of all night periods ($L_{night,outsite}$), the night period is usually from 11:00 pm to 7:00 am. These two indicators are generally reported by authorities and are widely used to assess noise exposure's health effects. The other indicators are also used to measure short-term health effects of road traffic noise, such as maximum sound pressure level occurring in a defined measurement period (L_{max}), and A-weighted equivalent sound pressure level within a time interval (LA-eq).

- **Objective 4.2: Reduce the exposure to road traffic noise**

  The objective focuses on decreasing the magnitude of the exposure to road traffic noise in terms of the number of exposed people and exposure duration. This objective can be measured by the percentage of the population exposed to road traffic noise above recommend thresholds, the proportion of the people living in proximity of traffic noise sources, the proportion of road users exposed to road traffic noise above the recommended thresholds, and average commuting time in major roads.

- **Goal 5: Promote transport-related physical activity**

Physical inactivity and insufficient physical activity are among the most health challenges associated with many health issues, including major non-communicable diseases, such as coronary heart disease, type 2 diabetes, obesity, and shorten life expectancy. Increasing physical activity through daily commuting is a potential approach to address these problems. The substantial evidence suggested that daily travel by active transport and public transport is associated with the increased daily physical activity level of commuters. In addition, promoting active transport and public transport could support achieving the other goals of the healthy transport system, such as decrease TRAP and noise pollution. The detail of the importance of these transport modes in the healthy transport system will be presented in section 6.3.

- **Objective 5.1: Promote active transport**

  The most common active transport modes are walking and cycling, and recently e-bike in some countries. Active transport like walking and cycling can substantially increase levels of regular physical activity. Many studies in developed countries suggested that the health benefits of physical activity through active transport exceed the risk of injuries and exposure to noise and air pollution. However, in developing countries, the risk of being injured and the level of exposure to air pollution and noise pollution while cycling or walking are estimated considerably high. Therefore, addressing these issues is crucial to encourage active travel. Transport mode share of walking, transport mode share of cycling, average walking/cycling time per trips, average walking/cycling distance per trip, percentage of population regular walk/cycle and frequency of walking/cycling trips can be used to measure the physical activity level of active transport.

- **Objective 5.2: Promote public transport**

Commuting by public transport also contributes to increasing commuters' physical activity level because public transport passengers often have to walk or cycle from or to public transport stations or stops. Some indicators can be used to measure this objective, such as transport mode share of public transport, average walking/cycling time from and to public stations/stops, average walking/cycling distance from and to public stations/stops.

- **Goal 6: Reduce transport-related greenhouse gas emission**

Transport is one of the largest contributors to global greenhouse gas emissions that is still increasing. It is also one of the major sectors facing difficulties in cutting its greenhouse gas emissions as a driving factor to climate change. As mentioned in the previous section, climate change is one of the greatest health challenges in the 21st century. Therefore, transport policies that aim to cut down on transport-related greenhouse gas emission are urgently needed. The greenhouse gas emission from the transport sector can be measured in tons of carbon dioxide equivalent (tons CO2e). This goal can be divided into five objectives including (1) improve vehicle energy efficiency, (2) improve efficiency of transport system, (3) shift travel demand to more energy-efficiency modes, (4) promote low-carbon alternative fuels, and (5) decrease private motorised transport demand.

- **Goal 7: Reduce transport-related land consumption**

Urban space is limited while the urban population is predicted to increase, resulting in the scarcity of urban land for housing, transport, green spaces, and other purposes. This goal focuses on optimising the efficiency of existing road infrastructure, parking spaces, and other transport facilities and reducing the land for road expansions and parking spaces. This goal can be measured by the percentage of the land area for transport in the city's total land area, the percentage of total road spaces in the total urban area, the efficiency of using parking facilities and the proportion of land use taken by all city transport modes. Two major objectives of this goal are (1) improve efficiency of existing transport facilities and (2) reduce road expansion and parking place for private motorised vehicles.

- **Goal 8: Reduce community severance caused by transport**

Transport-related community severance is defined when transport infrastructure or motorised traffic acts as a physical or psychological barrier to the movement of cyclists and pedestrians. Community severance affects health in different ways, such as increased independent travel (e.g., children, elderly), reduced social contact, increased social isolation, and others. However, the knowledge of the health impacts of community severance is still very limited and is often ignored in transport planning and policy development. Currently, studies that quantify the health effect of community severance are not yet available. Some qualitative indicators that can be used to measure community severance by transport include cross-ability (how easy to cross the barriers) and walkability (easy to walk around). Improve transport infrastructures and facilities for pedestrians and promote walkability are two main objectives of this goal.

6.3 Importance of active transport and public transport in addressing transport-related health impacts

Transport plays a vital role in providing accessibility for people; however, it also causes substantial negative health impacts, as presented in chapter 2. A number of actions have been implemented to mitigate the negative impacts of the transport system, such as mixed land use, control vehicle ownership, applying stricter emission standards, congestion charge, vehicle sharing, and parking control. However, the benefits of these actions are likely small and offset by the increase in travel demand. Among these actions, the shifting from private motorised transport to active transport (walking and cycling) and public transport is presented as an obvious solution to improve health and well-being. Figure 6-5 presents the sustainable transport hierarchy, in which walking, cycling, and public transport should be prioritised above the others to attain sustainable transport development. This hierarchy could be considered a healthy transport hierarchy also. The major health benefits related to active transport and public transport are described as below.

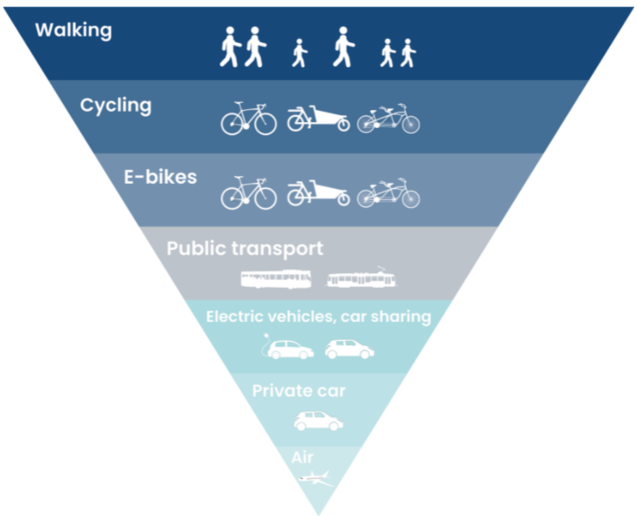

Figure 6-5: The sustainable transport hierarchy (source: https://energysavingtrust.org.uk/service/sme/)

- **Reduce health impacts of exposure to transport-related to noise and air pollution**

Compared to individual combustion vehicles, walking and cycling generate very low or no air pollution at all. Low-emission public transport emits less air and noise pollution, while it can transport a larger number of passengers. Bicycles and public transport also create fewer wastes and have lower life cycle costs than private cars, which indirectly affect health as well. Walking and cycling are the most efficient and environmentally sustainable means for short trips. In combination with public transport, they can serve longer trips. Therefore, the good integration between active transport and public transport are able to substitute for a large number of private motorised trips, helping mitigate adverse health effects related to private motorised transport.

- **Promoting physical activity**

Regarding active and public transport commuters, increasing evidence supports that the health benefits of physical activities related to these transport modes far outweigh the negative impacts of traffic injuries and exposure to air and noise pollution (Tainio et al., 2016). There was an estimation that worldwide physical inactivity was responsible for 13.4 million disability-adjusted life-years, and 31.1 % of the global adults (15 years or older) do not meet the public health guidelines from recommended levels of physical activity (Hallal et al., 2012). Physical inactivity and insufficient physical activity have been considered one of the leading risk factors that are associated with the increase in the risk of many adverse health effects, including major non-communicable diseases, such as coronary heart disease, type 2 diabetes, obesity, breast and colon cancers, and shortens life expectancy. Therefore, daily commuting by active transport and public transport is a promising approach to integrate physical activity into daily life to prevent harmful health impacts from physical inactivity and insufficient physical activity.

- **Improve safety**

Cities where active transport and public transport are dominant are likely safer than the city dominated by private motorised transport. Jacobsen examined the relationship between the numbers of people walking or cycling and the frequency of collisions between motorists and walkers or cyclists (Jacobsen, 2003). He found that motorists adjusted their behaviour in the presence of people walking and bicycling. Where, or when more people walk or cycle, they were less likely to be injured by motorists, which was defined as "safety in numbers". Recently, Marshall and Ferenchak reported that cities with high bicycling rates are not only safer for bicyclists but for all road users (Marshall & Ferenchak, 2019). They found that the safety for all road users results from a greater prevalence of bike facilities that are designed to attract cycling and reduce motorised traffic. Cities with higher public transport ridership are also reported safer than cities dominated by motorised traffic, and traffic fatality rate tends to decline with the increased public transport ridership (Thompson et al., 2020) (Litman, 2021) . Figure 6-6 presents the relationship between per capital transport ridership and total traffic fatalities in 35 large North American cities. Therefore, policies that encourage walking, cycling, and using public transport tend to be the effective approaches to improve safety.

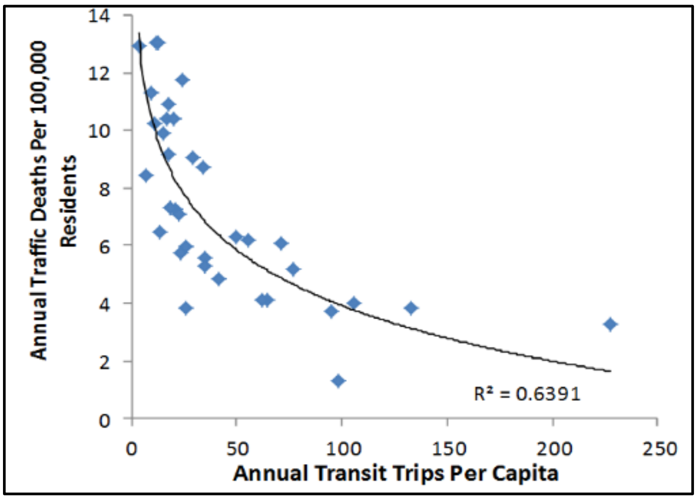

Figure 6-6: Traffic fatalities versus public transport trips in 35 US cities (Litman, 2021)

- **Reduce health inequity**

Active transport and affordable public transport services improve the accessibility and mobility for the low-income population, non-drivers, children, the elderly, and disable people. These transport options are inexpensive and easy to use by almost everyone, offering them better accessibility to services, job and education opportunities that are better for their health and enhance health equity. For example, active transport and public transport are important to the older population’s quality of life, maintaining old people's mobility. These transport options support healthy ageing and allow the older population to participate in the community and stay physically and mentally fit.

- **Cutting carbon emissions**

Shifting from private motorised transport will reduce transport-related greenhouse gas emissions that help to tackle climate change and improve air quality. For example, Neves and Brand estimated that replacing 41% of short car trips with walking and cycling in Wales contributed to saving nearly 5% of CO_2 emissions from car travel (Neves & Brand, 2019). Woodcock et al. reported that reduction in carbon dioxide emissions through increased active travel and reduced use of motorised vehicles produced larger health benefits in London and Delhi than those from the increased use of lower-emission motorised vehicles (Woodcock et al., 2009).

- **Improving community cohesion**

Community cohesion refers to the quality and quantity of interactions among people in a community. Active-friendly neighbourhoods can facilitate incidental social interactions between neighbours, foster social networks, and increase casual surveillance of the streets, creating and improving the sense of safety and security. A travel survey in the city of Vancouver indicates that people travelling by foot, bike, or public transport are more likely to engage in a friendly interaction than when commuting by private automobile (Chou et al., 2016). Figure 6-7 presents the likelihood of a friendly social interaction during the trip by transport mode, based on the transportation panel survey in Vancouver in 2016.

Figure 6-7: Likelihood of a friendly social interaction during the trip by mode (Chou et al., 2016)

- **Supporting sustainable development**

The synergies between sustainable transport policies and health-promoting transport policies are well-recognised (J. S. Mindell, Cohen, Watkins, & Tyler, 2011). The healthy transport policies reducing travel by private motor vehicles and increasing walking and cycling and using public transport, together with reducing in travel demand will all yield a wide range of benefits for individuals, local communities, wider society and the planet (J. S. Mindell, 2017a). Active transport and public transport are both essential components in the sustainable transport system, and promoting active transport and public transport is one of the most important actions needed to achieve sustainable mobility (Banister, 2008).

Figure 6-8 shows conventional transport planning and sustainable transport planning. Conventional planning favours motor vehicle transport and gives little consideration to other modes that creates a self-reinforcing cycle of expanded roadways, increased vehicle traffic, reduced travel options, and sprawled development patterns. This cycle increases urban transport problems and affects human health adversely. Whereas sustainable transport planning that promotes walking, cycling, and public transport diminishes or avoids conventional planning problems (Litman, 2014). It should be noted that sustainable transport planning does not mean to eliminate private motorised transport altogether, but the transport policies and transport interventions should encourage commuters to walk, cycle, and use public transport for all trips that can be substituted by individual motorised transport.

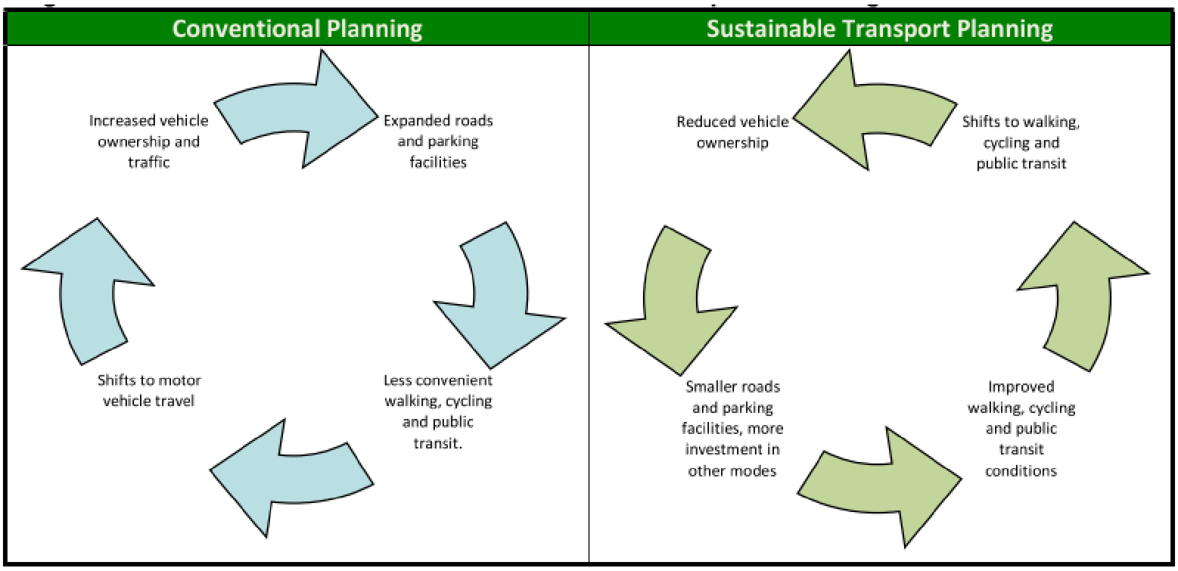

Figure 6-8: From conventional planning to sustainable transport planning (Litman, 2014)

- **Reduce transport-related land consumption**

Active transport and public transport are space-efficient modes. These transport modes require less space, compared to private motorised modes, particularly for parking spaces. In addition, active transport and public transport also increase the efficiency of existing road infrastructure that helps combat traffic congestions. Urban land is unchanged while the urban population is increasing. By reallocating road space for walking, cycling, and public transport, the urban transport system can still keep up with increasing travel demand and save land for housing, green spaces, parks, and other purposes.

In addition, active transport and public transport are also cost-effective modes for both commuters and the community. Motor vehicles are costly to own and operate, consume more space and energy and impose more congestions, accident and pollution costs. In contrast, the costs of infrastructures for walking, cycling and public transport are generally much lower than those of building and operating roads and parking facilities. As a result, investment in active transport and public transport can provide substantial savings.

Overall, promoting active transport and public transport provides many health benefits for commuters and the whole community. The major health benefits are increased physical activity, reduced air and noise pollution, decreased greenhouse gas emissions, increased social interaction, reduced land consumption, equal opportunity, livability and transport efficiency.

6.4 Proposed application in HCMC

Figure 6-9 presents the genetic model of the urban transport and land use evolution that Hung developed, based on the combination of two Barter's models (Barter, 1999) (Hung, 2006). Barter discovered that although the cities are developing in different directions, three main development directions of urban transport and land use are drawn for Asian cities: automobile city, modern transit city, and traffic saturated city. Based on Barter's model, Hung proposed three future scenarios of a motorcycle dependent city like Hanoi and HCMC, including a traffic saturated city, an automobile city, or a transit city. Depending on urban planning, transport planning, land-use pattern, and urban and transport policies, the urban transport system in motorcycle dependent cities could be developed by all three directions. Obviously, the desirable scenario for future development of urban transport and land use in motorcycle-dependent cities is the modern transit city.

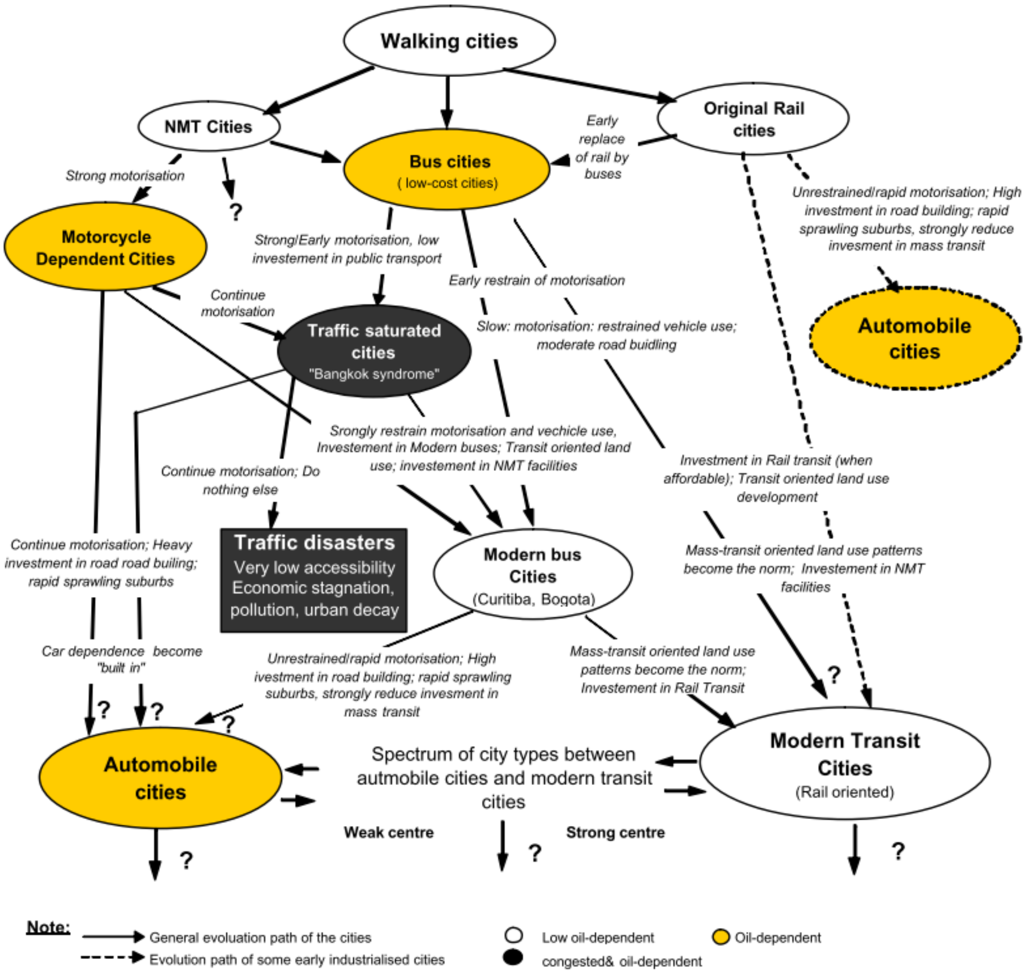

Figure 6-9: Generic model of urban transport and land use evolution (source: (Barter, 1999) (Hung, 2006))

The urban transport system in HCMC has experienced the imbalance between transport supply and transport demand. The development of road infrastructure cannot keep up with the increase in travel demand, which increases traffic congestions, traffic accidents, and air and noise pollution in the city. In 2017, nearly 7.5 million motorcycles and 285,000 passenger cars were operating in HCMC. Around 83% and 5.3 % of transport demand in the city are conducted by motorcycles and cars, respectively. HCMC is one of the cities with the highest motorcycle ownership rate worldwide, with nearly 860 motorcycles per 1,000 population. Compared to other cities, the car ownership rate in the city is relatively low, only 33 cars per 1,000 population. However, the number of private cars is increasing significantly in recent years as a result of economic development. Under the current road infrastructure and urban transport system, the motorcycle is still the most effective transport mode in HCMC. Because of the small size and high manoeuvre, the road-space use by motorcycles is more efficient than cars; therefore, road capacity is higher.

HCMC has been considered a motorcycle-dependent city. However, the city is in the transition process where private cars are increasing faster than motorcycles. Without controlling private motorised transport, the urban transport system in HCMC is likely to become a traffic saturated city where traffic is dominated by cars. As a result, transport-related health impacts in the city could be worsened rather than improved. However, the city has a huge opportunity to avoid this undesirable development path by promoting walking, cycling, public transport and restricting private motorised transport. Current travel patterns and land use in the city favour sustainable and healthy transport development in many ways. The urban structure is relatively compact with high population density and mixed land use combined with the dominant of motorcycles, generating many short and medium trips in the city. These trips can be potentially substituted by walking, cycling, and using public transport. The urban road network and daily lifestyle (e.g., daily shopping) in the city also create favourable conditions for encouraging active transport and public transport in HCMC instead of using cars. Recently, the evolution of electric vehicles (including electric bicycles) and share-mobility further supports the development of urban transport in HCMC toward a sustainable and healthy direction. For example, the high number of medium motorcycle trips can be easily conducted by electric bicycles. Share-mobility encourages people to share vehicles instead of owning them. If implemented correctly, the city may avoid the mistakes of other cities and take a shortcut to become a healthy and sustainable city.

In the interview survey mentioned in chapter 5, the commuters were asked if they had to select another transport mode for their daily commuting, which factors were the most important for them when they had to select this new transport mode. The given list of factors included health impact factors, travel time, travel cost, comfort, and convenience. The evaluation was 10 point scale; 1 is the least important and 10 is the most important. Figure 6-10 presents the result of commuters' evaluation. Overall, there are no big differences in the evaluation of various commuter groups. Safety, comfort, convenience, and travel time were regarded as the most important factors for all commuter groups when selecting their alternative transport options. The health impact factors, including safety, reducing exposure to noise and air pollution, and reducing CO2 emissions, were also considered relatively important for all commuters. Pedestrians and cyclists evaluated the importance of health impact factors (e.g., increase physical activity and reduce CO_2 emission) when choosing their alternative mode higher than other commuter groups. Therefore, promoting walking, cycling, and public transport as healthy transport modes could potentially encourage people to shift from motorcycles and cars toward these modes.

During the interview surveys, commuters were also asked about their willingness to change to healthier transport modes. The result showed that nearly half of the commuters would change their current transport mode to the healthier transport modes. Only 17% of the commuters responded that they would not change their transport modes, and 35% of commuters would take it into consideration. Then, the author assumed that walking, cycling, and using buses are healthier for commuters than cars and motorcycles. Motorcyclists and car users were asked if they were willing to change to these active and public modes. Bus passengers, pedestrians, and cyclists were asked if they would keep their current transport modes. The result showed that more than 75% of all bus users, pedestrians, and cyclists would keep commuting with their current transport modes. Whereas only 32% of car users would shift from their cars to walking, cycling, and using buses, and 39% of car users would not change their transport mode. Nearly half of the motorcyclists would change to active transport and public transport if these modes were healthier than motorcycles, and 41% of motorcyclists would consider changing, only 10% of them could keep travel with their motorcycles. The willingness of car users and motorcycle users to change to healthier modes is presented in figure 6-11.

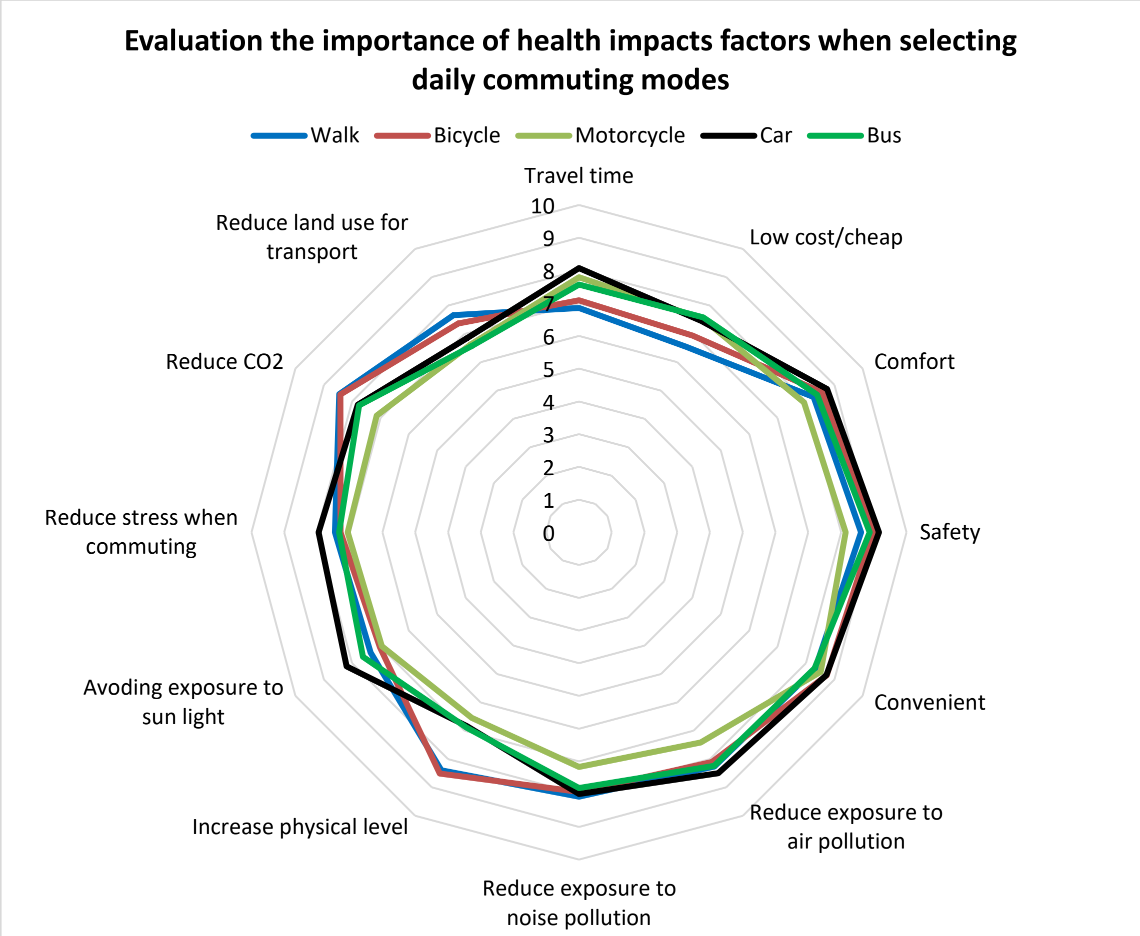

Figure 6-10: Evaluation of importance of health impacts factors when selecting alternative commuting modes

Overall, the interview survey results show that the awareness of health is relatively high among commuters in HCMC, especially among pedestrians, cyclists, motorcyclists, and bus users. And changing transport mode choices among motorcyclists seems to be easier than that among car commuters. Promoting active transport and public transport as healthy transport options would be a promising approach for changing road users' travel behaviours toward healthier and more sustainable transport modes. Around 80% of transport demands in HCMC are carried out by motorcycles; if half of these demands shift to walking, cycling, and using buses, the urban transport in the city could improve substantially.

Despite the health benefits of active transport and public transport, the public authorities, transport planners, and decision-makers in HCMC seem to underestimate the benefits of these transport modes, especially the health benefits associated with transport-related physical activity of these modes. Therefore, they need to be more aware of the health benefits of active transport and public transport by integrating health consideration into their decision-making process. Specific goals and objectives presented in part 6.2 can be selected to integrate into the existing goals and objectives of the city transport system. In addition, transport decision-makers also need to be more aware of the potential of substituting motorcycle transport by active transport and public transport. A large number of motorcycle trips in the city can be conducted by walking, cycling, and using buses, and a large proportion of motorcyclists are willing to shift to these transport options if they are better for their health.

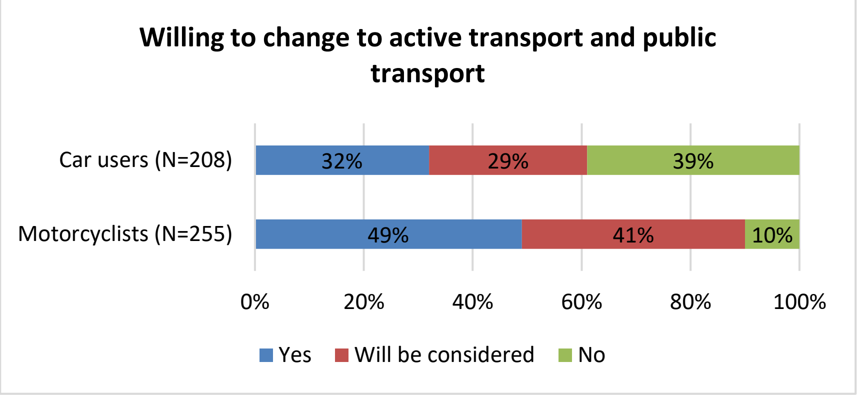

Figure 6-11: Willingness of car users and motorcyclists to change to active transport and public transport

6.5 Conclusions

The chapter has introduced the concept of a health-oriented transport policy by highlighting the importance of health and the contributions of the transport system in promoting health. Then goals and objectives of the health-oriented transport policy have been proposed, including 8 major goals and 25 specific objectives. Public authorities, transport planners, decision-makers, and other related stakeholders should aim to achieve these goals and objectives to optimise the positive and negative health impacts of the transport system. Active transport and public transport play essential roles in the healthy transport system that provides many health benefits for commuters and the whole community. The major health benefits are increased physical activity, reduced air and noise pollution, decreased greenhouse gas emissions, increased social interaction, reduced land consumption, equal opportunity, livability and transport efficiency. Also, the chapter has emphasised the potential of active transport and public transport in replacing motorcycle transport in HCMC.

7 Development of Strategies to Promote Active Transport and Public Transport

Chapter 6 highlighted the important contributions of active transport and public transport to reduce adverse transport-related health impacts and to promote positive transport-related health impacts. Active transport and public transport are not only health transport modes but also sustainable modes that contribute to addressing other transport-related problems, as well. Therefore, this chapter aims to answer the questions "how to promote active transport and public transport?". In the first section, the introduction of strategies to promote active transport and public transport is presented. Then, the measures included in each strategy are described from section 7.2 to section 7.6 The recommendations for applications and implements in Ho Chi Minh city are mentioned in section 7.7. Finally, the key findings of the chapter are summarised.

7.1 Development of strategies

The strategy has been defined as an action plan which includes a bundle of pre-defined measures to improve a defined initial situation. A situation is defined as a combination of certain events, problems, and conditions (Boltze & Fornauf, 2013). This section proposes five strategies that aim to promote active transport and public transport.

The urban transport system is a complex system that contains different transport modes with different functions in providing accessibility and mobility for commuters. These transport modes can be substituted, combined, and competed with each other. Therefore, measures which focus only on active transport and public transport without consideration of other modes will not promote active transport and public transport successfully. To encourage active transport and public transport, measures that restrict and control private motorised transport are also essential. Measures that improve the efficiency of the existing transport system by reducing traffic congestion, noise and air pollution also indirectly encourage active transport and public transport. In general, in this chapter, 5 strategies that consist of different measures are proposed to promote active transport and public transport, including:

(1) Strategy to promote walking

(2) Strategy to promote cycling (including traditional bikes and bikes with the assistant of electric motors)

(3) Strategy to promote public transport

(4) Strategy to control and avoid private motorised transport

(5) Strategy to improve the efficiency of the transport system

Three major purposes of these strategies are (1) to encourage people to shift from individual motorised transport to walk, cycle, and public transport, (2) to restrict and avoid individual motorised transport demand, and (3) to improve the efficiency of the transport system. The following sections present more detail of measures that could be included in each strategy.

7.2 Strategies to promote walking

Unlike the other transport modes, walking is the oldest and the most natural for human to move around. A safe and comfortable pedestrian environment provides the most natural way for people to interact with each other. All most every trip starts by walking and end by walking. People can do walking at all ages and walk does not require any special skills or equipment.

However, in many cities, planning and designing for pedestrians are still insufficiently considered or neglected. Low-quality sidewalks, occupied sidewalks, inappropriate crossing locations, missing facilities for disabled people are common pictures in Asian cities like Hanoi and Ho Chi Minh City. These conditions are strongly discouraged people from walking. Thus, pedestrian infrastructures and facilities that ensure safety, security, convenience, and comfort for all are vital conditions to promote walking. Vanderslice et al. identified some major principles for the pedestrian design that designers should attempt to achieve, including (Vanderslice et al., 1998):

- The pedestrian environment should be safe to minimise conflicts with vehicular traffic.
- The pedestrian network should be accessible to all by accommodating the needs of people regardless of age or ability.
- The pedestrian network should connect places where people want to go by providing continuous, direct routes and convenient connections between destinations such as schools, home, shopping areas, public transit, and recreational opportunities.
- The pedestrian environment should be designed that people can easily find a direct route to the destination, and delays are minimized.
- The pedestrian environment should provide good places to enhance the comfort and enjoyment of pedestrians. The pedestrian environment includes open spaces, street arts, special paving, building architecture, benches, and trees could encourage more people to walk and walk more often.
- The pedestrian environment should be used for many purposes, such as selling food, coffee, restaurants, advertising, and other public activities.

The essential facilities for pedestrians are described below.

- **Sidewalks**

Sidewalks are essential infrastructure for pedestrians and are a fundamental component of the urban transport system. Sidewalks are not only providing movement for pedestrians, but they are also important social spaces where people interact and walk together, use public transport, do window shopping, or drink a cup of coffee. Therefore, sidewalks should be wide enough to accommodate pedestrian movement and amenities such as benches to facilitate social interactions. Not all streets in urban areas have sidewalks; however, where the walking demands are available, providing sidewalks should be considered. Providing safe, accessible, convenient, comfortable, and connected pedestrian networks is essential to encourage walking. The design of sidewalks should consider the needs of different pedestrian groups, including children, the elderly, and disable people.

Obstacles along sidewalks that affect the safe and smooth movement of pedestrians have to be eliminated. In some cities like Hanoi and HCMC, the sidewalks are often occupied by parked vehicles, street vendors, and many other obstacles. Pedestrians are often forced to walk on the roads that increase their risks of being involved in traffic accidents. As a result, many people are strongly discouraged from walking.

- **Pedestrian crossing facilities**

The majority of accidents involving pedestrians has happened at pedestrian crossing points where conflicts between people and vehicles occur. Therefore, crossing facilities should be carefully designed to ensure pedestrians' safety and convenience when crossing the streets and to minimise the adverse effects on vehicular traffic. Several types of crossings are intersection crossing, mid-block crossing, roundabout crossing, and grade-separated crossings. The basic element facilities of most pedestrian crossings are marked crossings, stop lines and kerb ramps. The design of pedestrian crossings has to ensure the visibility for both pedestrians and drivers that allows them to predict coming traffic or pedestrians and to adjust their travel behaviour accordingly. Kerb parking and on-street parking near pedestrian crossings should be prohibited. Depending on pedestrian demand, traffic volume, vehicle speed, road width, and other factors, additional facilities have to install at pedestrian crossings. For example, pedestrian actuated signals should be implemented at mid-block crossings where pedestrian demand is high, and the volumes and speeds of traffic are also high, or at intersections where the level of pedestrian demand is relatively low, but the traffic volume and speed of the vehicle are high. The pedestrian push buttons are often used to activate actuated signals for pedestrians at these crossing points. These push buttons should be located near the end of sidewalks at an appropriate height and reachable by all pedestrians waiting to cross. At the signalised intersections where pedestrian volumes at all directions are high, providing an exclusive pedestrian signal phase should be considered. Some features of common pedestrian crossing facilities and their applications are described below.

- **Kerb crossing ramps**

  Kerb crossing ramps provide a smooth transition between sidewalks and roadways that make mobility impaired pedestrians, people with children strollers, or kids with walker balance bikes to cross the street more easily. Kerb ramps should be provided at all intersections and at every pedestrian crossing point. The length and gradient of kerb rams should be correctly calculated to ensure the safety of pedestrians.

- **Pedestrian island** (also called refuge island or pedestrian refuge)

  A Pedestrian island is a median with a refuge area that provides a location for pedestrians to safely stop and wait before finishing crossing a road (Zegeer et al., 1998). Pedestrian islands can be provided at intersections or midblock locations and often implemented on wide and multi-lane roads. The presence of a pedestrian refuge at the intersection or midblock location allows pedestrians to focus on one direction of traffic at a time as they cross and give them a place to wait for the second stage of the crossing. Therefore, the safety and comfort of pedestrians are improved. The pedestrian islands may also enhance the visibility of the crossing and reduce the speed of coming vehicles.

- **Mid-block crossing**

  In streets where distances between intersections are long, mid-block crossing points should be provided for the pedestrian to cross safely. In the areas where pedestrian volumes are high such as schools, parks, or public stops, mid-block crossing should also provide. Marked crosswalks such as zebra ladder or piano bar markings should always be provided at the mid-block crossing to guide pedestrians to cross at the safest location and increase drivers' visibility. Depending on traffic volume, traffic speed, road width, pedestrian actuated signals, medians, or refuge islands may be implemented to ensure a safe crossing for pedestrians. Advanced warning signs and pedestrian crossing signs have to be installed in advance of mid-block crossings to raise drivers' awareness and allow them to adjust their travel behaviours.

- **Pedestrian overpasses and bridges (grade-separated crossings)**

  Grade-separated crossings refer to facilities that allow pedestrians and motor vehicles to cross at different levels that substantially improve pedestrian safety and minimise disruption to vehicle traffic. Compared to other types of crossing facilities, grade-separated crossings are much more expensive. Where are high pedestrian volume, heavy traffic with the high-speed flow, and the provision of other crossing facilities are not possible or cause heavy traffic delay. Providing grade-separated crossing should be considered. It should be noted that grade-separated crossings should be easy and convenient for pedestrians to access.

- **Pedestrian zone**

Pedestrian zones (also known as car-free zones or pedestrian mall) are most beneficial in central business districts and in high pedestrian volume areas where sidewalks are overcrowded, and vehicle volumes are low. In the pedestrian zones, motorised vehicles are restricted, and the pedestrian can use the entire space. Cyclists may allow entering to pedestrian zones as well. Pedestrian zones can be permanent for pedestrians or only operate at the weekend. The main measure purposes of pedestrian zones are to promote walking and discourage motorised vehicle transport. This also supports local businesses by attracting people to visit for shopping, entertaining, eating, and using other services in the areas—pedestrian zones also good places to enhance social interaction and improve community cohesion.

7.3 Strategy to promote cycling

The measures included in the strategy are cycling infrastructures and cycling facility measures, bike-sharing schemes, and cycling promotion measures.

7.3.1Infrastructure measures/facilities measures

Providing safe and convenient cycling infrastructures is crucially important to promote cycling. Cycling infrastructures can be classified into three main groups including measures related to cycling network, measures at intersections and crossings, and cycling parking facilities. Some basic design principles have been adopted in designing guidance and standards for cycling infrastructures in many countries, which include "**Safety, Directness, Cohesions, attractiveness, and comfort"** (Deffner, Hefter, Rudolph, & Ziel, 2012), (PRESTO Project, 2010c).

- **Safety** is the fundamental requirement to encourage people to cycle as safety concern is the greatest barrier to cycling. Increasing safety for cyclists can be done by separated cyclists from motorised traffic, reduce traffic intensity and speed.
- **The directness** of cycle routes that reduce travel time and distance for cyclists will increase the competitiveness of cycling compared with motorised transport. This can be done by reducing detours, the number of stops and crossing, traffic signal priority for cyclists.
- **Cohesions** mean that every cyclist can reach their all-desired destinations by bike easily through a good cycling network and connection with the public transport network.
- **Comfort** is aiming to improve the cycling experience by creating an enjoyable, smooth, and relaxed cycling condition. The mental and physical effort should be minimized as much as possible such as avoiding frequent stop and start and ensuring quality of cycling infrastructure.

- **Attractiveness** means that cycling infrastructure is well integrated into agreeable surroundings.

These requirements should be considered as objectives of all cities when planning and designing for cycle infrastructures. This also can be used as criteria to assess the quality of cycle infrastructure among cities. Cities where infrastructure is more likely to meet these criteria are more likely to increase cycling. This section presents the most common cycling infrastructures that are common in many cities, including measures for cycling networks, measures at intersections and crossings, and cycling parking facilities.

- **Cycling networks**
  - **Cycle lanes**

Cycle lanes or on-road cycle lanes that can be "mandatory" or "advisory". A mandatory cycle lane is a part of the road exclusively reserved for cyclists and visually separating them from traffic. Motorised vehicles are usually not allowed to travel or park on these cycle lanes. An advisory cycle lane or suggestion lane indicates an area of the road intended for cyclists without being exclusively reserved for their use, and other vehicles are allowed to enter or cross it. The advisory cycle lane may appropriate when the cyclist volume is low, and there is not enough space for a dedicated cycle lane. Two major advantages of cycle lanes are relatively cheap and can be quick and easy to implement. They are using existing road space and are indicated by road markings and possibly colour or bicycle logos. Cycling lanes can be applied outside of built-up areas on roads with relatively low traffic volume and vehicle speed below 60 km/h. Within built-up areas, cycle lanes are recommended for major roads but only when traffic speed is low (less than 30 km/h) (PRESTO Project, 2010b). In some cities, cyclists are allowed to use dedicated bus lanes. In this case, the design of shared bus-bike lanes should ensure safety and efficiency for both cyclists and buses (Cazorla, 2017)

In cities with a low level of cycling, offering cycle lanes may increase the safety for cyclists compared to mix traffic lanes. It should be noted that cycle lances usually do not have physical separations between cyclists and motorised traffic. As a result, illegal parking and wrong driving lane may happen along cycle lanes that pose a potential accident risk to cyclists. Therefore, the enforcement of traffic rules may also be necessary, particularly in cities where cycling culture is not common. Cycle lanes should be designed with adequate widths, clear signage, and smooth surfaces and be integrated with the cycle network/cycle lane network.

  - **Cycle tracks**

A cycle track (also known as a cycle path) is an exclusive part of the road reserved for cyclists, and it is physically separated from motorised traffic through a kerb, parking lane, parking lane, or planted area (SUTP, 2010). Cycle tracks can be located within or next to the roadways and also located independent of the road network called a solitary cycle track. Compared to cycle lanes, cycle tracks are more costly and require more space. However, it offers a significantly higher level of safety and comfort for cyclists. Cycle tracks are highly recommended on the roads where traffic speed is more than 60 km/h, the cycling volume is high, and the motorised traffic volume is high (PRESTO Project, 2012).

Constructing cycle tracks may take space from motorised traffic, which may result in increased traffic congestions. At intersections, the sudden mixing of cyclists and other road traffic can result in traffic accidents. Therefore, these issues should be carefully considered when planning for implementing cycle tracks.

- **Cycle streets**

Cycle streets are also known as bicycle boulevards or Fahrradstraße in Germany. A cycle street is mixed-traffic streets, however, its design favour for cyclists. Motorised vehicles are allowed to assess bicycle streets, but bicycles are dominant transport modes (Walker, Tresidder, Birk, Wiegand, & Dill, 2009). In general, there are some key design principles for successful cycle streets (Sustrans, 2014):

- It should be designed to provide a clear indication that cyclists have priority over motorised traffic.
- Speed limits for motorised traffic should be below 30 km/h.
- Provide the right-of-way for cyclists at intersections and crossing points.
- Minimize nuisance caused by parked vehicles for safety and comfort.
- Parking on the roadway is not allowed.

- **Cycle highways**

A Cycle highway is a high-quality functional cycling route that enables direct, rapid, safe cycling trips and encourages long-distance cycling trips (Taylor & Hiblin, 2017). Compared to other cycling infrastructure measures, cycle highways are costly and require significant time and human resources; therefore, it is not common cycling infrastructure. However, an effective cycle highway network may help to increase the connectivity for cyclists by increase their speed, safety, and comfort level for long-distance cycle journeys that can substitute for motorised trips effectively. As a result, health problems caused by motorised traffic will reduce, and physical activity's health benefits through cycling will increase. For example, Denmark is planning to extend its national cycle highway up to 45 routes with 746 km by 2045. It is estimated that every year, there will be 6 million more bike trips and 1 million fewer car trips, resulting in a socio-economic surplus of 765 million euros (Office for Cycle Superhighways, 2018). Another study estimated the health impact of two bicycle highways Antwerp-Mechelen and Leuven-Brussels (Buekers, Dons, Elen, & Int Panis, 2015). The result showed that overall physical activity outweighed other health impacts. The benefit of cost ratio for health impacts and infrastructure construction costs was mainly positive, even when reduced congestions, noise, and CO2 were not taken into account. Although there are large uncertainties, they suggested that further investment in cycle highways should be promoted.

- **Contra-flow cycling**

Contra-flow cycling is when cyclists are allowed to ride in both directions in a one-way street. The use of contraflow cycling is popular in many European countries such as Germany, Belgium, and Netherland. In cities where one-way traffic streets are common, that may have significant negative effects on cycling. For example, cyclists have to make detours and ride a longer distance. Providing contra-flow cycling helps improve the convenience, directness, accessibility, and comfort for cyclists, increasing the attractiveness of cycling and encouraging a model shift from car to cycle. In addition, it also improves safety for cyclists, as it discourages cyclists from using dangerous alternative routes and increases visual contact between cyclists and drivers (ETSC, 2018). Clear road signage and markings are highly important for contra-flow cycling to increase the attention from motorised traffic. However, in cities where traffic enforcement is low and people often do not obey traffic rules, it should be carefully considered when planning for contra-flow cycling to ensure the safety of cyclists.

- **Measures at intersection and crossing**

Intersections include junctions, traffic-signalised intersections, non-traffic signalised intersections, and roundabouts. The quality and number of intersections along cycleways may affect the attractiveness of cycling as they can increase the accident risk and waiting time. Therefore, appropriate designing intersections that ensure cyclists' safety, directness, and comfort are essential to encourage cycling. Some main features of a good intersections design are (1) avoid mixing motorised traffic with cyclists where traffic volume and/or traffic speed is high, (2) maximise the separation of cyclists from dangerous traffic movements, (3) maximise the visibility of cyclists, (4) cyclists should be given priority at intersections, and (5) intersections should be easy to identify, understand, and use by all transport modes (European Commision-Mobility and Transport, 2021). The function of the cycle route, types of intersection, traffic intensity, local condition, traffic speed, and level of cycling should be taken into account when selects the design for the intersection. Elements of a good intersection for cyclist may include colour, signage, medians, pavement markings, and signal detection (NACTO, 2014). Different types of intersections can be designed differently to ensure safety and comfort for cyclists. Three types of intersections and their application were mentioned in the project report “Promoting cycling for everyone as a daily transport mode (PRESTO)” (PRESTO Project, 2010c).

- **Right-of-way intersections** are used to give priority to one road over another without signalization. This is recommended for roads with low traffic intensities and a speed limit below 30 km/h. The design ensures the visibility of cyclists is essential to ensure safety for them. Providing traffic islands, speed tables, intersection crossing markings, and right-of-way for main cycle routes can improve safety for cyclists at these interactions.
- **Roundabouts** are recommended when the cycle route crosses moderately busy roads. The single-lane roundabouts are considered the safest solution for all users on moderately busy roads. They reduce the speed of approaching traffic and allow the smooth movement of traffic flow through the intersection. However, multiple-lane roundabouts are much more dangerous for cyclists as there are more conflicting interactions between motorised traffic and cyclists. A separated cycle track around a multiple-lane roundabout can improve safety for cyclists; however, it is more costly and requires more space.
- **Signalised intersections** are common in urban areas that are standards between main roads with heavy traffic flows. Because of the large numbers of motorised traffic involved, the design that increases cyclists' safety and visibility are important (SUTP, 2014). There are several ways to increase cyclists' safety, including providing an advanced stop line (bike box), a separate traffic light for cyclists, and providing right-turning cycle bypass (PRESTO Project, 2010a). Providing a bike box or an advanced stop line at the signalised intersection is a simple and very effective design to increase

the safety and visibility of cyclists. That provides an area for cyclists to wait in front of traffic during the red signal phase and facilitates cyclists to safely cross the intersection ahead of the traffic (NACTO, 2014). Designing the bicycle box located next to the traffic light at the intersection can also reduce a large amount of UFP exposure for cyclists (Luengo-Oroz & Reis, 2019).

- **Grade separation** infrastructure for cyclists includes cycling tunnels and cycling bridges that offer safe and direct ways to cross the barriers such as railway lines, busy roads, and rivers. This will increase the accessibility and attractiveness of cycling and encourage more people to cycle. However, these infrastructures are often more expensive than at-grade intersection measures, and it may require more physical efforts for cyclists. Additionally, cyclists may feel insecure when crossing through tunnels if there are few cyclists or during the night-time. These issues should be careful consideration when designing tunnels and bridges for cyclists.

- **Cycling parking facilities**

Cycling parking facilities is an important part of the cycling network that strongly affects the attractiveness of cycling. Similar to car parking demand, cycling parking demand varies by time, location, and cyclist groups. However, cycling parking has been received very little attention or often neglected in transport planning in many cities, especially in cities where the cycling demand is low. The availability, convenience, security, quality, and used costs of parking facilities can facilitate or hinder cycling (Heinen & Buehler, 2019). Cycling parking facilities that easy to access, safe and secure, and inexpensive to use will encourage people to cycle. In contrast, the absence of parking facilities or parking facilities that difficult to access, unsafe and insecure, expensive to use will deter both current and potential cyclists from cycling.

Three main principles for planning and designing cycling parking include fit-for-purpose, secure, and well-located (Transport for London, 2016).

- **Fit-for-purpose**: Demand for cycling parking varies by different user groups. Cycling parking needs to consider all these users' needs, including disadvantaged user groups such as people who use handcycles and tricycles.
- **Secure cycle parking:** Bicycle theft or the fear of theft and vandalism will significantly reduce the attractiveness of cycling from both existing and potential cyclists deterring them to cycle. Cyclists need to be sure that their bicycles will be safe and secure where it is parked, and that they will also be safe and secure when they access and use the cycling parking.
- **Well-located:** Convenient, accessible, and close proximity to user destinations are key features of well-located cycle parking.

The facilities at cycle parking are varying greatly across locations, cities, and countries. It can be simple cycle racks to extensive automated underground and multi-storey cycling facilities serving thousands of spaces, secure, and all-day access. Some examples of these facilities are presented in figure 7-1. These simple and complex parking facilities are both common and widely provided in many cities where the cycling levels are high. However, in cities where cycling levels are low, like Hanoi and Ho Chi Minh City, the separated cycling parking is very limited or not provided at all. Parking facilities in these cities are often designed to accommodate the parking demand of motorcycles and cars that further discourage cycling.

To provide appropriate parking facilities, it is crucial to understand the users' needs. For example, for people who want to park their bicycles for only a short time, proximity and convenience may be more important than a high level of security. People will be happy with basic parking facilities such as simple bicycle racks located in front of their destinations since they do not want to lose time using a locker or walking to a guarded facility. Whereas, for people who wish to park their bicycles for a longer time, a high level of security and protection is more important than proximity and speed. They are more willing to spend extra time walking to more secure parking facilities with lockers or shelters (PRESTO Project, 2010c). After identifying the type of parking required, quantify parking demand and select parking locations are needed. In cities where the cycling level is low, providing reserved cycling parking spaces with stands or racks close to major destinations and in the busiest areas may enough. However, when the number of cyclists begins to increase or in cities with higher cycling levels, more cycling parking will be needed to meet the parking demand. To increase the effectiveness of cycling parking facilities, unused bicycles and abandoned bicycles should be removed.

Bicycle parking should be provided at all key destinations, including residential areas, shopping centres, city centres, working places, educational buildings, entertainment and leisure locations, and public transport stops/stations. For each destination, the consideration of users' needs and their demand is needed to provide appropriate facilities, quality, and parking spaces.

- **Bicycle parking at resident areas**

  Cyclists want to park their bicycles safely and securely through the night. Many people can park their bikes at their homes. However, not all people can do it. For example, people who are living in the small houses or in the multi-stories building without offered parking spaces, the providing public cycling parking at residential areas for these people are necessary to encourage cycling and bicycle ownership.

Source: pushbikes.org.uk

Source: cyclinguk.org

Figure 7-1: Some examples of bicycle parking facilities

- **Bicycle parking at the city centres**

  City centres are the concentrations of many attractive destinations. Therefore, it is essential to provide multiple types of parking facilities in the city that meet the needs of different user groups. For example, at crowded shopping streets, people tend to park their bicycles for a quick stop, so providing a marked parking area may enough. But, at the shopping malls or book stores, people tend to park for a longer time, and they want their bicycles still there when they come back. Thus, providing bicycle parking with bicycle racks may better.

- **Bicycle parking at public transport stops/stations**

  Bicycle parking at public transport stops/stations can increase the demand for both transport modes (Krizek & Stonebraker, 2011). Cycling parking at public transport stops/stations is one of the key components for promoting and integrating cycling and public transport. The cycling facilities at the public stops/stations vary greatly across locations ranging from simple bicycle racks to bicycle parking hubs integrated with other services such as repair services.

- **Bicycle parking at workplaces**

  To encourage people to cycle to work, providing cycle parking at workplaces is needed. The well-designed cycle parking at workplaces should be secure, covered, conveniently located, and offer complementary facilities (e.g., showering and changing facilities, basis repairing tools).

  Other bicycle-related facilities or services such as bicycle pump stations, self-service repair points, vending machines for bicycle inner tubes, bike inspection services, and bike repairing workshops should also be provided at the appropriate locations. This will increase the convenience and attractiveness of cycling.

7.3.2Promote bike-sharing schemes (BSS)

- **Measure description**

Bike-sharing schemes, also known as bike-sharing systems, have been implemented in many cities worldwide as policies to facilitate cycling, reduce congestion, mitigate climate change, and provide accessibility to access to public transport. BSS is a service in which bikes are made available for shared use to individuals for limited periods. BSS may encourage people who do not cycle to cycle by allowing them to use bicycles without bicycle ownership and the accompanying concerns of storage, theft prevention and maintenance. BSS is relatively cheap for use; many BSS is free for an initial limited period (e.g., free for the first 30 minutes). Most bike-sharing systems require users to register before accessing bicycles by providing multiple options for registration and payment (e.g., smart card, credit card, mobile application). BSS usually has docking stations or hubs where bicycles require to be or are encouraged to be returned. However, with technology development such as electronic tracking and payment, dockless bike-sharing schemes are becoming popular in some cities.

The most common type of bicycle included in BSS is conventional bicycles. Some cities have recently included or considered adding electric bikes into their BSS such as Madrid, Milan (Italy), and Lisbon (Portugal). Including electric bikes into BSS allows people to travel longer distances that can substitute for many car trips. E-bike sharing schemes are a potential approach to encourage cycling in cities with hilly conditions or hot temperatures.

- **Health benefits**

The health benefits from BBS come from the increase in the physical activity level of people who cycle and reduce the number of trips taken previously by private motorised transport. The benefit is greater when bike share is used in combination with public transport modes. Some studies examined the health and economic benefits of BSS. For example, a study modelled the health impacts of the London bicycle sharing system on its users. The health impacts were modelled by changes in physical activity level, exposure to air pollution, and risk of traffic injuries. The result showed that London's bike-sharing system generates positive health effects for all, but these benefits vary among different user groups. Man and older users obtain large benefits compared to women and younger users (Woodcock, Tainio, Cheshire, O'Brien, & Goodman, 2014). Another study investigated the health and economic benefits of 12 larger European BSS (including e-bike sharing) in six countries (Germany, France, Belgium, Italy, Poland, and Spain) (Otero, Nieuwenhuijsen, & Rojas-Rueda, 2018). The health risks and benefits (physical activity, traffic fatalities, and exposure to air pollution) of car trips substituted by bike trips from European BSS with more than 2000 bikes were quantified. Four scenarios were created to assess the health impacts of shifting from car to BSS bikes, including (1) minimum observed car trips substitution, (2) 12% of the BSS trips come from car trips, (3) 50% of the BSS trips come from car trips, and (4) 100% of the BSS trips come from car trips. Their results showed that in all scenarios and cities, the health benefits of physical activity outweighed the health risks of traffic fatalities and air pollution with a benefit/risk ratio of 19:1. In the first scenarios, there was estimated that each year five deaths could be avoided in the twelve BSS, corresponding to 18 million Euros saving annually. If all BSS trips substituted car trips, 73.25 deaths could be prevented that equal to 225 million Euros saving each year, that shows the significant potential health benefits of BSS in European cities.

BSS is still expanding rapidly throughout the world. Different technological improvements in BSSs such as e-bikes, dock-less, and mobile apps make it more attractive and easier for users. BSSs encourage more people to cycle and may help moralise cycling as a daily transport mode around the city. BSS is potentially beneficial in cities with any levels of cycling. The introduction of BSS in a city with a low share of cycling can be a useful way to increase the visibility of cycling in both the general public and the city's authority. Providing safe infrastructure for cycling is essential to encourage the use of shared bicycles. Other measures such as restricting access and use of private motorised transport in certain areas also encourage BSS.

Although BSS has been successfully implemented in many cities both in developed countries and in developing countries such as Lyon (France), Berlin (Germany), and Hangzhou (China), they are also facing some challenges that need to be addressed and considered when introduce and promote BSS in other cities. The major issues include theft and vandalism, overuse/underuse/misuse, occupied sidewalks (with dock-less BSS), space conflicts, redistribution of bicycles, and conflicting with bike rental shops (Fernández, 2011). Cities that are considering introducing a BSS should learn the experience from other cities to select the appropriate scheme.

7.3.3Cycling promotional activities

Despite the significant benefits of cycling in improving health and addressing transport-related challenges, not all populations and decision-makers are well understood about these benefits. The perception of cycling varies greatly across individuals, cities, and countries (Deffner et al., 2012). For example, in the cities where the cycling level is high, the perception of cycling is generally positive or at least neutral. Whereas cities with low cycling levels like Hanoi and Ho Chi Minh City, people often perceive cycling as unsafe, uncomfortable, and for low-income people. Providing cycling infrastructure alone may not enough to increase the cycling level significantly. According to Pucher, Dill, and Handy, the cities that are most successful at increasing cycling level have implemented an integrated package of cycling infrastructure provision combined with promotional activities, including awareness-raising, information provision, training/education programs, and others (Pucher, Dill, & Handy, 2010)

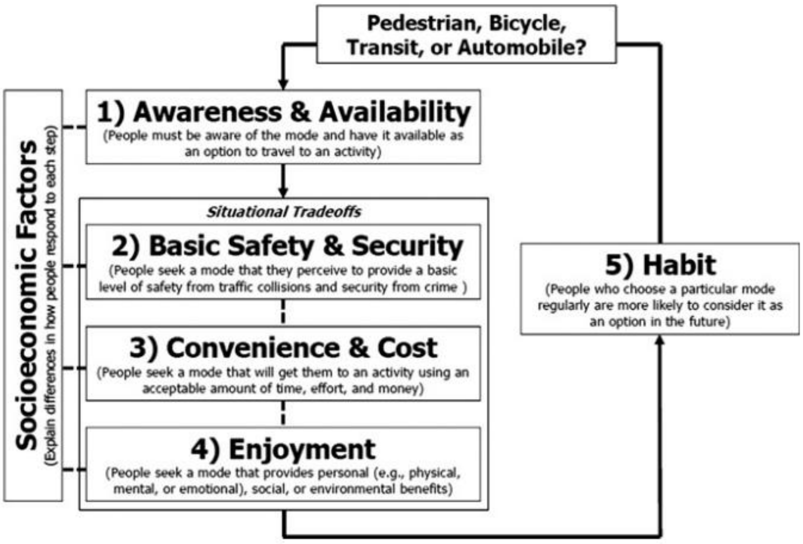

Figure 7-2: Proposed theory of routine mode choice decisions (Schneider, 2013)

Travel behaviour is a complex issue and is influenced by many factors including factors related to the social and built environment (e.g., land-use characteristics, transport system supply, natural environment) to individual factors (e.g., income, age, gender). Figure 7-2 presents steps and factors that may affect routine mode choice decisions of individuals proposed by Scheider. The primary objective of cycling promotional activities is to increase cycling level focusing on both existing cyclists and potential cyclists. For existing cyclists, promotional activities should aim to increase their frequency, time, and distance of cycling. For potential cyclists, the interventions should focus on shifting their private motorised transport to cycling.

In general, cycling is accessible for most populations regardless of their genders, ages, and incomes. However, different groups have different perceptions and attitudes of cycling and different travel behaviours, and no single method can appeal to such a wide range of people (Deffner et al., 2012). Therefore, it is essential to identify the target groups to address their needs and wants from cycling and deliver the right messages to them to promote cycling effectively. According to Urbanczyk, there are two successive stages to promote cycling effectively including segmentation and targeting (Urbanczyk, 2010). Segmentation is dividing audiences with similar needs into sub-groups. The audience groups can be segmented based on age, gender, bicycle ownership, cycling level, and attitudes toward different transport modes. In the second stage, these sub-groups with certain shared characteristics are assessed according to their potential for bicycle take-up. Specific promoting measures should be developed for each sub-group to meet their needs and desires. The sources and efforts should focus on the group(s) with the highest potential of cycling take-up first, which is called "targeting". Deliver specific promotion messages for different target groups also contribute to encouraging people to cycle. The messages connect cycling with emotional feeling like the spirit of fun, independence, and joy may generate positive associations to cycling. Some examples of messages for different target groups are presented in table 7-1.

Table 7-1: Example of messages for different target groups (Urbanczyk, 2010)

Targeting groups	Messages
School children	Cycling is fun, makes you feel free and independent. You are part of the traffic
Adults	Cycling is fun, makes you fit and healthy
Commuters	Cycling saves time and money and keeps you fit
Leisure cyclists	Cycling is a relaxing way to see the local are
Novice cyclists	Cycling is quick, easy, and flexible
Females	Cycling is chic, fun and shapes your body
Immigrants	Cycling means freedom of movement and independence. It is quick and easy
Elderly	Cycling is relaxing and good for health
Car drivers	Cycling is fast and convenient and saves money

There is a wide range of activities, policies, and programs to promote cycling that can be grouped into four major groups: information provision, awareness campaigns, training and education programs, and incentives. These promotional activities focus on both existing cyclists and potential cyclists.

- **Information provision**

Cycling information includes cycle routes, cycle parking, repairing and maintaining shops/services, bike rental/bike-sharing points (stations), cycling benefits, and other cycling facilities. This information should be accessible and widely provided to everyone. By providing information, the existing cyclists can plan their cycle trips effectively. For potential cyclists, effectively delivering information may increase their confidence and motivations to cycle by giving them all the necessary information to start to cycle. Cycling information can be provided by printed forms, mobile apps, cycling websites, information/mobility centres, tourist locations.

- **Awareness campaigns**

Schneider proposed a process of routine mode choice decisions; the first step of this process is awareness and availability. People must be aware of the transport mode and have it available to travel to an activity (Schneider, 2013). Therefore, whether a person decided to cycle or not depends not only on the quality of cycling infrastructure but also on their cycling awareness. People often have their perceptions of transport modes based on their experiences and personal beliefs. The awareness campaigns aim to raise awareness about the bicycle by changing people's perceptions, attitudes towards, and acceptance of cycling. As a result, the uptake of cycling will increase. The lack of cycling awareness may keep people continuing to travel with their motorised transport modes.

A wide range of activities can raise the awareness of cycling, ranging from broad promotion campaigns and targeted cycling programs to cycling events. Depending on the objectives and targeted groups, cycling awareness campaigns should be designed appropriately and convincible. A successful campaign must influence factors that are relevant to cycling-related attitudes, cycling constraints, specific needs, travel behaviours, and choice of transport mode (Difu, 2012). In general, the awareness campaigns can be divided into three major groups, including broad promotional campaigns, targeted cycling campaigns, and cycling events (Urbanczyk, 2010).

- **Broad promotional campaigns** typically focus on the general population to encourage potential cyclists who currently do not cycle and improve the profile and positive image of cycling in general. These broad campaigns are more appropriate in cities with a high level of cycling, help to reinforce its' cycling culture, and encourage non-cyclists to cycle. In cities with low cycling levels, broad campaigns may not be effective unless there are some reasonably good cycling conditions. Some examples of these campaigns are campaigns "Kopf an: Motor aus" ("Bain on: Engine off") (http://www.kopf-an.de/), and "Radlust" ("The Joy of Cycling") (http://radlust.info/) in Germany.
- **Targeted cycling campaigns** focus on specific targeted groups that can be classified based on their similarity of mobility styles, demographic characteristics, and cycling perceptions. These campaigns focus on addressing their constraints, needs, and desires of bicycles more directly. Some campaigns are: cycle to school, cycle to work, and safe cycling campaigns.
- **Cycling events** can be bicycle exhibitions, bicycle flea markets, car-free days, cycling days, bicycle testing track, or inaugurations of new bicycle paths, parking, or bicycle-sharing schemes. This is considered one of the most effective ways to raise awareness and create interest for and acceptance of the bicycle. Cycling events can be integrated with existing events such as European mobility week and the city's anniversary. These events can be reached and effective to many different target groups. The information of events should be published widely through various ways such as posters, flyers, and social media.

- **Training and education programs**

Training and education programs are designed to increase bicycling skills and knowledge of bicycling traffic rules (Scheepers et al., 2014). For example, safety is one of the major barriers that prevent people from cycling. Offering people cycling training/education programs that teach them how to ride a bicycle and handle traffic may increase cycling safety. The training and education programs can focus on specific audience groups such as children, the elderly, woman, and adult novice cyclists. For example, in Germany, children are provided extensive training in safe and effective cycling skills as a part of their regular school curriculum (Pucher & Buehler, 2008). This includes both classroom lessons and on the road lessons. Then, the children have to take a cycling test with the participation of real police officers, who offer them official certificates when they pass the test. This improves cycling safety for children and also benefits them in later life.

- **Incentives**

In general, cycling is an inexpensive transport option in both purchasing and operating. However, offering financial incentives or rewards may motivate people to own bicycles and to cycle. Several cities have offered financial support for people who buy a bicycle for commuting such as Paris (people can gain up to 25% of the purchase price of a pedelec) and Mannheim in Germany (subsidies the purchase of every new bicycle with 50 Euro) (Deffner et al., 2012). Some other cities are considering offering allowance for people who cycle based on their kilometres of cycling. For example, in France, a pilot program, "Cycling kilometric allowance", has been implemented. People who use their own bike for commuting can receive 0.25 EUR per kilometre cycled and up to 200 EUR annually. The result showed that cycling experienced a 50% increase in its modal share among employees (Boschetti, 2017). In addition to direct financial incentives, offering rewards based on the level of cyclings, such as offering discount transit tickets and free bicycle parking, could also encourage people to cycle.

7.4 Strategies to promote public transport

The measures aim to increase the attractiveness of public transport over private motorised transport by making it becomes faster, more convent, more comfortable, more reliable, and more affordable. The public transport systems, public transport service quality, and perception and attitude of the population about public transport are different across cities and countries. Therefore, a wide range of measures has been implemented to promote public transport usage across the world. For example, in developed countries where the public transport systems have well-established with various public transport options (incl. buses, tram, and metro systems) that can transport a large number of passengers and usually good at both facility aspects and operational aspects. Promotional measures such as free public transport (PT) tickets or discounted PT tickets can be effective to encourage PT. However, in developing countries where public transport system and their quality are relatively poor, people tend to shift from public transport to cars or motorcycles when they can afford these modes. Thus, the measures that improve public transport service quality, such as renovate vehicle fleet and increase accessibility to public transport, should be given higher priorities.

This section focuses on both measures improving public transport service quality and promotional actions. Ngoc reviewed factors influencing service quality of public transport, including service availability (temporal and spatial availability, capacity and information availability), service reliability, travel time, travel cost, comfort and convenience, safety and security, and customer care services (Ngoc, 2015). Therefore, measures to improve public transport services described in this section focus mainly to improve and influence these factors. The promotional activities focus on influencing the perceptions and attitudes of both existing public transport passengers and potential passengers. The measures in this section focus on bus services only.

7.4.1Public transport priority measures

Buses usually share the same road spaces with private motorised vehicles, which strongly influence the operations of buses. Bus priority measures aim to reduce or eliminate these traffic disturbances on buses operating at intersections, travel ways, and bus stops. Therefore, travel time and unreliability of bus services are reduced leading to improve public transport services in general. Public transport priority measures increase the urban transport efficiency and equity by giving higher-value trips and more space-efficiency modes over lower-value trips and space-intensive modes (Litman, 2016). Furthermore, effective priority measures may also increase buses' vehicle energy efficiency that reduces operating costs and external impacts on the environment. Priority measures can be grouped into three groups: priority measures on the roadways, traffic signal priority measures, and measures at bus stops (Nam, 2013).

- **Signal priority measures**

Giving the signal priority for buses at signalised intersections helps to reduce the delay time and waiting time of buses, resulting in reduced travel time of bus trips. This is considered a cost-effective measure to improve the quality of bus services and has been widely implemented in many cities. The signal priority can be passive or active.

Passive priority does not require any special investments in vehicle detections and signal control systems. The traffic signal programs are designed based on the knowledge of transit routes and ridership patterns. The measure is effective when transit operations are predictable with a good understanding of routes, passenger loads, and schedules. Reducing traffic signal cycle lengths, coordinating signals on transit corridors, phase splitting, and prolonging green times for transit routes are considered passive priorities (H. R. Smith & Hemily, Brendon, Ivanovic, Miomir, Fleming, 2005).

The active priority aims to prioritise specific transit vehicles and operate dynamically with the operation of transit vehicles and traffic situations. Unlike passive priority, special technical equipment such as detectors and signal controllers at intersections and on vehicles are needed (H. R. Smith & Hemily, Brendon, Ivanovic, Miomir, Fleming, 2005). Two levels of signal priority include (1) absolute priority that allows buses to pass through intersections without stops and waiting time, or within considerable waiting time, and (2) conditional priority is used when the interests of other motorists and cyclists are respected, and potential conflicts have to be reduced (Nam, 2013). Some common active priority strategies are green extension, early green, phase rotation, and phase insertion. In general, the active priority is more effective in reducing delay and waiting time for buses at intersections compared to passive priority.

- **Priority measures on roadways**

The major travel time of bus trips are on the roadways, relocation of road spaces from motorised vehicles to buses will significantly reduce the travel time by buses. Some common measures to provide the priority for buses on roadways are busways, exclusive bus lanes, time-restricted bus lanes, reversible bus lanes, bus lanes shared with other modes, high-occupancy vehicle (HOV) lanes, queue jump lanes, discontinuous bus lanes, and partly dynamic bus lanes. In general, these measures are more popular in the United States and many European countries. However, in developing countries, these measures are still not widely implemented and accepted due to the low quality of bus services, insufficient finance, lack of regulation enforcement, and difficulties in dealing with high volumes of private motorised vehicles.

  - **Fully separated travel ways for buses**

    The fully separated travel ways include exclusive bus lanes, busways, and bus streets designed only for busses. These measures are taken space away from other traffics and provide the greatest priority level for buses. Implementing busways or bus streets is not popular as limited road spaces and high investment costs in city centers. Providing separated bus lanes is more common and widely implemented in developing cities and developed cities. Providing the separated bus lane allows the buses to avoid congestions, which has significant positive effects on reducing travel time and improving bus services' reliability, offering benefits directly to bus passengers. Especially in heavy traffic and congested streets, the measure has a huge opportunity to attract new passengers. In addition, an effective bus lane can carry more passengers than a general traffic lane that increases road capacity and efficiency of bus services as well.

    The bus lane can be separated from other traffic by physical barriers or road markings. The bus lane can be located in the curb lane, middle lane, centre lane, and median lane of the streets that is illustrated in figure 7-3. Each location has its advantages and disadvantages. Depending on the bus operations, road conditions, traffic conditions, and several other factors, the arrangement of bus lanes should be selected carefully to ensure the bus operation's efficiency and minimize adverse effects to other traffic. To ensure the efficiency of bus lanes, strong regulation enforcement of on-street illegal parking and lane violation is needed.

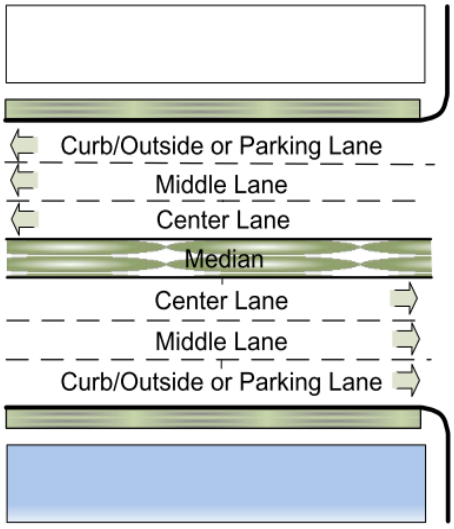

Figure 7-3: The potential locations of bus lane (Lerner et al., 2011)

- **Reversible bus lanes**

The measure can be applied when the road space is limited to have two lanes for buses in both directions. A reversible bus lane serves the operation of buses in both directions, but each direction will be served in certain periods, depending on certain conditions. This measure has also been used to manage the general traffic to improve the traffic flow and road capacity during peak hours. The location of bus stops, accessibility to bus stops should be designed carefully to ensure the safety of passengers when implementing this measure. Thus, traffic control, traffic enforcement, and technical efforts must be required sufficiently (Nam, 2013).

- **Time-restricted bus lanes**

A time-restricted bus lane allows buses to operate in certain periods of the day, usually in the peak hours, and outside these hours, the lane can be used by all traffic. The measure aims to reduce the travel time by buses during the peak hours, encourage people to travel by buses instead of their cars. In some cities, bicycles and taxis are allowed to share with buses during their operation time.

- **HOV lanes**

This measure is common in the United States. The HOV lanes are designed for High–Occupancy Vehicles to increase the efficient use of road space. HOV lanes have potential encouragement model shift from single-occupant vehicles to higher occupancy vehicles. The high–occupancy vehicles often consist of buses, taxis, carpools, and emergency vehicles. In some cases, single-occupant vehicles may allow using the HOV lane if they pay for a toll. The HOV lane carries more people in fewer vehicles that reduce congestions, save travel time, reduce fuel consumption and vehicle emissions. However, HOV lanes' implementation often requires some prerequisite conditions such as enough road lanes, proper traffic control, and traffic enforcement measures.

- **Bus lanes shared with other modes**

In this measure, the buses are operated with other specific transport modes in the same lane. This measure gives higher priority to buses in comparison with the mixed traffic lanes and can increase the efficiency of road use, especially when the bus volumes are not high enough to arrange exclusive bus lanes. However, the specific vehicles that share the same lane with buses should be chosen carefully to ensure the safety and accessibility of these vehicles and bus as well. Usually, taxis and bicycles are two common vehicles that allow sharing the same lanes with buses.

- **Queue jump lanes**

At signalised intersections, vehicular ques may impede buses from approaching stop lines and receive their green time. Intersections with heavy traffic loads, without priority, busses often experience noticeable delays due to a severe queue of vehicles leading to increased travel time for bus commuters. Providing a queue jump lane at these intersections is an effective measure to address this problem. A queue jump lane is constituted by a partial curb-side lane or a long bus bay ending at the stop line, allowing buses to avoid long queues of other vehicles at traffic signalised intersections (Nam, 2013). In general, a priority signal for buses is provided to allow buses to depart safely and easily before the release of other traffics. A study reported that the combination of queue jump lane combined with traffic signal priority for bus rapid transit (BRT) line led to 13-22% reduction in travel times, better corridor progression, lower intersection delays and numb of stops, increased speed (22%), and better travel time reliability and headway adherence (Zlatkovic, Stevanovic, & Reza, 2013). Another study suggested that implementing queue jump lanes at multiple intersections along signalised arterials could reduce travel times and improve travel time reliability for public transport passengers considerably (Truong, Sarvi, & Currie, 2016).

- **Discontinuous bus lanes**

Discontinuous bus lanes provide buses with their own lanes on certain sections of the roads that aim to reduce disturbances of other vehicles on bus operations at these sections. This measure was developed based on practical requirements and specific conditions of motorcycle-dependent cities like Hanoi and Ho Chi Minh city (Nam, 2013). An example of an arrangement of discontinuous bus lanes is presented in figure 7-4. Implementation discontinuous bus lanes must contain at least two traffic lanes, and the length of the road section between consecutive intersections must be long enough to realize these lanes. The measure is recommended when the bus volume is relatively high, and the right-turning traffic at the forthcoming traffic signal is low.

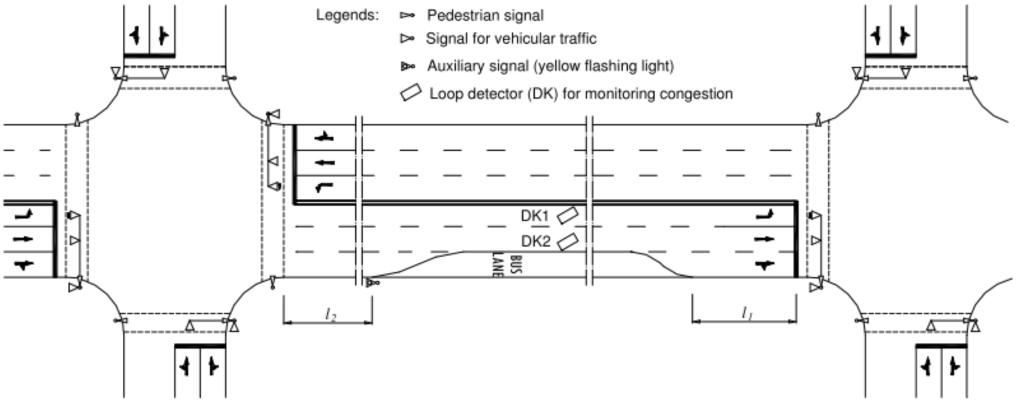

Figure 7-4: An example of the arrangement of discontinuous bus lane (Nam, 2013)

- **Dynamic bus lanes**

When certain traffic lanes between two given intersections are activated temporally for the use of buses in response to their occurrences, these lanes are considered dynamic bus lanes. Their activation is carried out by the automatic switching of special signal heads to notify road users that specific lanes on the following sections will be closed for serving forthcoming buses. Detection systems are required to perceive information about arriving buses beforehand. Then control systems will activate the dynamic lanes for the buses. When the buses are confirmed to pass through their active lanes, the signal will be deactivated, and these lanes will return to normal traffic lanes for other vehicles. These bus lanes can be fully dynamic or partly dynamic to bus operations (Nam, 2013).

Fully dynamic bus lanes are recommended for streets with reasonable traffic volumes and low to medium bus volumes. On heavily loaded roadways with high bus volumes, fully dynamic bus lanes might cause critical impacts for other vehicles since a considerable reduction in capacities of intersection approaches will be induced during the activation time of these bus lanes. This disadvantage can be avoided by implementing partly dynamic bus lanes. The main difference between full and partly dynamic bus lanes is their activations' design and control algorithm.

Partly dynamic bus lanes are activated if activating conditions are met. When the bus lane is deactivated, it operates as a normal traffic lane. The aim of this measure is basically the same with discontinuous bus lanes. The separation by proper pavement markings between partly dynamic bus lanes with other traffic lanes is essential. The measure is recommended for at least three lanes' roads, and the distance between two consecutive intersections has long enough to realize these lanes. Additionally, the warning and information have to be clear and visible for road users to help them prepare for proper reactions.

- **Bus stop improvements**

Bus stops are a key element of bus services, which provide accessibility for passengers to use public transport. The location, design, and operation of the bus stop impact significantly on the bus (passenger) journey travel time and customer satisfaction. A well-selected location and well-design bus stop contribute to reducing the total travel time of bus trips (by reducing boarding and alighting time of passengers), reducing the effect to traffic flows and movement of other vehicles, and increasing safety and security for passengers and other road users.

The location of bus stops and type of bus stops depend widely on the roadway conditions, traffic volume, traffic speed, the volume of passengers, travel pattern of passengers, sidewalk conditions and type of buses, etc. Thus, when design or install a bus stop, those factors should be considered carefully. In addition, bus stops/station locations and designs must be accessible for all passenger groups, including people with limited mobility (e.g., disable, elderly).

- **Locations of bus stops**

  In general, there are three categories of bus stop locations including far-side stops (stops after intersections), near-side stops (stops before intersections, and mid-block stops (stops away from intersections) (TRB, 1996). Each location has its own advantages and disadvantages and depends on the bus operations, passenger demands, traffic conditions, and road conditions. The appropriate locations should be selected. It is highly recommended to select the locations located near passengers' trip origins and destinations to improve the convenience and accessibility of bus services. In addition, the bus stops must ensure safe access for passenger's vice sidewalks and appropriate street crossing locations. The parking restrictions or prohibitions near or at the bus stops are necessary to minimize the disturbance of bus operations. The visibility of bus stops should be clear for bus drivers, passengers, and other road users to reduce the incident risks between busses and other road users.

- **Types of bus stops**

  Similar to bus stop locations, there are several types of bus stops (presented in figure 7-5), they can be situated directly on normal traffic lanes (curb-side stops) or outside those lanes (bus bay stops), and curb extension (TRB, 1996). They have their pros and cons and can be implemented under certain conditions.

  A curb-side stop is inexpensive and easy to install that provides easy access for bus drivers. However, it may cause traffic congestion and traffic accidents because other vehicles have to queue behind a stopped bus or drivers make unsafe maneuvers to avoid a stopped bus. A bus bay is often separated from travel lanes. It minimizes the delay of traffic flow regardless of the stops of buses and provides a protected area away from moving traffic for buses and bus users. Bus bay stops are often recommended on travel ways operating with high traffic volume or high speed. However, bus bay stops may present a problem for bus drivers when attempting to re-enter traffic flow, particularly during periods of high traffic volume. And it consumes more space and is more expensive to install a bus bay stop than a curb-side stop. The stops with curb extension can be installed to streets having curbside parking lanes. In this case, some parking spaces are removed for bus stops. Curb extension increase the visibility of pedestrians by aligning them with the parking lane and reducing the crossing distance for passengers. As a result, the safety, comfort, and accessibility for passengers increase.

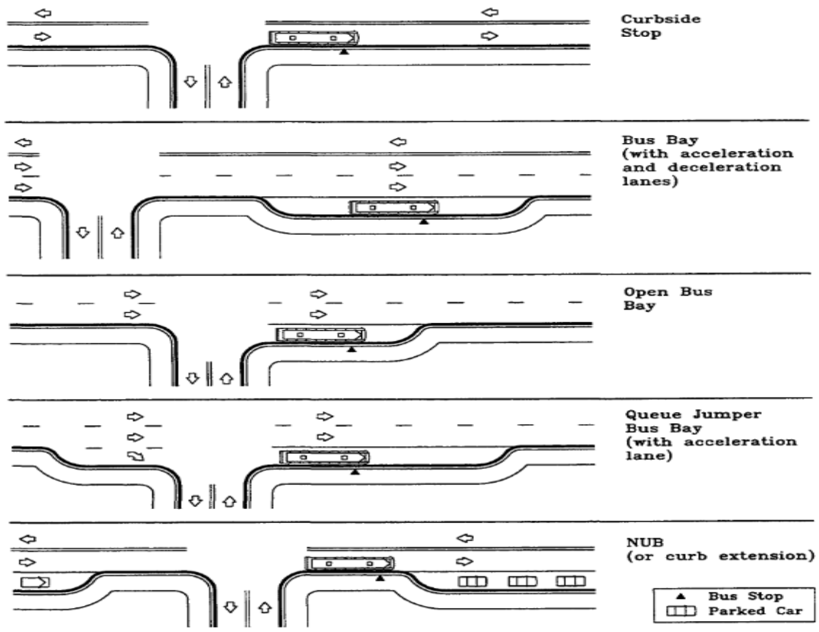

Figure 7-5: Types of bus stop designs (TRB, 1996)

7.4.2Public transport routing and public transport network improvement

A public transport route (transit line) is the infrastructure and service provided on a fixed route by vehicles operating on a predetermined schedule. And a public transport network (transit network) is a set of transport routes that are coordinated for efficient operation and provision of integrated services for the convenience of passengers (Vuchic, 2005). Public transport (PT) routing and network improvement influence network coverage (e.g., percentage of population/area served by PT), network density, and service directness of PT services. Therefore, appropriate changes in PT routing and network may improve PT accessibility and availability; reduce the travel time, walking distance, and the number of transfers for passengers; attract potential passengers, and increase the operation efficiency of PT services considerably. Some common methods to improve PT routing and network are network expansion, network restructuring, providing circulator/distributor routes, and feeder routes (TRB, 2004).

- **Network expansion**

The measure involves system-wide extension by adding new bus routes that aim to widen the bus services coverage. The open new bus routes should be provided for new development areas or previously un-served areas to offer the accessibilities to public transport services in these areas.

- **Network restructuring**

This measure aims to restructure the existing bus network to rationalize or simplify service, reduce route circuitry and route overlapping, improve route directness, accommodate new travel patterns, and ease or eliminate transfers for passengers. The appropriate network restructuring may improve accessibility and convenience and reduce travel time by bus for customers. Additionally, this may also enhance the effectiveness and performance of public transport services as the redundant or ineffective services are removed and new or better-targeted services are introduced. The restructuring may include realignment of routes, recombination among routes, and classified the route functions (e.g., trunkline, feeder routes, express routes).

- **Circulator/distributor routes**

The circulator/distributor shuttle services are often designed to supplement or substitute for regular bus services, where regular bus service may be impractical due to street patterns, terrain, densities, or operation cost. Furthermore, the circulator routes are also designed to offer the services that provide localised trips and are generally confined to a single community. The circulator routes enhance connectivity within downtowns or other activity centers or between activity nodes in close proximity. In general, the circulator routes may be multipurpose or target specific objectives (e.g., for tourist mobility).

- **Feeder routes**

Feeder routes connect passengers from residential areas and/or employment areas to bus rapid transit routes, trunk bus routes, and rail transit, or they may also serve as community circulators. In general, the feeder service improves the network coverage and accessibility of PT services and improves the performance of trunk services.

7.4.3Passenger amenities improvement

Passenger amenities, both on vehicles and bus stops/stations, play an integral role in building transit ridership. The measure provides a better travel experience for users by making it more comfortable, safer, and more enjoyable. In addition, amenities improvement may also change the perceptions of potential passengers and whole communities about public transport services, leading to increased public transport ridership. The experience from public transport agencies has shown that investing in amenities can be a cost-effective approach to build ridership (TRB, 1999).

- **Passenger amenities improvement at bus stops/bus stations**

The bus stops/bus stations are the first contact points between customers and the bus services. Therefore, providing facilities at bus stops/ bus stations enhances passengers' safety, security, and comfort, which are important actions to improve passenger satisfaction.

Generally, the basic requirements at all stops/stations are clear visibility and accessibility for passengers and drivers, adequate lighting, and route maps, and operating schedule information. Additional amenities such as shelters, real-time information, benches, trash bins, ticket machines, vending machines, phone boxes, park and ride facilities are often provided at stops/stations. The provision of these facilities at stops/stations is largely affected by the number of passengers, bus headways, and space of bus stops. For the bus station it is possible to provide all of these facilities, but for some bus stops it is not necessary to provide all of these facilities. For example, benches are recommended for bus stops where headways of buses are longer than 15 minutes, shelters are recommended for all bus stops which have more than 50 passengers per day (KFH Group, 2009). Additionally, the bus stops/ bus station should be provided with facilities for disabled people such as ramps, elevators, signage, and accessible heights that can be accessing path, supporting information system for the disabled.

- **Passenger amenities improvement on vehicles**

Basically, on-vehicle amenities for passengers may include the space and facilities provided for people to board or leave the vehicles, space for people to stand, sit, and circulate on board, and to get information and pay for tickets, air conditioners, on-vehicle passenger information displays (e.g., visual and audible information of route name, next stops, connected lines,), lighting, security cameras, free Wi-Fi, and bike racks. The vehicles should also be designed to be accessible for disabled passengers, older people, people with baby strollers, and luggage. Improving onboard amenities aims to enhance the comfort and convenience of passengers. Depend on the finance sources, the improvement can be done by simply keeping the vehicles clean and working properly through regular inspection and maintenance. When necessary, the renovating vehicle fleet should be considered. Recently, many cities are planning to replace conventional buses with electric buses to reduce emissions from public transport. This also improves the comfort for passengers as electric buses emit less air and noise pollutions.

7.4.4Improvement ticketing system

The changes in fare level, fare structure, fare payment method, and fare system strongly influence public transport ridership. Public transport pricing and fare changes will affect public transport usage significantly. To attract new passengers and retain current users, the cost of using public transport must be competitive with the cost of using private transport modes. The possible improvements are (1) change fare level and fare structure, (2) improve the payment system, and (3) integrate the ticketing system.

- **Change fare levels and fare structures**

Fare is the monetary charge for making a trip by public transport and it is an important factor in an individual's transport mode choice decision. Changing fare levels and fare structures will influence the level of public transport demand. Reducing fare levels is likely to increase public transport ridership and reduction in private motorised transport use, resulting in reductions in traffic congestions, air and noise pollutions, traffic accidents, and other environmental impacts. In contrast, the increase in fare levels will lead to a reduction in public transport ridership. Various reduced fare options can be implemented depending on the targeted customers, such as deeply discounted options for students and free tickets for the elderly. Changing fare based on the type of services (e.g., express, normal services) or time period (e.g., peak-hours, off-peak hours) are also used to manage public transport demand. However, it is essential to note that reducing fares may lead to severe crowded on vehicles and reduce the revenue of public transport operators. These unexpected outcomes should be minimized.

Public transport fares are organized under different fare structures that passengers can pay based on criteria such as distance traveled and time of the day. The fare structure should offer different fare options allowing passengers to select the fare options that fit their needs and be simple and easy for them to understand. The three common types of fare structures are (1) flat fare means that flat fare is charged for every trip made regales of distance traveled or type of passengers, (2) zone-based fare charge a passenger a price that depends on the number of zones crossed, and (3) distance-based fare charge a passenger based on their distance traveled. In addition, some other types of fare structures also can be applied, including time differentiated fares, differentiation by trip purposes, differentiation by the regularity of use, and concessions for particular passenger groups. Each of the fare structures has its own advantages and disadvantages and impacts on public transport demand differently. For example, the flat fare structure is easy to collect fare and control and easy for passengers to understand. However, it can be seen as unfair/inequitable for short-distance trips or off-peak users. Therefore, selecting the appropriate fare structure is an important task of public authorities or/and public transport agencies, which will influence the passenger travel behaviours and the revenue of public transport operators.

- **Fare collection improvements**

In many cities, the tickets for using buses are still in paper forms. Passengers buy the tickets directly from bus drivers or from ticket machines located at the bus stops/stations, leading to increased travel time by buses and inconvenience for passengers. Therefore, the payment for using public transport should be designed as conveniently as possible through offering various payment options that easy to understand and to use for different passenger groups. In addition to paper form tickets, many public transport agencies have implemented automated fare collection methods based on magnetic farecard and/or smartcard technologies. Recently, passengers also can buy tickets via mobile applications (mobile tickets) that enable passengers to purchase and download a virtual ticket on their smartphones or other digital devices. Applying these collection methods significantly improves the convenience for public passengers and provides valuable data on the travel behaviours of passengers that is important for transit agencies. This is also an essential condition for implementing the integrated ticketing.

- **Integrated ticketing system**

Integrated ticking allows public passengers to transfer within or between various public transport modes, operators, or geographies by using a single ticket for their entire journey (National Academies of Sciences Engineering and Medicine, 2007). Integrated ticketing is bringing benefits for both passengers and transport operators. Regarding passengers, integrated ticketing will increase their convenience and ease when commuting by public transport by eliminating the need to pay for each trip. They do not need to understand complex fare structures and travel conditions from different public transport operators. Their travel time also can be saved by not having to buy different tickets and quicker boarding time by using smart cards. Passengers also can save costs from discounted and flexible ticketing. For operators, they benefit from faster boarding of passengers enabling more efficient scheduling of services and potential reduction in operating costs. They may also increase their revenue as integrated ticketing can attract new passengers.

To implement integrated ticketing, the common agreement of fare structure, travel conditions, and methods for distributing the investment costs and revenue of integrated tickets among key stakeholders (e.g., PT operators, transport authorities) is needed. This is considered a major barrier to implement integrated ticketing, especially in cases where there is competition between transport agencies. In addition, information campaigns to achieve the acceptance and use of integrated ticketing systems among users are also needed (Mirco & Cocchi, 2013) .

7.4.5Scheduling and frequency improvement

Scheduling and frequency modifications are among the most popular service changes that public transport operators make to improve service effectiveness. An appropriate and effective operational schedule and frequency of service result in reduced passenger journey time and enhance their convenience and increase the vehicles and crew utilization efficiency. To increase ridership, scheduling and frequency adjustment should respond to passenger demand accordingly. Several types of scheduling and frequency changes are frequency changes, service hours changes, frequency changes with fare changes, combined service frequencies, and regularized schedules (National Academies of Sciences Engineering and Medicine, 2004).

- **Frequency changes**

Frequency changes may increase or decrease the number of vehicle trips per time unit (per hour or per day). This affects passengers' waiting time and transfer time; increased frequency results in reducing vehicle headways and passengers' waiting time and vice versa. In peak hours, public transport demand is often high. Increasing vehicle frequencies during this period will also avoid the over crowed on vehicles. That improves passengers' comfort and attracts potential passengers to place their vehicles at home and commute with public transport. The increased frequency may be implemented with a decrease in fares, aiming to encourage more people to use public transport, particularly attracting potential customers of public transport.

- **Service hours changes**

This refers to change in the span of public transport services by extending or shortening service operating time during the day or the week. Depending on the passenger demand, services may extend later into the evening or earlier in the morning and/or on weekend days.

- **Integrated schedules**

Integrated schedules offer a combination of different transit services to minimize the transfer times and waiting time between and within public transport services. Thus, the total travel time by public transport is reduced, leading to improve the attractiveness of services. Generally, waiting at stops/stations is often associated with the negative feeling of travelers.

- **Regularized schedules**

The measure uses rescheduling to achieve a regularized service frequency making it easy to remember. Regularized schedules help passengers having a better plan for traveling by public transport. Thus, the waiting time transfer time will be minimized.

7.4.6Public transport information provision and promotion

- **Public transport information**

To select the travel options, people need to know the information of these options (e.g., where to use, how to use, how much it cost). Especially when traveling by public transport, providing information on route maps, operating time, and ticket prices are crucially important to retain existing passengers and attract potential users. This may happen that people prefer to use their cars because they simply do not know about public transport services. The provided information should focus on customers' needs, determining what information do they need. The questions regarding where, when, and how to disseminate information are also crucially important.

Public transport information provision allows passengers to plan and make their trips more easily, thus making public transport more convenient and comfortable to travel. For example, good public transport information allows people to plan their trip in advance effectively by enabling them to select the travel options (e.g., bus routes, departure time, fares, expected levels of crowding on vehicles) that fit their needs and their schedule. During the trips, the information of next stops, possible delays, connected routes is also important for passengers. Integrated public transport information from different operators and services allowing passengers to access all relevant information with a single platform will markedly improve passengers' convenience.

The development of information and communication technologies can provide real-time information for passengers. Real-time passenger information (RTPI) brings benefits for both public transport users and operators. This allows passengers to access real-time information regarding their travels such as arrival and departure of vehicles, service disruptions, and service changes. This information can be displaced at stops/stations, information centres, on vehicles, websites, text messaging, and smartphone applications. Providing RTPI reduces the psychological anxiety associated with uncertainty and frustration of services and waiting time at stops/stations. For example, a study reported that passengers using mobile real-time information perceived their waiting time as 30 % shorter than passengers without using real-time information. In addition, the travelers without real-time information perceived their waiting time was longer than the actual waiting time, while travelers with real-time information do not (Watkins, Ferris, Borning, Rutherford, & Layton, 2011). For transport operators, RTPI help to improve their fleet management and increase the performance of services.

Public transport information should be accessible and understandable for all user groups. Therefore, offering a variety of information provision options through various formats is necessary. For example, for the elderly who are not familiar with the internet and smartphones, printed information may be important for them. Or people with reading problems, offering audio announcements at bus stops/stations and on vehicles are useful for them. In tourist cities, public transport information should be presented and provided in different languages.

- **Public transport promotion and marketing**

Public transport promotion and marketing aim to improve public transport image, attracting passengers, and strengthening its usage. A good public transport service may not associate with the increase in ridership if there are missing information, promotion, and marking for this service. For example, in Ho Chi Minh city, bus services have improved significantly through renovating vehicle fleets, providing real-time information for passengers, and improving bus stop/station conditions. However, the number of bus users is still low. Lack of information about improved services, lack of promoting and marking actives may play as one of the reasons for this situation. The majority of people in HCMC still perceive bus services as poor, unreliable, and uncomfortable. Therefore, the promotional activities together with offering user incentives (e.g., discounted tickets, free travel by buses on certain days) are essential to boost the bus ridership in the city. However, it is essential to note that a good public transport promotion and marketing also cannot increase public transport usage if the public transport services are poor.

7.5 Strategy to reduce private motorised transport

The strategy aims to reduce and avoid individual motorised transport by making private motorized to transport slower, less attractive, inconvenient, and more expensive to use. Measures included in this strategy are classified into four main groups consisting restriction measures, pricing measures, carsharing and ridesharing, measures to substitute private motorised transport.

7.5.1Restriction measures

Measures aim to restrict the ownership and the use of private motorised vehicles. The common measures are vehicle registration control, parking restriction, and access control, and traffic calming.

- **Vehicle registration control**

The urban space is limited, while the urban population is growing continuously. As a result, travel demand will also increase. Without restriction in vehicle ownership, private motorised vehicles will grow significantly, consume large amounts of urban space, and cause numerous negative consequences. Therefore, vehicle registration control aims to limit the increase in the number of individual motorised vehicles. Several countries have been implemented vehicle ownership restriction measures and have gained positive outcomes in reducing the number of newly registered cars and increase public transport use. For example, in Singapore, introducing the vehicle quota system resulted in the annual growth rate of vehicle population at only about 3% that significantly lower than before the introduction of vehicle quota (Koh, 2003). Another study reported that the combination of license plate restriction and driving restriction policies increased the public transport demand by 20-30% in six Chinese cities (Zhang, Long, & Chen, 2019).

- **Parking restriction**

The major forms of parking restriction are time-restricted, duration-restricted, location-restricted, vehicle type-restricted, and users' restricted measures (Thanh, 2017). Restricted parking time is often implemented to handle the peak travel demand. Parking is restricted at certain times of a day (e.g., morning and afternoon hours) or a certain day of a week. Limited parking duration aims to avoid long parking duration and to improve the efficiency of parking spaces. Location-restricted parking aims to diminish the parking demand in specific locations in the cities. Parking restrictions can also apply to certain types of vehicles and user groups. Some groups (e.g., disabled people, local residents) are permitted to park in the location as priority parking users, while others are not allowed to park.

Furthermore, parking restrictions can also be implemented by the limited number of parking spaces. For example, a study reported that limited parking spaces at the workplace effectively reduced car-use on work trips (Christiansen, Engebretsen, Fearnley, & Usterud Hanssen, 2017). These measures make parking more difficult and inconvenient by limiting opportunities to access the parking, which reduces the use of private motorised transport. However, it is important to note that when applying restricted parking measures, providing or improving alternative travel options must be considered.

- **Vehicle access restriction**

This measure focuses on limited or excluded the accessibility of vehicles (or certain vehicle groups) and can be implemented in the cities or specific areas. The most common way to restrict the access of private motorised vehicles is pedestrian zones and low emission zones. These measures have been widely implemented in European countries such as Germany, Austria, and Switzerland and have shown the effectiveness to reduce car use and improving air quality. For example, a study investigated the effectiveness of low emission zones (LEZs) in Germany. The result showed that the measure has brought significant positive effects on reducing air pollution concentrations and could potentially improve if stricter regulation is applied (Jiang, Boltze, Groer, & Scheuvens, 2017). They also found that the introduction of LEZ has raised the population awareness of transport-related to air pollution. This may result in changing the perception of car commuting and car ownership among the population.

- **Traffic calming**

Traffic calming aims to reduce vehicle speed through physical and regulatory measures. Although the measure does not directly restrict vehicle access, it decreases motorised traffic's attractiveness and increases the safety of cyclists and pedestrians. The vehicle speed can be reduced through physical measures such as speed humps, rumble strips, and raised crosswalks and speed limited regulation such as 30 km/h zones and 20 mph zones (Gonzalo-Orden, Pérez-Acebo, Unamunzaga, & Arce, 2018). A study reported that the areas of London that introduced 20 mph zones was led to a 42% reduction in road causalities period 1986-2006 after adjusting for underlying secular trends (Grundy et al., 2009). Another study found that implementing traffic calming measures surrounding schools was strongly, significantly, and positively associated with the percentages of students reported as walking or cycling to schools (Nicholson et al., 2014).

7.5.2Pricing measures

The pricing measures include parking pricing, vehicle taxes, fees, and fuel taxes, and road pricing. Pricing measures aim to charge for vehicle use and ownership, making driving and owning vehicles more expensive. As a result, people may shift to more affordable transport options such as walking, cycling, and using public transport.

- **Parking pricing**

Parking pricing refers to direct charge for using a parking space. Efficient parking pricing can bring significant potential benefits, including increasing parking turnover, reducing parking demands, reducing vehicle travel, reducing areas needed for parking, encouraging alternative transport modes, and generating revenue (Litman, 2018). Depending on the measure's objective, parking fees can be charged based on parking location, parking time, or parking duration. For example, higher parking fees can be applied in city centres where parking spaces are limited to reduce the parking demand in this area. However, parking pricing should be implemented as part of an integrated parking management program to achieve its highest effectiveness.

Parking pricing measures have been widely implemented across countries and have gained considerable positive effects on reducing the pressure of parking demand and car use in many cities. For example, Khordagui examined the impacts of parking prices on the decision to drive to work in California (Khordagui, 2019). He reported that with 10% increase in parking fees could potentially reduce the probability of driving to work alone by 1-2 percentage points and suggested that parking pricing can be an effective traffic management approach. A study in Hanoi (Vietnam) found that parking pricing may also help to increase public transport use(Thanh, 2017). Parking users are more likely to shift to public transport when parking fees are higher. She also found that motorcyclists and cyclists are more sensitive to parking prices than car users. Furthermore, parking pricing can also cause various changes in travel patterns such as trip destination shifts, parking location changes, trip scheduled changes, and shorter trip duration (Litman, 2018).

- **Vehicle taxes, fees, and fuel taxes**

Vehicle taxes and fuel taxes aim to increase the cost of owning and using vehicles that reduce vehicle population and vehicle travelled kilometres. There are various types of taxes and fees as well as the collecting methods varying from country to country. The most common types of taxes for buyers, owners, or users of a private motorised vehicle are value-added taxes (VAT) on the purchase, registration tax pay at the time of acquisition, periodical tax on ownership or/and use (e.g., annual vehicle tax, annual road maintenance fee), and fuel tax (Runkel, Mahler, Beermann, & Hittmeyer, 2018). Increasing VAT tax may discourage the ownership of vehicles while increasing fuel tax will discourage vehicle use. The tax amount can be charged differently based on the types of vehicles, engine size, vehicle weight, fuel used, and level of CO_2 emission. Recently, the transport emissions of carbon dioxide (CO_2) have not decreased as much as expected. Many countries have collected vehicle registration taxes and taxes on vehicle ownership based on the level of CO_2 emission, giving incentives for low-emission vehicles. For example, in Germany, owners of a car that emits up to 95 g CO_2/km are exempt from CO_2 tax; owners of a car that emits about this level, emissions are taxed at a rate of 2 EUR per g CO_2/km (Wappelhorst, Mock, & Yang, 2018). Therefore, taxes and fees are not only a tool of discouraging vehicle ownership and use but also an effective tool to promote cleaner vehicles.

- **Road pricing**

Road pricing refers to the direct charges for the use of the road. “Road pricing is often introduced as a method to internalize the externalities generated by road users, thereby removing external effects caused by car drivers” (Johansson & Mattsson, 1995). The road pricing can be charged to road users for driving on a specific road or driving in a specific area. There are different road pricing options and scheme designs, including road tolls (drivers have to pay a fee for on a particular road), cordon (zone) tolls (drivers have to pay for crossing or driving in a particular area), and congestion pricing (drivers have to pay higher prices under congested conditions and lower prices at the less congested conditions). The charge level can be fixed or variable based on the type of vehicles (e.g., public transport, emergency vehicles are exempt), time of the day, day of the week, and locations. However, the structure of the charging level should also be simple and understandable to all road users. The primary objective of the road toll is to raise revenue for road infrastructure improvements such as highways, bridges, or tunnels and often applied outside the urban areas. Whereas the cordon toll and congestion charging are usually implemented in urban areas, especially in city centres aiming to reduce traffic congestion and raise revenue. Some successful international examples of road pricing measures are electric road pricing in Singapore and congestion charging schemes in London, Stockholm, Milan, and Gothenburg (Amelsfor, Eichhorst, & Strompe, 2015). In all these cases, car traffic volume decreased in a range of 10-30% depending on the system's design, while increased the public transport ridership. Consequently, the other problems related to car traffic, such as air pollution, noise pollution, and traffic accidents in charged zones, are also mitigated.

7.5.3Carsharing and ridesharing

Shared mobility or shared transport is becoming popular and is growing rapidly in many cities around the world. There are different forms of carsharing and ride-sharing, including station-based, free-floating (dockless), personal vehicle sharing, carpooling, and vanpooling. These sharing services are still evolving to provide flexible and convenient services for users that potentially change the population's perception of car ownership and reduce car use. Ridesharing also helps to increase the efficiency of vehicle use by increase the vehicle occupancy rate. However, car-sharing and ridesharing may also generate unwanted effects such as reduce public transport and active ridership and encourage car travel in some groups (e.g., elderly, children).

The effect of carsharing and ridesharing in reducing total travel demand and traffic situation is inconsistent across studies. For example, a study investigated the impacts of carsharing on car ownership in two German cities (Berlin and Munich). The result shows that carsharing leads to the reduction in private car ownership and carsharing in both cities and tends to reduce car use (Giesel & Nobis, 2016). Chapman, Eyckmans, and Van Acker evaluated the impacts of carsharing on reducing car use in Flanders (Belgium) (Chapman, Eyckmans, & Van Acker, 2020). They reported that carsharing might reduce car use, but only if a considerable number of users reduce their car ownership. In contrast, a study analyzed the effect of car-sharing services on reducing greenhouse gas (GHG) emissions in Korea. The result showed that GHG emissions resulting from the shift from public transport or individual-owned vehicles to carsharing were higher than the GHG reduction due to unpurchased or unproduced vehicles (Jung & Koo, 2018).

In some Asian cities like Ho Chi Minh city, and Hanoi (Vietnam), ride-hailing services are more common than carsharing. This is on-demand ride service, in which a passenger book for their rides online usually via a smartphone application, and the driver will take them to their destinations without sharing the vehicle with other riders. The introduction of these app-based motorcycle/car taxi services has contributed to diversifying the travel options in HCMC. By offering better service quality, more affordable, easy to access by smartphone, the entry of these services has quickly captured the travel demand of the traditional taxi and motorcycle taxi in the city and even public transport and non-motorized transport. However, the effect of ride-hailing on total travel demand and traffic situation is largely unknown.

In general, these shared mobility services may potentially reduce car ownership and car travel demand, but it may also cause unexpected effects. The impacts of shared mobility on reducing car travel demand are still unclear and inconsistent across countries. Further studies are desirable to identify the appropriate operating conditions for shared mobility services to optimize its effectiveness.

7.5.4Measures to avoid/substitute private motorised travel

The potential of telecommunication and delivery services has been considered to substitute for travel for a long time. With the rapid development of information and communication technologies (e.g., High-Speed Internet, Zoom, Google Meeting, Skype, Microsoft Team), many people can easily work or learn from home without the need for travel. To what extent the telework will be lifted after Covid-19 is still unclear but telework will be more likely to be more widely accessible and acceptable after Covid-19 as many people have gained significant experience working with various forms of telework. A study that examined the effect of telework and daily travel in Sweden concluded that telework had positive impacts on reducing car travel, relieving traffic congestions, and increasing active travel (Elldér, 2020).

In addition, online shopping and delivery services are also emerging that allow people to access many goods and services without the need to travel or access by walking, cycling, or public transport instead of driving. These mobility substitutes are potential approaches to provide accessibility for people while decreasing travel needs. To ensure the effectiveness and avoid unintended consequences of these travel substitutes, careful consideration of these substitutes in the transport planning and mobility management program is necessary.

7.5.5Travel awareness campaigns

The travel awareness campaign aims to improve the general public understanding of problems caused by transport mode choices and what can be done to solve these problems, including changing their travel behaviours (Hodgson & Tight, 1999). Pricing measures and restriction measures discourage private motorised travel by making it more costly and less convenient. However, these measures may not be effective as expected, especially for people who are passionate about car driving, people who lack knowledge about the problems associated with their travel, or people who lack information about the other alternative transport options. Similar to cycling promoting measures, to ensure the effectiveness of travel awareness campaigns to encourage car commuters to shift to other sustainable transport options, it is crucial to understand the behaviour and the mechanisms of behavioural change to design appropriate actions.

Generally, changing travel behaviours of car users is a process that happens through several key stages, including (KonSULT, 2016) :

- **Awareness:** Car commuters must be aware of the problems caused by car traffic (e.g., congestions, pollution).
- **Accepting responsibility**: Car users must accept that they are playing a part in contributing to traffic problems and have the responsibility to solve these problems.
- **Perception of alternative travel options:** The perception of car users on alternative modes is different depending on both characteristics/quality of alternative options and their personal beliefs and social norms of these modes. The better perception of a transport mode, the more likely that this transport mode will be selected.
- **Evaluation of alternative travel options:** People only change their transport mode if they have a positive perception of the alternative mode with regard to factors that are most important for them. For example, if the most important factor for them is cost, they may be more likely to select the transport mode less expensive, although it may take longer travel time.
- **Making a choice:** This stage is related to whether a person really intends to change their car to an alternative mode for certain trips.
- **Experimental behaviour:** People try to travel with a new transport mode for certain trips. If their travel experience with the new transport mode is positive, then this change may become more permanent. However, if their experience is negative, they may change to other options or keep commuting in their cars.
- **Change habitual behaviour:** This is the final stage of changing the travel behaviour process, whether or not a person decided to use the new transport mode for a long-term period. At this stage, the old travel habit has been broken and a new habit established.

The travel awareness campaign should make people more aware of the impacts of car commuting on the environment, including air and noise pollution as well as impacts on their health and the health of others. Then, inform them of the alternative travel options (e.g., bicycle, public transport), its benefits, knowledge of how to use them, and even incentives for using them (e.g., free public transport tickets). Of course, one approach cannot address the needs of all people. Therefore, depending on the targeted groups and objectives of campaigns, specific methods should be applied.

7.6 Strategy to improve the efficiency of the transport system

Improve measures aim to improve vehicle and fuel efficiency and optimize the performance of urban transport infrastructure and urban transport modes. In the future, private motorised transport is still playing an important role in serving travel demand. Therefore, improving fuel and vehicle efficiency is vital to reduce vehicle emissions and its' impacts on health. In addition, the capacity of urban transport infrastructure is usually unchanged, but the traffic demand changes over time and location. This could lead to situations in which demand exceeds the supply resulting in traffic congestions and environmental degradation. Measures that aim to improve the traffic flow, improve intermodal and multimodal transport, ensure the proper working of transport infrastructure, increase the efficiency of parking facilities, and provide travel information are also meaningful to increase the performance of the transport system.

7.6.1Measures to improve fuel and vehicle efficiency

The measures aim to increase the energy efficiency for both new vehicles and in-use vehicles, meaning that vehicles consume less fuel and/or emit less pollutants per unit of distance travelled.

- **Stringent vehicle emission standards and fuel quality standards**

Emission standards set quantitative limits on the amount of specific air pollutants that allows to be released by new vehicles and engines over a predefined test cycle. The vehicle emission standards are varying across countries. However, the United States, Japan, and the European Union have led the way with the design of increasingly rigorous requirements for all types of new vehicles. The standards are different for different kinds of vehicles. The mature, regularly updated vehicle emission standards in the United States and the European Union play as a roadmap of progressively stringent regulation for many countries. These standards have been widely adopted in many countries across the world. The adoption of more stringent vehicle emission standards will significantly reduce vehicle emissions that improve air quality, human health, and climate. There was an estimation that globally, more than 210,000 early deaths in the year 2030 could avoid and a gain of 25 million years of life cumulatively from 2025 to 2030 if accelerating the adoption of the most stringent vehicle emission standards and fuel standards (Chambliss, Miller, Façanha, Minjares, & Blumberg, 2013) . They also reported that the early implementation of vehicle emission standards would be the most beneficial in countries with rapidly increasing vehicle sales as vehicles meeting higher standards more quickly become a greater share of the total vehicle fleet.

Fuel quality strongly influences the effectiveness of vehicle emission standards as more advanced technologies are precluded or diminished by certain fuel parameters such as lead in gasoline or high sulfur levels in gasoline or diesel. Therefore, standards for clean fuels and vehicles should be introduced as a package to ensure that advanced emissions control technologies are properly used and optimized (Bansal & Bandivadekar, 2013) . Low-and ultra-low-sulfur fuels are critical to enabling the vehicle with emission controls can operate with the appropriate fuel. For example, tightening standards to 50 ppm sulfur diesel will be necessary to achieve the major PM2.5 and NOx reductions offered by Euro IV technology. Further tightening to 10–15 ppm sulfur diesel could enable the full extent of reductions from technologies compliant with Euro V and VI standards (Chambliss et al., 2013).

- **Vehicle Replacement programs**

Older vehicles often emit a considerably high amount of air pollutants compared to newer vehicles. Although they are accounted for a small percentage of the overall vehicle fleet, they are responsible for a large share of total emissions. For example, a study in India estimated that pre-2003 vehicles were only 20% of the total vehicle fleet but accounted for nearly 50% of all vehicular PM emissions and 30% of the total NOx emissions in 2011 (Bansal & Bandivadekar, 2013). The result of global modelling of PM emission by vehicle model and technology conducted by (Yan, Winijkul, Jung, Bond, & Streets, 2011) reported that high-emitter vehicles could potentially contribute more than 50% of particulate matter (PM) and black carbon (BC) emissions after 2020 globally. Therefore, addressing these highly polluting vehicles is essential to reduce transport-related air pollution emissions, and improve air quality and human health. There are several ways to control and reduce the emission of these vehicles, including vehicle replacement, retrofit programs, and repower programs (Posada, Wagner, Bansal, & Fernandez, 2015). These programs can be implemented separately or simultaneously as well as voluntary or mandatory.

  - **The vehicle replacement program** aims to eliminate full vehicles from the vehicle fleet and replace them with newer and lower-emission vehicles.
  - **The retrofit program** aims to install additional pollution control equipment (e.g., diesel particulate filter) on existing vehicles that allow complete vehicles to continue operating.
  - **The repower program** aims to replace the engine and emission control equipment of existing vehicles, including changing the fuel type. This program may appropriate for some specialized vehicles with expensive components such as fire trucks and refuse trucks.

Before implementing the vehicle retirement program, it is important to understand the characteristics of the vehicle fleet to identify which vehicles are targeted for replacement. Some indicators that can be used to define high-polluted vehicles are vehicle ages, vehicle emission standards, and vehicle kilometres travelled. In general, vehicle replacement programs are voluntary and supported by some forms of incentives such as direct subsidies for purchasing new vehicles. The incentives should be designed appropriately to encourage people to scrap their vehicle instead of selling it to another person. To achieve the maximum benefit, the old vehicle should be replaced by a new vehicle that is as clean as possible and meets much more stringent emission standards. It is also important to have a clear regulation of destruction or dismantling and recycling old vehicles to avoid the risk of being transferred to another region where they will continue to operate (Posada et al., 2015). Removing old and highly polluting vehicles not only reduces vehicle emissions but also reduces vehicle noise emissions and improves vehicle safety.

- **Vehicle inspection and maintenance (I/M) programs**

Vehicles tend to deteriorate with age and usage that increases the level of vehicle emissions significantly. Therefore, the vehicle inspection and maintenance program aim to identify vehicle problems and assure their repair so that emissions are within legal limits. I/M programs are mandatory in many countries and are considered one of the most cost-effective measures to reduce traffic emissions of in-use vehicles. The testing procedures and standards for I/M vary across countries as they have different emission limits for vehicles and testing methods (Dandapat, Ghosh, Shankar, Maitra, & Maitra, 2020). The I/M can be conducted both at the testing centres and/or on-road locations. The frequency of I/M can be annually or biannually, depending on the type of vehicle. Although the periodic I/M is an effective way to control the emission from in-use motorised vehicles, in Vietnam, where motorcycles are dominant transport modes in urban traffic, there is still missing the legal requirement for implementing I/M on motorcycles. As a result, air pollution in major cities such as Ho Chi Minh City and Hanoi in Vietnam is considerably high.

- **Alternative fuels**

Some common alternative fuels for gasoline and diesel fuel are compressed or liquefied natural gas (CNG/LNG), ethanol, liquefied petroleum gas (LPG), and biofuel. These alternative fuels offer opportunities for reducing vehicle emissions and increase the efficiency for certain types of vehicle categories. For example, natural gas vehicles that are fuelled with either CNG or LNG may produce significantly lower levels of carbon monoxide (CO), particulate matter (PM), and nitrogen oxide (NOx) compared to conventional fuels. Posada estimated that buses that used CNG emit 70% and 30% of PM and NOx lower than diesel buses, respectively (Posada, 2009). For using alternative fuels, vehicles are designed in different ways, depending on how they use fuel. For example, vehicles can be engineered to use one alternative fuel; dual-fuel vehicles can use either a conventional or an alternative fuel, stored in separated tanks, or a mixture of both, stored in the same tank (Bansal & Bandivadekar, 2013) .

- **Promote electric vehicles**

Electric vehicles are considered one of the promising approaches to reducing CO_2 emissions and the dependence on petroleum products. In general, electric vehicles can be classified into two main categories include electrically-chargeable vehicles (ECVs) and hybrid electric vehicles (HEVs) (ACEA, 2018).

ECVs include full battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) that require recharging infrastructure.

- Battery electric vehicles (BEVs) are fully powered by an electric motor, using electricity stored in an onboard battery that is charged by plugging into the electricity grid. These vehicles have no CO_2 emissions coming from their tailpipe.
- Plug-in hybrids electric vehicles (PHEVs) combine an internal combustion engine and a battery-powered electric motor. The combustion engine supports the electric motor when needed, and the battery is rechargeable. PHEVs can potentially reduce tailpipe CO_2 emissions up to 75% depending technology used.
- Hybrid electric vehicles (HEVs) are powered by an internal combustion engine but also have a battery-power electric motor. The electricity is produced internally from regenerative braking and the internal combustion engine; therefore, they do not need recharged infrastructure.

In urban areas, electric vehicles can greatly improve urban air quality and reduce traffic noise from conventional vehicles that could benefit urban population health. A study estimated the health impacts EVs through air pollution in 53 large metropolitan areas in the United States. The result showed that significant health benefits had been gained in all areas, even when electricity is fully supplied by fossil fuel plants (Choma, Evans, Hammitt, Gómez-Ibáñez, & Spengler, 2020). However, the other study that examined the health and environmental benefits of introducing EVs in European countries reported that not all countries would benefit from introducing EVs. The benefits of EVs varied across countries and highly depended on the sources of producing electricity (Buekers, Van Holderbeke, Bierkens, & Int Panis, 2014). In general, in cities where the population densities are high, introducing EVs or replacing conventional vehicles with EVs can significantly reduce air pollution and its consequences for public health, and therefore, should be promoted. The countries with a high share of renewable energy sources have the largest benefits.

- **Eco-driving**

The levels of fuel consumption and emissions of a vehicle are also highly influenced by driving style, but it is often overlooked. Eco-driving is a driving style that can improve fuel efficiency by up to 45% (Sivak & Schoettle, 2012). Some common features of eco-driving are (1) accelerate and decelerate smoothly, (2) avoid excess idling in non-traffic situations, (3) maintain a steady speed, (4) keep tires properly inflated to recommended pressures, (5) limit the use of air conditioning, and (6) avoid overloading. In general, training programs and in-vehicle feedback devices are commonly used to implement eco-driving skills (Y. Huang et al., 2018). Compared to the other measures of improving fuel and vehicle efficiency, eco-driving is relatively low-cost and could be implemented immediately that can significantly reduce fuel consumption and emission.

7.6.2Measures to improve the performance of the urban transport system

Measures that improve the efficiency of urban transport infrastructure mainly focus on improving traffic flow through traffic management measures to ease traffic congestion, promoting intermodal and multimodal transport, and ensuring the proper working of transport infrastructure.

- **Park and ride facilities**

Active transport and public transport may not be able to serve all travel demand, at some points they need to combine each other or with private motorised transport to meet the travel demand of people. Providing park and ride facilities at public transport stations, transport hubs, interchange points is vital to promote intermodal and multimodal transport. For example, personal motorised transport users can park their vehicles at these parks and ride facilities and continue their trips with public transport modes. Other mobility services may also offer at the park and ride facilities including bicycle sharing, car-sharing, and taxi service. Users' amenities such as waiting areas, toilets, and travel information are often provided at park and ride facilities as well. At the larger facilities, extra services such as coffee shops, bakeries, luggage lockers, and travel offices may be provided.

- **Promote the applications of intelligent transport systems (ITS)**

Intelligent transport system (ITS) covers a wide range of advanced communication and information technologies applications to provide solutions for various transport problems (Andersen & Sutcliffe, 2000). The main applications focused on ITS in urban transport are traffic management and control techniques, real-time information for users, advanced safety systems, electronic payment systems, public transport management, and emergency management. ITS applications can improve the efficiency of vehicles and the capacity of existing transport infrastructure and road safety; reduce the environmental damage caused by motorised transport; save costs for authorities, operators, and users; and improve the jo significantly. For example, advanced traffic control systems help minimise travel delays and queue length at intersections and prioritise public transport vehicles and emergency services vehicles. Or advanced travelled information systems help commuters to plan for their trips before leaving their home or office. Thus, they can select the most appropriate transport modes or routes for their trips. The applications of ITS are varying across countries. ITS applications have been well-used in developed countries (e.g., Japan, Singapore, Germany), but ITS applications are still limited in many developing countries. However, the rapid development of information and communication technologies will quickly facilitate ITS applications in these countries, which provide a huge opportunity to address their current transport problems.

- **Dynamic traffic management/control system**

Traditionally, traffic problems are addressed in isolation in terms of locations, times, and problems. However, there is an interrelatedness between these problems; solving a traffic problem at one location may result in other problems at other locations. Therefore, a dynamic traffic control system that integrates and coordinate traffic signal controls in urban areas help to address the problems more dynamical in response to the changes in traffic demand, unexpected incidents, and other condition over time. The major positive impacts of dynamic traffic management include reducing travel time and traffic congestions, increasing the smoothness of traffic flows and improving the whole network's performance.

- **Road maintenance**

The road is a crucial component of the transport system that highly influences the efficiency of the system. The low quality of road conditions or deterioration of roads affects the smooth of traffic flow, increases travel time and accident risks and causes congestions, results in increasing vehicular emissions and its adverse impacts on health. For example, (Setyawan, Kusdiantoro, & Syafi'i, 2015) estimated that average emissions exhausted from vehicles increased by 2.5% in very poor road conditions than excellent road conditions. Therefore, road maintenance is needed to ensure that pavements, sidewalks, cycle routes, and other transport infrastructures such as traffic lights, vegetation, and road markings work properly.

- **Intersection improvements**

Intersections have strongly influenced the capacity of road networks. Inappropriate designs and inefficient traffic signal programs at intersections may cause significant time loss, traffic accidents, and increase vehicle emissions. In developing countries like Vietnam, some simple improvements such as providing clear signs and road markings and optimising traffic signal programs could considerably increase the safety and road capacity. In addition, providing priority to cyclists, pedestrians, and public transport at intersections through bicycle boxes, advanced stop lines, or prioritised traffic signals increases the attractiveness of these transport modes and encourages travel behavioural changes.

7.7 Recommendations for applications in HCMC

This section aims to give general recommendations for the application of the above-proposed strategies in HCMC. Before going more detail to the recommendations of each strategy, some major suggestions for public authorities, transport planners, decision-makers, and relevant stakeholders should be kept in mind to promote active transport and public transport effectively, including:

- They should be aware of the importance of active transport and public transport in terms of promoting health, addressing transport-related issues, and achieving sustainable transport development.
- They should be aware of the potential of active transport and public transport in terms of replacing motorcycle transport in the city because a large number of motorcycle trips can be conducted by active transport and public transport.
- They should be aware that transport policies promote active transport and public transport as healthy transport modes are effective approaches to encourage behavioural changes among motorcyclists. Because a large proportion of motorcyclists would be willing to shift to these modes if they know the potential health benefits.
- Walking and cycling should be included in urban transport planning and transport policy development.
- To effectively promote active transport and public transport require the combination of different strategies and measures, including measures to limit motorcycle and car transport.

Based on the existing urban transport condition in HCMC, recommendations for each strategy are presented below.

- **Strategy to promote walking**

Basically, measures that improve the quantity and quality of walking infrastructure and facilities in the city are strongly needed. Sidewalks are usually available on car-based urban roads; however, they are often occupied by motorcycle parking, street vendors, and other residential activities. Sidewalk surfaces are often uneven, and the lighting system is insufficient or inadequate provided. These conditions make walking uncomfortable and difficult for pedestrians. Thus, improving the quality of existing sidewalks is required. On the smaller roads or alleys, providing road markings and signs for pedestrians can be implemented that may raise the awareness of motorcyclists to reduce their speeds or give priority to pedestrians along these roads. Providing a connected sidewalk network could enhance the smoothness of walking and increase convenience and comfort for pedestrians.

Regarding pedestrian crossing, basic facilities and features such as vehicle stop lines, road marking for pedestrian crossing (e.g., zebra, ladder), and warning signs at all crossing points have to be provided clearly, sufficiently, and properly. The crossing safety of pedestrians could potentially improve by these simple improvements. Pedestrians cross the streets at wrong crossing points are common behaviours of pedestrians in HCMC, resulting in many crashes between traffic and pedestrians. Therefore, installing mid-block crossings at appropriate locations is highly recommended, especially at schools, parks, and areas where attracting high walking demand. It is important to note that designing sidewalks and crossings must consider the needs of disadvantaged pedestrian groups such as disabled people, children, and the elderly.

Extending pedestrian zones in city centres and locations where attract high walking activities are highly recommended. Daily lifestyle and sidewalk business in HCMC are in favour of promoting the walking environment. Creating a pedestrian-friendly environment in the city is not only encourages walking but also facilitates sidewalk economics in the city.

- **Strategy to promote cycling**

The strategy to promote cycling in HCMC is based on the sequence of cycling development efforts developed by Dufour (2010). Based on cycling conditions and cycling rates, Dufour classified three types of cycling city including starter cycling cities, climber cycling cities, and champion cycling cities (presented in figure 7-6). HCMC is considered a starter cycling city because of its poor cycling conditions and low cycling rate. Promoting cycling in this city faces the hardest challenges. Strong support and commitment of public authorities, transport planners, and decision-makers are crucially important to encourage cycling in HCMC. They need to have a clear vision, goals, and objectives for the cycling system. Dufour also proposed a sequence of cycling development efforts across three cycling cities that defined broad goals and packages of measures suited to each level of cycling city (Dufour, 2010) . This sequence is presented in figure 7-7. It is highly recommended that HCMC should adapt this sequence framework to develop a step-by-step strategy to encourage cycling.

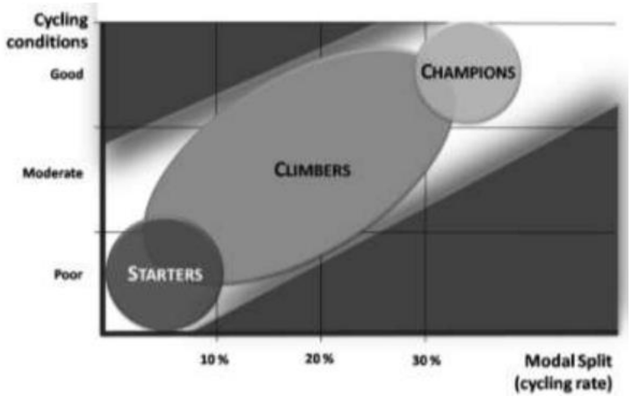

Figure 7-6: Classification of type of cycling cities based on cycling conditions and cycling rates (Dufour, 2010)

At the first stage, the city government should make cycling possible, safe, and respectable by investing in cycling infrastructure. Two primary requirements of cycling infrastructure at this stage are to ensure the safety and directness of cycling. These are pre-required conditions to encourage people to cycle. Currently, a pilot project on bike-sharing is implementing at some locations in HCMC. Expanding of this bike-sharing scheme is recommended together with providing infrastructure for cycling. Providing parking facilities that avoid theft and vandalism also vital to promote cycling. The flat terrain in HCMC is an advantage for promoting cycling in the city. However, the hot and humid weather in the dry season and heavy rains in the rainy season are disadvantages for promoting cycling. These factors should be carefully considered in the designing and providing infrastructures and facilities for cycling. Encouraging e-bikes could be an effective approach to overcome these disadvantages. In addition, based on finding from chapter 5 and 6, marketing and branding cycling as a healthy transport option is an effective way to encourage cycling.

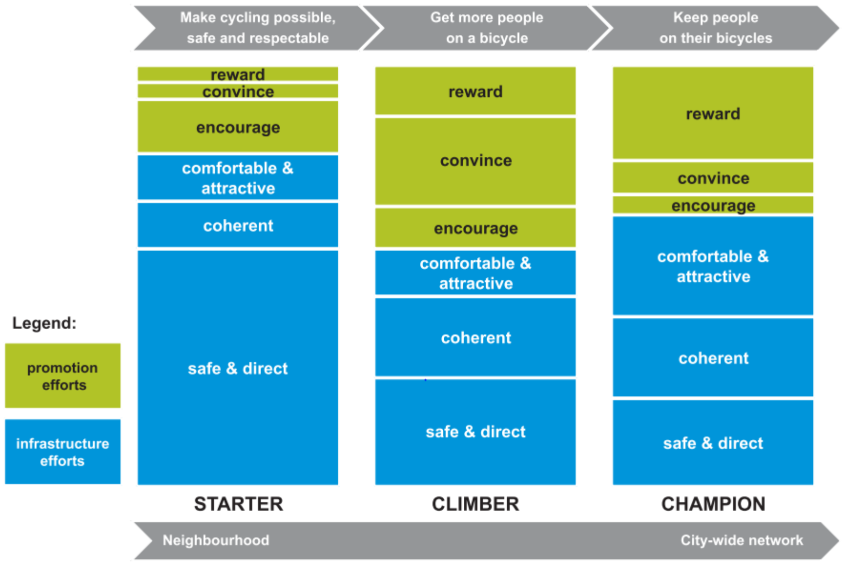

Figure 7-7: Sequence of cycling strategy efforts (Dufour, 2010)

- **Strategy to promote public transport**

Public transport services in HCMC have been improved significantly in recent years. However, many improvements are still needed to increase public transport ridership in the city. Public transport priority measures may not feasible and acceptable in HCMC because of the limited road space and low enforcement of traffic rules.

Regarding public transport routing and network, expanding bus services to suburban areas and rural areas is strongly recommended. In the urban area, re-structuring the bus network that clearly distinct trunk routes, feeder routes, and distributor routes could be an effective way to increase public transport ridership and improve bus services' effectiveness. Especially feeder routes that can enter small routes and collect passengers to trunk routes. Adjusting and improving the schedule and frequency of public transport services based on passenger demand are cost-effective measures to increase public transport usage as well. In addition, replacing old buses and improving passenger amenities at bus stops and on vehicles are highly recommended to improve passengers' comfort and bus's image in HCMC. Public transport facilities supporting disadvantaged groups (e.g., disabled people, children, old people) should also be provided.

Improving the public transport ticketing system in the city is required as well. For using buses, passengers usually have to buy a single ticket for a single bus trip. Tickets are in paper form, and passengers can buy the ticket from staff on the vehicle or buy a ticket pad from selling points located at some major bus stations. This is inconvenient for passengers and may affect the operations of buses if drivers have to sell tickets on their own or increasing the labor cost for one ticket staff control. Improve fare structure and fare collection methods such as offering monthly tickets, using smart cards and electronic tickets, installing ticket machines at major bus stations could improve the public transport services in the city.

Public transport information provision and promotion also need to be improved. The basic information of bus services such as bus routes, bus stops, operating schedules, and ticket prices must be provided sufficiently and adequately at all bus stops and on vehicles. Offering various information provision options through various formats is recommended to ensure that all passengers can get all information that they need for using public transport. Furthermore, the promotional activities that change people's perception of public transport in HCMC are necessary. Although public transport in the city has improved significantly recently, not many people have recognised the improvement. Promotional activities such as free travel by bus on certain days or discounted bus tickets that encourage people to travel by bus can effectively change people's perception of public transport.

- **Strategy to reduce private motorised transport**

Motorcycle and car travel demand in HCMC are increasing continuously that has already caused many adverse effects, including increased traffic congestions, air and noise pollutions, traffic accidents, and insufficient parking places. Therefore, measures limiting the increase in the number of motorcycles and cars, such as vehicle registration control and vehicle ownership restriction, are strongly recommended. In addition, parking restriction, vehicle access restriction, and traffic calming could potentially discourage motorcycle and car use in the city by making use of these modes less convenient. Traffic calming such as reduced vehicle speed limit and speed humps should be provided in the streets where high pedestrian volume to improve safety for pedestrians in the city. Currently, the speed limit in the urban area in HCMC is 50 km/h that may cause serious injuries for pedestrians if accidents happen. In addition, pricing measures including parking pricing, vehicle taxes, fee, and fuel taxes, and road pricing could also discourage car and motorcycle transport in the city by making these modes more expensive to own and to use.

Currently, the use of carsharing and ridesharing services in HCMC is increasing. This type of shared mobility could change the perception of commuters by sharing vehicles instead of owning them. Good integration of these services with public transport systems can be the potential to reduce motorcycle and car demand and to increase public transport users. Therefore, this measure should also be considered by public authorities, transport planners, and decision-makers.

Finally, to a certain extent, commuters in HCMC should be more aware of problems caused by their daily travel behaviours that can be done by implementing travel awareness campaigns such as car-free days, motorcycle-free days.

- **Strategy to improve the efficiency of the transport system**

Measures to improve fuel and vehicle efficiency are urgently required to improve air quality in HCMC, especially measures to reduce emissions from in-use motorcycles. Replacing old motorcycles and implementing vehicle inspection and maintenance programs are two promising measures that should be applied to decrease motorcycle emissions. Regarding new vehicles, although the city already has a plan for stringent vehicle emission standards, stricter vehicle emission standards are more desirable. Promoting electric vehicles by giving user incentives (e.g., reduce registration fees, vehicle taxes) is also recommended for HCMC, particularly electric motorcycles.

Providing park and ride facilities at major public transport stops and stations are necessary, allowing people to park their vehicles and use buses for their journeys. Providing park-and-ride facilities at all bus stops would not be feasible and effective in HCMC due to the lack of space and insecurity. However, after establishing the first metro system, park-and-ride facilities should be provided at every train station. The design of these facilities should consider all parking demands of users, including cyclists. In addition, facilitating applications of Intelligent Transport Systems is highly recommended. ITS applications could potentially improve the efficiency and the capacity of the urban transport system in HCMC.

7.8 Conclusions

The chapter proposes five strategies to promote active transport and public transport that are summarised in table 7-2. Then, the application of these strategies for HCMC is recommended. To encourage walking, measures improving the quality and quantity of sidewalks and crossing facilities are urgently needed to ensure the safety and convenience of pedestrians. Extending pedestrian zones in city centres and locations where attract high walking activities is also highly recommended. To promote cycling, at the first step, the city has to make cycling possible, safe, and respectable by investing in cycling infrastructure. Two primary requirements of cycling infrastructure are to ensure safety and directness. Providing parking facilities to avoid theft and vandalism also is vital to promote cycling. Bike-sharing schemes should be facilitated as well. To encourage public transport, measures improving bus services are necessary. To restrict private motorised transport, measures limiting the increase in the number of motorcycles and cars are strongly recommended. Parking restriction, vehicle access restriction, and traffic calming should also be considered for implementation. Measures to improve fuel and vehicle efficiency are urgently required to improve air quality in the city, especially measures to reduce emissions from in-use motorcycles. Replacing old motorcycles and implementing vehicle inspection and maintenance programs are two promising measures that should be applied to decrease motorcycle emissions. Providing park and ride facilities and facilitating applications of Intelligent Transport Systems is highly recommended.

Table 7-2: Summary of strategies and measures (Source: Author)

Strategy 1: Promote walking		**3.5**	Scheduling and frequency improvement
1.1	Sidewalks/walkways		Frequency change
1.2	Pedestrian zones		Service hours changes
1.3	Pedestrians and public transport		Integrated schedules
1.4	Pedestrian crossings		Regularised schedules
Strategy 2: Promote cycling		**3.6**	Importation provision and promotion
2.1	Cycling infrastructures and facilities		Public transport information
	Cycling network		Public transport promotion and marketing
	Intersections and crossings	**Strategy 4: Reduce private motorised transport**	
	Cycling parking facilities	**4.1**	Restriction measures
2.2	Bike-sharing schemes		Vehicle registration control
2.3	Cycling promotional activities		Parking restriction
	Information provision		Vehicle access restriction
	Awareness campaigns		Traffic calming
	Training and education programs	**4.2**	Pricing measures
	Incentives		Parking pricing
Strategy 3: Promote public transport			Vehicle taxes, fees, and fuel taxes
3.1	Public transport priority		Road pricing
	Signal priority	**4.3**	Carsharing and ridesharing

	Roadway priority	**4.4**	Substitute private motorised travel
	Bus stop improvement	**4.5**	Travel awareness campaigns
3.2	Public transport routing and network improvement	**Strategy 5: Improve the efficiency of the transport system**	
	Network expansion	**5.1**	Improve fuel and vehicle efficiency
	Network restructuring		Stringent vehicle emission standards and fuel quality standards
	Circulator/distributor routes		Vehicle replacement programs
	Feeder routes		Vehicle inspection and maintenance programs
3.3	Passenger amenities improvement		Alternative fuels
	At stops/stations improvement		Promote electric vehicles
	Onboard improvement		Eco-driving
3.4	Improvement ticketing system	**5.2**	Measures to improve performance of transport system
	Change fare levels and structures		Park and ride facilities
	Fare collection improvements		Applications of the intelligent transport system
	Integrated ticketing system		Dynamic traffic management/control systems
			Road maintenance

8 Conclusions and Recommendations

This chapter first summarises the contents and highlights the findings of the study. Then, the significance and limitations of the study are described. And finally, the recommendations for further studies are presented.

8.1 Summary of the research results

The study has accomplished the research goal and objectives described in section 1.2. The results are summarised below.

- **Determine principal health impacts of transport**

Health is always an important aspect of every individual and every community to ensure a happy life, happy community, increase productivity, well-being, and save health care costs. Poor health causes significant adverse impacts on quality of life, reduce productivity, and increase healthcare costs. Therefore, for every individual and community, good health is considered one of their main goals and one of the vital inputs to enable the achievement of the other goals. However, human health is a complex issue and is influenced by many sectors beyond the health sectors. Among these sectors, transport plays an essential role in both promoting and threatening health.

Health benefits of transport include providing people with access to employment, education, shops, recreation, social and family networks, health care services, a wide range of other services, and giving the opportunities for integrating physical activity into daily life through walking and cycling. However, transport also creates tremendous detrimental health effects through traffic accidents, air pollution, noise pollution, stress, community severance, land consumption, and climate change. Figure 8-1 presents potential health impacts of transport. In this study, four primary transport-related health impacts have selected for detailed investigation, including traffic accidents, health impacts of exposure to traffic-related air pollution, health impacts of exposure to traffic-related noise pollution, and transport-related physical activity.

The road traffic accident is a well-known and earliest recognised health impacts of transport, which is associated with traffic fatalities, traffic injuries, and premature mortality. The health impacts of traffic accidents are not only for victims but also for their families and society. To accurately estimate the health impacts of road traffic accidents remain a global health challenge because of lacking of harmonised definitions, underreporting, and misreporting on road traffic deaths and level of injury severities. The magnitude of impacts varies across countries. The low- and middle-income countries suffer the greatest burden of health impacts.

Transport is a primary contributor to air pollution, particularly in the urban area with the high number of motorised vehicles. The health impacts of exposure to traffic-related air pollution are considered the second largest health impacts of transport. Vehicles emit a wide range of air pollutants, among which $PM_{2.5}$, PM_{10}, NO_x, and O_3 are the most health-harmful pollutants. The primary health impacts of exposure to traffic-related air pollution include ischemic heart disease, strokes, lower respiratory infections, chronic obstructive pulmonary disease, and lung issues. The urban population is generally at a higher risk because they are exposed to a higher level of air pollution concentration than the rural population.

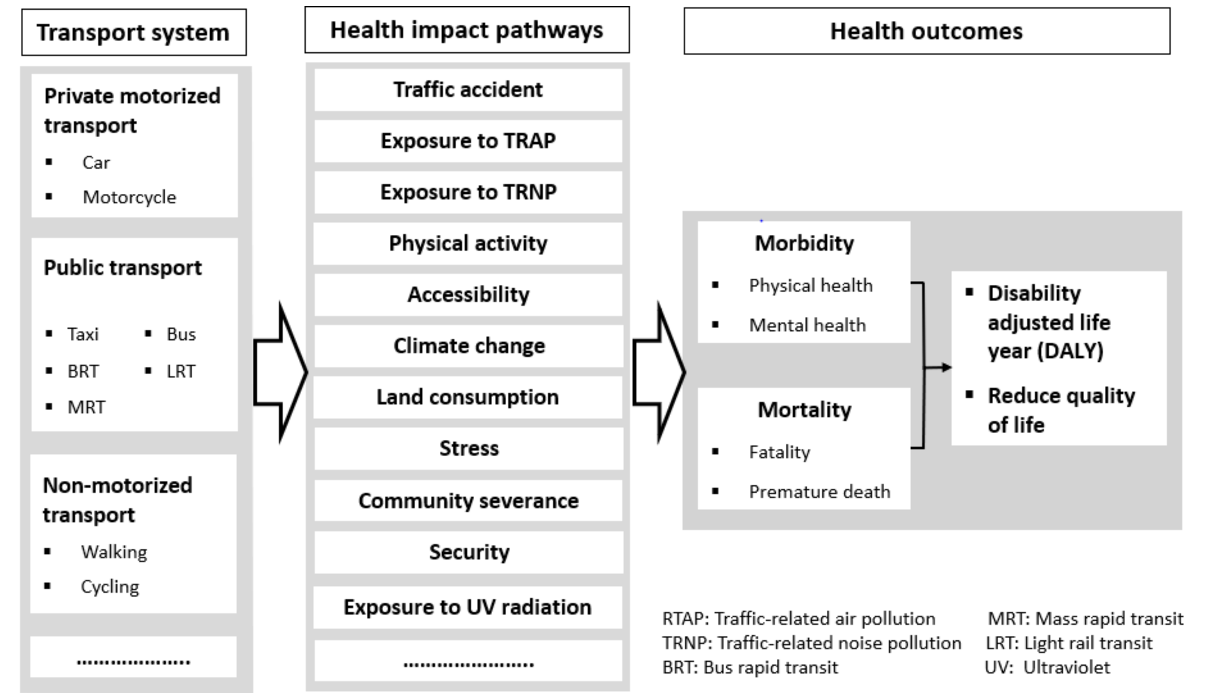

Figure 8-1: Health impacts of transport (Source: Author)

Noise is one of the major environmental issues affecting a large proportion of the population. In urban areas, traffic noise is a principal noise source. With continuing urbanisation and increasing population, traffic noise is a growing problem. Sleep disturbance, annoyance, cardiovascular diseases, and mental health impacts are among the most common health effects of exposure to road traffic noise. The studies about the health impacts of exposure to road traffic are still limited and have gained very little attention in many countries, both for the general population and authorities.

Physical inactivity and insufficient physical activity are associated with the increase in the risk of many adverse health effects, including major non-communicable diseases such as coronary heart disease, type 2 diabetes, obesity, breast and colon cancers, and shortens life expectancy. Daily commuting by walking, cycling, and using public transport is a potential source of physical activity for people. Active and public transport commuters have proved better in both physical and mental health with a lower risk of obesity and a better body mass index than other commuter groups.

The cause-effect relationships have been developed for these four major transport-related health impacts. These cause-effect chains explain the health impact pathway of transport that helps the general population, transport planners, and decision-makers to have a better general understanding. Notably, factors influencing transport-related health impacts have been described clearly in this chapter, providing meaningful knowledge for authorities, policymakers, and relevant stakeholders to develop interventions to mitigate negative health impacts and promote positive health impacts of transport.

- **Transport mode use and its health impacts on users and the general population**

The transport mode choice affects health in different ways, both positively and negatively. The individual transport mode choices affect not only commuters' health but also the health of other road users and the general population.

Regarding traffic accidents, motorcycles seem to be the most dangerous mode for users, while public transport and car seem to be the safest for its users; cycling and walking are much safer than riding motorcycles. However, when taking into account the health risk imposed on other road users, cycling and walking have the lowest risks, compared to other road users, while motorised vehicles impose considerably higher risk.

Regarding the health impacts of exposure to TRAP, levels of exposure to TRAP of active commuters may be higher or lower than those of motorised transport commuters. However, when taking under consideration the respiratory minute ventilation and travel time, the inhaled dose of active commuters has found significantly higher than that in non-active modes. Therefore, pedestrians and cyclists are most affected by exposure to TRAP. In contrast, cycling and walking emit almost no air pollution at all. As a result, there are no negative impacts on the other road users and the general population. A similar trend is also found in the health impacts of exposure to traffic-related noise pollution.

Regarding transport-related physical activity, people who travel by active transport and public transport are more likely to meet physical activity level recommendation than those travelling by motorised transport modes, which are associated with many health benefits. The existing evidence strongly supports that the health benefits of transport-related physical activity on active commuters and public transport commuters are higher than negative health impacts from exposing to increased air and noise level and the risk of traffic accidents. Therefore, promoting active transport and public transport could significantly improve the health of active commuters, other road users, and the general population.

- **Health impact assessment**

The lack of adequate consideration of human health in policy development may result in many unexpected adverse health consequences. Human health has been considered in transport planning and policy development for a long time in the transport sector. However, the health assessment is often limited to some environmental risk factors or totally ignored in the transport decision-making process. HIA is a promising approach to facilitate health considerations into the transport decision-making process, supporting transport decision-makers to select the better alternatives for health and raise the awareness of their decisions on health. For conducting HIA in the transport sector, a health impact pathway is proposed. The proposed framework provides the fundamental background for transport planners, decision-makers, and other stakeholders an overview of how a transport policy could affect health. This also enables them to initially predict or estimate the health impacts of a proposed policy, programme, or project and decide whether an HIA should be implemented.

To apply the proposed framework, an HIA of increasing active transport and public transport use in HCM is conducted. Active transport and public transport are an instrumental factor in promoting health and addressing other urban transport problems in the city. For conducting this HIA, two surveys were conducted, including the measurement survey and interview survey. These surveys collect primary data to explore the level of exposure to air pollution and noise pollution and the health status of different road users based on their transport mode use. In total, 141 vehicle trips were carried out during the measurement survey, representing approximately 760 km of travel. And 1801 commuters were interviewed during the interview survey. The survey results showed that the health benefits of transport-related physical activity among pedestrians, cyclists, and bus commuters outweigh the negative health impacts of exposure to high noise and air pollution. Among commuter groups, people who cycle have gained the largest health benefits from transport-related physical activity. On average, cyclists spent 24 minutes on their daily commuting, equal to 120 minutes/5 week-days. By everyday cycling only, cyclists approximately met WHO physical recommendation for adults (150 minutes per week). Compared to cyclists, motorcyclists had no health benefits from transport-related physical. This may explain why they have more health issues than cyclists and other road user groups.

A qualitative assessment of the health impacts of increased active transport and public transport in HCMC was carried out with an assumption that the basic safety level for cyclists and pedestrians will be provided. Increasing walking, cycling, and using buses in HCMC provides benefits for many people, including existing and new pedestrians, cyclists, bus passengers, and the general population. Regarding commuters who shift from cars and motorcycles to walk, cycle, and buses, positive health impacts are estimated greater than its negative impacts. However, the magnitude of benefits depends on which transport modes an individual shifts to and the safety measures provided for cycling and walking. The general population will benefit from increased walking, cycling, and public transport use lower traffic-related air and noise pollution. The magnitude of benefits depends on how many people shift to walking, cycling, and using buses. It is recommended that car and motorcycle commuters should change their transport modes to active and public transport to improve their health and the others' as well. The city government in HCMC should promote active transport and public transport by investing in infrastructures, policies, and interventions to support these transport modes.

This is the first study investigating the health impacts of transport mode uses on different commuter groups in Vietnam. Results of the two surveys could contribute to the scarce database of transport-related health impacts in the country as well as in developing countries in general. The results also further reinforce the potential of active transport and public transport in terms of addressing health impacts of transport. The health benefits of transport-related physical activity on active commuters and public transport commuters are potentially higher than negative health impacts from exposure to increased air and noise level and the risk of traffic accidents. Therefore, transport policies promoting active transport and public transport could significantly improve the health of active commuters, public transport commuters, other road users, and the general population.

- **Health-oriented transport policy**

Transport systems that place health as a central goal of policy development can address transport-related health problems, promote health, and support achieving other sustainable development goals. The transport policies that aim to optimise the health impacts of transport by maximising positive health impacts and minimising negative health impacts are considered health-oriented transport policies. A goal system of the health-oriented transport policy has been proposed, including eight major goals and 25 specific objectives. Eight goals are (1) Improve accessibility and mobility, (2) Improve traffic safety for all, (3) Reduce health impacts of exposure to TRAP, (4) Reduce health impacts of exposure to traffic noise, (5) Promote transport-related physical activity, (6) Reduce transport-related greenhouse gas emissions, (7) Reduce transport-related land consumption, and (8) Reduce community severance. Depending on local context and development priorities, certain goals and objectives can be selected and integrated into the existing urban transport development goal system.

Active transport and public transport play essential roles in the healthy transport system that provides many health benefits for commuters and the whole community. Shifting from private motorised transport to active transport and public transport is presented as an obvious solution to improve health and well-being through increased physical activity, reduced air and noise pollution, decreased greenhouse gas emissions, increased social interaction, reduced land consumption, provided equal opportunity, livability and transport efficiency without the side-effect of pollution. These transport modes should be promoted to become the backbone of the transport system. The interventions that promote active transport and public transport should make it safer, more attractive, affordable and desirable than motorised transport.

The potential of active transport and public transport in replacing motorcycle transport and avoiding undesirable transport development direction in HCMC is highlighted. Travel patterns and land use in the city favour sustainable and healthy transport development in many ways. The urban structure is relatively compact with high population density and mixed land use combined with the dominant of motorcycles, generating many short and medium trips in the city. These trips can be potentially substituted by walking, cycling, and using public transport. The city's urban road network and daily lifestyle also create favourable conditions for encouraging active transport and public transport in HCMC instead of using motorcycles and cars.

Furthermore, health awareness is relatively high among commuters in the city, especially among pedestrians, cyclists, motorcyclists, and bus users. A large proportion of motorcyclists are willing to shift to these active transport and public transport if they are better for their health. Therefore, promoting active transport and public transport as healthy transport options would be a promising approach for changing road users' travel behaviours toward healthier and more sustainable transport modes,

- **Strategies to promote active transport and public transport**

Five strategies that consist of different measures are proposed to promote active transport and public transport, including: (1) Strategy to promote walking, (2) Strategy to promote cycling, (3) Strategy to promote public transport, (4) Strategy to control and avoid private motorised transport, (5) Strategy to improve the efficiency of the transport system. To promote active transport and public transport effectively, measures that restrict and control private motorised transport are strongly needed. Measures improving the efficiency of the existing transport system that reduce traffic congestions, noise and air pollution also enhance the environment for active transport and public transport. Application of proposed strategies is then recommended for HCMC.

8.2 Significance and limitations of the study

- **Significance of the study**

The potential transport-related health impacts have been comprehensively examined. Based on the magnitude of health impacts, four major transport-related health impact were selected for detail analysed, and a cause-effect relationship was developed for each of these health impacts. The study has provided the fundamental knowledge of transport-related health impacts.

The study has emphasised the contributions of health impact assessment in facilitating health consideration into the transport decision-making process and supporting decision-makers to select better alternatives for health. A causal pathway of transport and health has been proposed that provides the guidance for conducting HIA in the transport sector. A qualitative HIA of increase active transport and public transport in HCMC was carried out. The results provide further support for the idea that the health benefits of transport-related physical of active and public transport commuters outweigh the negative health impacts of exposure to the high level of noise and air pollution.

The study has also proposed a goal and objective system for a health-oriented transport system. The importance of active transport and public transport in terms of promoting health has discussed. The potential of encouraging these transport modes in HCMC has also presented. Then, strategies for promoting active transport and public transport have proposed.

The study could potentially increase the awareness of public authorities, transport planners, decision-makers, and the general population about the health impacts of transport. The results of this study would be meaningful for public authorities, transport planners, and decision-makers to understand how their decisions may affect health and how to formulate effective transport policies to improve transport-related health impacts.

- **Limitations of the study**

The data relating to the health impacts of transport is still limited. Therefore, some findings might be subjective and are limited because they reflect individual viewpoints and opinions. Because of the lack of epidemiological background, the health impact assessment of increasing active transport and public transport in HCMC is also limited at qualitative.

The survey is conducted in city of developing country

Although active transport and public transport may significantly affect children and school children's health, in this study, the health impact assessment of increased active transport and public transport in HCMC does not consider commuters less than 15 years old.

An individual's health is affected by many factors, and daily commuting mode is only one of these factors. This study only focused on the general health problems of different commuter groups. Therefore, the recommendation of shifting from private motorised transport to active transport and public transport may not be reasonable for specific groups such as people with adverse pre-existing health issues or some older people.

8.3 Recommendations for further research

For further studies, quantifying transport-related health impacts is desirable. In HCMC the studies investigating transport-related health impacts are highly recommended regardless of quantitative or qualitative approaches. The health impacts of transport mode choice on commuter groups less than 15 years old should be examined.

The other factors influencing an individual's health, such as age, gender, income, and daily habits, should be considered for future studies in detail to examine the health impacts of daily commuting modes and propose appropriate recommendations for each group.

Regarding the application of strategies to promote active transport and public transport in HCMC, assessments of the health effects and effectiveness of proposed measures are suggested.

List of Tables

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List of Abbreviations

AQG	Air Quality Guideline
BRT	Bus Rapid Transit
BBS	Bike-sharing schemes
CBD	Central Business District
DALY	Disability Adjusted Life Year
HCMC	Ho Chi Minh City
HIA	Health impact assessment
ITF	International Transport Forum
ITS	Intelligent Transport System
LRT	Light Rail Transit
MAIS	Maximum Abbreviated Injury Score
MET	Metabolic Equivalent of the Task
MRT	Mass Rapid Transit
NCD	Non-communicable diseases
TOD	Transit-oriented Development
TRAP	Transport-related air pollution
TRNP	Traffic-related noise polluion
UV	Ultraviolet
WHO	World Health Organisation

References

ACEA. (2018). *Making the transportation to zero-emission mobility-Adressing the barriers to the uptate of electrically -chargeable cars in the EU*. Retrieved from www.acea.be

ADB. (2010). *Hochiminh City Adaptation to Climate Change*. *Asian Development Bank* (Vol. 76). https://doi.org/10.1080/01944363.2010.502047

Aldred, R., Johnson, R., Jackson, C., & Woodcock, J. (2020). How does mode of travel affect risks posed to other road users? An analysis of English road fatality data, incorporating gender and road type. *Injury Prevention*, 1–6. https://doi.org/10.1136/injuryprev-2019-043534

Almström, P., Markstedt, A., Schantz, P., Strömgren, M., Wahlgren, L., Sommar, J. N., … Johansson, C. (2017). Impacts on air pollution and health by changing commuting from car to bicycle. *Science of The Total Environment*, *584–585*, 55–63. https://doi.org/10.1016/j.scitotenv.2017.01.145

ALR. (2016). Moving Toward Active Transportation: How Policies Can Encourage Walking and Bicycling. *Active Living Research*, (Figure 1), 1–8. Retrieved from http://activelivingresearch.org/ActiveTravelreview

Amelsfor, D. van, Eichhorst, U., & Strompe, F. (2015). *Introduction to Congestion Charging: A Guide for Practitioners in Developing Cities*. Retrieved from http://hdl.handle.net/11540/4318%5Cnhttps://trid.trb.org/view/1360401

Anciaes, P. R. (2015). *Street mobility and network accessibility : What do we mean by " community severance "?*

Anciaes, P. R., Boniface, S., Dhanani, A., Mindell, J. S., & Groce, N. (2016). Urban transport and community severance: Linking research and policy to link people and places. *Journal of Transport and Health*, *3*(3), 268–277. https://doi.org/10.1016/j.jth.2016.07.006

Anciaes, P. R., Jones, P., & Mindell, J. S. (2014). Quantifying community severance A literature review, 1–35.

Anciaes, P. R., Jones, P., & Mindell, J. S. (2016). Community Severance: Where Is It Found and at What Cost? *Transport Reviews*, *36*(3), 293–317. https://doi.org/10.1080/01441647.2015.1077286

Andersen, J., & Sutcliffe, S. (2000). Intelligent Transport Systems (ITS) - An Overview. *IFAC Proceedings Volumes*, *33*(18), 99–106. https://doi.org/10.1016/s1474-6670(17)37129-x

Andersson, A. L., Dahlback, L. O., & Allebeck, P. (1994). Psychosocial consequences of traffic accidents: a two year follow-up. *Scandinavian Journal of Social Medicine*, *22*(4), 299–302.

APA. (2016). *Health Impact Assessment Toolkit for Planners HIA*.

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

Apparicio, P., Gelb, J., Carrier, M., Mathieu, M. È., & Kingham, S. (2018). Exposure to noise and air pollution by mode of transportation during rush hours in Montreal. *Journal of Transport Geography*, *70*(December 2017), 182–192. https://doi.org/10.1016/j.jtrangeo.2018.06.007

Argalášová, Ľ., Ševčíková, Ľ., Štefániková, Z., Babjaková, J., Vondrová, D., Filová, A., … Jurkovičová, J. (2017). Is Transportation Noise Associated with Obesity? *Procedia Engineering*, *190*, 597–602. https://doi.org/10.1016/j.proeng.2017.05.385

ATSB. (2002). *Cross Modal Safety Comparisons*. *Australian Transport Safety Bureau* (Vol. 96). https://doi.org/10.1016/j.yexmp.2014.03.001

Babisch, W. (2014). Updated exposure-response relationship between road traffic noise and coronary heart diseases: A meta-analysis. *Noise and Health*, *16*(68), 1. https://doi.org/10.4103/1463-1741.127847

Badeau, A., Carman, C., Newman, M., Steenblik, J., Carlson, M., & Madsen, T. (2019). Emergency department visits for electric scooter-related injuries after introduction of an urban rental program. *American Journal of Emergency Medicine*, *37*(8), 1531–1533. https://doi.org/10.1016/j.ajem.2019.05.003

Banister, D. (2008). The sustainable mobility paradigm. *Transport Policy*, *15*(2), 73–80. https://doi.org/10.1016/j.tranpol.2007.10.005

Banister, D. (2011). Cities, mobility and climate change. *Journal of Transport Geography*, *19*(6), 1538–1546. https://doi.org/10.1016/j.jtrangeo.2011.03.009

Bansal, G., & Bandivadekar, A. (2013). *Overview of India'S Vehicle Emissions Control Program Past Successes and Future Prospects*. *International Council on Clean Transportation*. Retrieved from http://www.theicct.org/sites/default/files/publications/ICCT_IndiaRetrospective_2013.pdf

Barter, P. (1999). *An International Comparative Perspective on Urban Transport and Urban Form in Pacific Asia: The Challenge of Rapid Motorisation in Dense Cities*. *Murdoch University*. Retrieved from http://researchrepository.murdoch.edu.au/3332/

Basner, M., Babisch, W., Davis, A., Brink, M., Clark, C., Janssen, S., & Stansfeld, S. (2014). Auditory and non-auditory effects of noise on health. *The Lancet*, *383*(9925), 1325–1332. https://doi.org/10.1016/S0140-6736(13)61613-X

Batista Ferrer, H., Cooper, A., & Audrey, S. (2018). Associations of mode of travel to work with physical activity, and individual, interpersonal, organisational, and environmental characteristics. *Journal of Transport and Health*, *9*(February), 45–55. https://doi.org/10.1016/j.jth.2018.01.009

Baum, F., Lawless, A., Delany, T., Macdougall, C., Williams, C., Broderick, D., … Marmot, M. (2014). Evaluation of Health in All Policies: Concept, theory and application. *Health Promotion International*, *29*, i130–i142. https://doi.org/10.1093/heapro/dau032

Beck, L. F., Dellinger, A. M., & O'Neil, M. E. (2007). Motor vehicle crash injury rates by mode of travel, United States: Using exposure-based methods to quantify differences. *American Journal of Epidemiology*, *166*(2), 212–218. https://doi.org/10.1093/aje/kwm064

Bekhit, M. N. Z., Le Fevre, J., & Bergin, C. J. (2020). Regional healthcare costs and burden of injury associated with electric scooters. *Injury*, *51*(2), 271–277. https://doi.org/10.1016/j.injury.2019.10.026

Berglund, E., Lytsy, P., & Westerling, R. (2016). Active traveling and its associations with self-rated health, BMI and physical activity: A comparative study in the adult Swedish population. *International Journal of Environmental Research and Public Health*, *13*(5). https://doi.org/10.3390/ijerph13050455

Berkowicz, R., Hertel, O., Larsen, S. E., Sørensen, N. N., & Nielsen, M. (1997). *Modelling traffic pollution in streets*. *National Environmental Research Institute, Roskilde, Denmark* (Vol. 10129). https://doi.org/10.1287/mnsc.1090.1070

Berntsen, S., Malnes, L., Langåker, A., & Bere, E. (2017). Physical activity when riding an electric assisted bicycle. *International Journal of Behavioral Nutrition and Physical Activity*, *14*(1), 1–7. https://doi.org/10.1186/s12966-017-0513-z

Bezai, N. E., Medjdoub, B., Al-Habaibeh, A., Chalal, M. L., & Fadli, F. (2020). Future cities and autonomous vehicles: analysis of the barriers to full adoption. *Energy and Built Environment*. https://doi.org/10.1016/j.enbenv.2020.05.002

Bhalla, K., Shotten, M., Cohen, A., Brauer, M., Shahraz, S., Burnett, R., … Denterner, F. (2014). *Transport for Health The Global Burden of Disease from Motorized Road*

Transport.
Bhalla, K., Shotten, M., Cohen, A., Brauer, M., Shahraz, S., Burnett, R., … Murray, C. J. L. (2014). *Transport for Health: The Global Burden of Disease from Motorized Road Transport*. https://doi.org/10.1016/B978-012373960-5.00335-X
Bhatia, R, Farhang, L., Heller, J., Lee, M., Orenstein, M., Richardson, M., & Wernham, A. (2014). *Minimum Elements and Practice Standards for Health Impact Assessment*. *North American HIA Practice Standards Working Group*. Retrieved from http://hiasociety.org/wp-content/uploads/2013/11/HIA-Practice-Standards-September-2014.pdf
Bhatia, Rajiv, Gilhuly, I., Harris, C., Heller, J., Lucky, J., & Farhang, L. (2011). *A Health Impact Assessment Toolkit: a Handbook to conducting HIA, 3rd Edition*. *Human Impact Partners*. https://doi.org/10.2140/gt.2012.16.2067
Blaizot, S., Papon, F., Haddak, M. M., & Amoros, E. (2013). Injury incidence rates of cyclists compared to pedestrians, car occupants and powered two-wheeler riders, using a medical registry and mobility data, Rhône County, France. *Accident Analysis and Prevention*, *58*, 35–45. https://doi.org/10.1016/j.aap.2013.04.018
Bloom, D. E., Cafiero, E. T., Jané-Llopis, E., Abrahams-Gessel, S., & Fathima, S. (2011). *The Global Economic Burden of Non-communicable Diseases*. *World Economic Forum and the Harvard School of Public Health* (Vol. 10).
Boarnet, M. G., Houston, D., Edwards, R., Princevac, M., Ferguson, G., Pan, H., & Bartolome, C. (2011). Fine particulate concentrations on sidewalks in five Southern California cities. *Atmospheric Environment*, *45*(24), 4025–4033. https://doi.org/10.1016/j.atmosenv.2011.04.047
Böcker, L., Dijst, M., & Faber, J. (2016). Weather, transport mode choices and emotional travel experiences. *Transportation Research Part A: Policy and Practice*, *94*, 360–373. https://doi.org/10.1016/j.tra.2016.09.021
Boer, L. C. (Eelco) den, & Schroten, A. (Arno). (2007). *Traffic noise reduction in Europe Health effects , social costs and technical and policy options to reduce road and rail traffic noise*.
Boltze, M., & Fornauf, L. (2013). A Method To Develop Dynamic Traffic Management Strategies. *13th World Conference on Transport Research*, 1–20.
Boogaard, H., Borgman, F., Kamminga, J., & Hoek, G. (2009). Exposure to ultrafine and fine particles and noise during cycling and driving in 11 Dutch cities. *Atmospheric Environment*, *43*(27), 4234–4242. https://doi.org/10.1016/j.atmosenv.2009.05.035
Boone-Heinonen, J., Evenson, K. R., Taber, D. R., & Gordon-Larsen, P. (2009). Walking for prevention of cardiovascular disease in men and women: A systematic review of observational studies: Obesity Prevention. *Obesity Reviews*, *10*(2), 204–217. https://doi.org/10.1111/j.1467-789X.2008.00533.x
Borowy, I. (2013). Road traffic injuries: Social change and development. *Medical History*, *57*(1), 108–138. https://doi.org/10.1017/mdh.2012.83
Borrell, C., Plasència, A., Huisman, M., Costa, G., Kunst, A., Andersen, O., … Mackenbach, J. P. (2005). Education level inequalities and transportation injury mortality in the middle aged and elderly in European settings. *Injury Prevention*, *11*(3), 138–142. https://doi.org/10.1136/ip.2004.006346
Boschetti, F. (2017). *Handbook of good practice case studies for promotion of walking and cycling*. Retrieved from www.eltis.org
Bourcier, E., Charbonneau, D., Cahill, C., & Dannenberg, A. L. (2015). An Evaluation of Health Impact Assessments in the United States, 2011–2014. *Preventing Chronic Disease*, *12*, 140376. https://doi.org/10.5888/pcd12.140376
Brown, A. L., & van Kamp, I. (2017). WHO environmental noise guidelines for the European region: A systematic review of transport noise interventions and their impacts on health.

International Journal of Environmental Research and Public Health, *14*(8), 1–44. https://doi.org/10.3390/ijerph14080873
Buehler, R. (2011). Determinants of transport mode choice: a comparison of Germany and the USA. *Journal of Transport Geography*, *19*(4), 644–657. https://doi.org/10.1016/j.jtrangeo.2010.07.005
Buekers, J., Dons, E., Elen, B., & Int Panis, L. (2015). Health impact model for modal shift from car use to cycling or walking in Flanders: Application to two bicycle highways. *Journal of Transport and Health*, *2*(4), 549–562. https://doi.org/10.1016/j.jth.2015.08.003
Buekers, J., Van Holderbeke, M., Bierkens, J., & Int Panis, L. (2014). Health and environmental benefits related to electric vehicle introduction in EU countries. *Transportation Research Part D: Transport and Environment*, *33*, 26–38. https://doi.org/10.1016/j.trd.2014.09.002
Buonanno, G., Fuoco, F. C., & Stabile, L. (2011). Influential parameters on particle exposure of pedestrians in urban microenvironments. *Atmospheric Environment*, *45*(7), 1434–1443. https://doi.org/10.1016/j.atmosenv.2010.12.015
Cappuccio, F. P., D'Elia, L., Strazzullo, P., & Miller, M. A. (2010). Sleep duration and all-cause mortality: A systematic review and meta-analysis of prospective studies. *Sleep*, *33*(5), 585–592. https://doi.org/10.1093/sleep/33.5.585
Carlos Dora, Jamie Hosking, Pierpaolo Mudu, E. R. F. (2011). *Urban Transport and Health - Sustainable transport: A sourcebook for policy-makers in developing cities*. *Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH*.
Carmichael, L., Townshend, T. G., Fischer, T. B., Lock, K., Petrokofsky, C., Sheppard, A., … Ogilvie, F. (2019). Urban planning as an enabler of urban health: Challenges and good practice in England following the 2012 planning and public health reforms. *Land Use Policy*, *84*(February), 154–162. https://doi.org/10.1016/j.landusepol.2019.02.043
Castro, A., Gaupp-Berghausen, M., Dons, E., Standaert, A., Laeremans, M., Clark, A., … Götschi, T. (2019). Physical activity of electric bicycle users compared to conventional bicycle users and non-cyclists: Insights based on health and transport data from an online survey in seven European cities. *Transportation Research Interdisciplinary Perspectives*, *1*, 100017. https://doi.org/10.1016/j.trip.2019.100017
Cavoli, C., Christie, N., Mindell, J., & Titheridge, H. (2015). Linking transport, health and sustainability: Better data sets for better policy-making. *Journal of Transport and Health*, *2*(2), 111–119. https://doi.org/10.1016/j.jth.2014.08.001
Cazorla, P. (2017). Cycling and public transportation sharing space: An option to increase cycling ridership. *Maskana*, *8*(2), 71–81. https://doi.org/10.18537/mskn.08.02.06
CECODES, VFF-CRT, RTA, & UNDP. (2020). *The Viet Nam provincial governance and public administration performance index (PAPI):Measuring Citizens' Experiences*. Ha Noi, Viet Nam. Retrieved from http://papi.org.vn/eng/
CEMHCM. (2018). *Hiện trạng chất lượng không khí tại thành phố hồ chí minh*.
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*(1), e23–e34. https://doi.org/10.1016/S2468-2667(16)30021-4
Chambliss, S., Miller, J., Façanha, C., Minjares, R., & Blumberg, K. (2013). *the Impact of Stringent Fuel and Vehicle Standards on Premature Mortality and Emissions*. *Report* (Vol. ICCT'S GLO).
Chang, C. J., Yang, H. H., Chang, C. A., & Tsai, H. Y. (2012). Relationship between air pollution and outpatient visits for nonspecific conjunctivitis. *Investigative Ophthalmology and Visual Science*, *53*(1), 429–433. https://doi.org/10.1167/iovs.11-8253

Chapman, D. A., Eyckmans, J., & Van Acker, K. (2020). Does car-sharing reduce car-use? An impact evaluation of car-sharing in flanders, Belgium. *Sustainability (Switzerland)*, *12*(19), 1–27. https://doi.org/10.3390/su12198155

Choma, E. F., Evans, J. S., Hammitt, J. K., Gómez-Ibáñez, J. A., & Spengler, J. D. (2020). Assessing the health impacts of electric vehicles through air pollution in the United States. *Environment International*, *144*(February), 106015. https://doi.org/10.1016/j.envint.2020.106015

Chou, S., Preston, R., Krueger, P., Chiang, G., Zipf, M., & Bracewel, D. (2016). *Walking + Cycling in Vancouver*.

Choudhary, A., & Gokhale, S. (2016). Urban real-world driving traffic emissions during interruption and congestion. *Transportation Research Part D: Transport and Environment*, *43*, 59–70. https://doi.org/10.1016/j.trd.2015.12.006

Christian, T. J. (2012). Trade-offs between commuting time and health-related activities. *Journal of Urban Health*, *89*(5), 746–757. https://doi.org/10.1007/s11524-012-9678-6

Christiansen, P., Engebretsen, Ø., Fearnley, N., & Usterud Hanssen, J. (2017). Parking facilities and the built environment: Impacts on travel behaviour. *Transportation Research Part A: Policy and Practice*, *95*, 198–206. https://doi.org/10.1016/j.tra.2016.10.025

Clark, C., & Paunovic, K. (2018a). WHO environmental noise guidelines for the european region: A systematic review on environmental noise and cognition. *International Journal of Environmental Research and Public Health*, *15*(2). https://doi.org/10.3390/ijerph15020285

Clark, C., & Paunovic, K. (2018b). WHO Environmental Noise Guidelines for the European Region: A Systematic Review on Environmental Noise and Quality of Life, Wellbeing and Mental Health. *International Journal of Environmental Research and Public Health*, *15*(11), 2400. https://doi.org/10.3390/ijerph15112400

Clifford, A., Lang, L., Chen, R., Anstey, K. J., & Seaton, A. (2016). Exposure to air pollution and cognitive functioning across the life course - A systematic literature review. *Environmental Research*, *147*, 383–398. https://doi.org/10.1016/j.envres.2016.01.018

Cohen, A. J., Brauer, M., Burnett, R., Anderson, H. R., Frostad, J., Estep, K., … Forouzanfar, M. H. (2017). Estimates and 25-year trends of the global burden of disease attributable to ambient air pollution: an analysis of data from the Global Burden of Diseases Study 2015. *The Lancet*, *389*(10082), 1907–1918. https://doi.org/10.1016/S0140-6736(17)30505-6

Costello, A., Abbas, M., Allen, A., Ball, S., Bell, S., Bellamy, R., … Patterson, C. (2009). Managing the health effects of climate change. *The Lancet*, *373*(9676), 1693–1733. https://doi.org/10.1016/S0140-6736(09)60935-1

Dahlgren, G., & Whitehead, M. (1991). *Policies and strategies to promote social equity in health*.

Dahlgren, G., & Whitehead, M. (2006). *European strategies for tackling social inequities in health: Levelling up Part 2*. Retrieved from http://www.google.co.uk/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&ved=0CDoQFjAB&url=http%253A%252F%252Fwww.euro.who.int%252Fdocument%252Fe89384.pdf&ei=cffzUIXhFOel0QWZ64DQAw&usg=AFQjCNEeEocMTylwWDIWZal7n90IF5DncA&bvm=bv.1357700187,d.d2k

Dandapat, S., Ghosh, T., Shankar, U., Maitra, S., & Maitra, B. (2020). A relook at the pollution certification of in-use vehicles in India and a way forward. *Asian Transport Studies*, *6*(July), 100020. https://doi.org/10.1016/j.eastsj.2020.100020

Dannenberg, A. L. (2016). Effectiveness of Health Impact Assessments: A Synthesis of Data From Five Impact Evaluation Reports. *Preventing Chronic Disease*, *13*, 1–15. https://doi.org/10.5888/pcd13.150559

Dannenberg, A., West, J., White, S., Ross, C., Ricklin, A., Wier, M., & Schwartz, M. (2014). Use of Health Impact Assessment for Transportation Planning Importance of Transportation Agency Involvement in the Process. *Transportation Research Record: Journal of the Transportation Research Board*, *2452*, 71–80. https://doi.org/10.3141/2452-09

de Bont, J., Casas, M., Barrera-Gómez, J., Cirach, M., Rivas, I., Valvi, D., … Vrijheid, M. (2019). Ambient air pollution and overweight and obesity in school-aged children in Barcelona, Spain. *Environment International*, *125*(January), 58–64. https://doi.org/10.1016/j.envint.2019.01.048

de Hartog, J. J., Boogaard, H., Nijland, H., & Hoek, G. (2010). Do the health benefits of cycling outweigh the risks? *Environmental Health Perspectives*, *118*(8), 1109–1116. https://doi.org/10.1289/ehp.0901747

de Nazelle, A., Bode, O., & Orjuela, J. P. (2017a). Comparison of air pollution exposures in active vs. passive travel modes in European cities: A quantitative review. *Environment International*, *99*, 151–160. https://doi.org/10.1016/j.envint.2016.12.023

de Nazelle, A., Bode, O., & Orjuela, J. P. (2017b). Comparison of air pollution exposures in active vs. passive travel modes in European cities: A quantitative review. *Environment International*, *99*, 151–160. https://doi.org/10.1016/j.envint.2016.12.023

de Nazelle, A., Fruin, S., Westerdahl, D., Martinez, D., Ripoll, A., Kubesch, N., & Nieuwenhuijsen, M. (2012). A travel mode comparison of commuters' exposures to air pollutants in Barcelona. *Atmospheric Environment*, *59*, 151–159. https://doi.org/10.1016/j.atmosenv.2012.05.013

De Nazelle, A., Nieuwenhuijsen, M. J., Antó, J. M., Brauer, M., Briggs, D., Braun-Fahrlander, C., … Lebret, E. (2011). Improving health through policies that promote active travel: A review of evidence to support integrated health impact assessment. *Environment International*, *37*(4), 766–777. https://doi.org/10.1016/j.envint.2011.02.003

Dediu, H., Bruce, O., & Rubin, J. (2019). *Micromobility The First Year*.

Deffner, J., Hefter, T., Rudolph, C., & Ziel, T. (2012). *Handbook on cycling inclusive planning and promotion-Capacity development material for the multiplier training within the mobile2020 project*. Frankfurt am Main/Hamburg. Retrieved from http://www.mobile2020.eu/get-trained/handbook.html

Difu. (2012). *Campaigning for Public Awareness on Cycling*. Retrieved from https://ec.europa.eu/transport/sites/transport/files/cycling-guidance/difu_cycling_expertise_campaigning_for_public_awareness_of_cycling_0.pdf

Ding, D., Gebel, K., Phongsavan, P., Bauman, A. E., & Merom, D. (2014). Driving: A road to unhealthy lifestyles and poor health outcomes. *PLoS ONE*, *9*(6), 1–5. https://doi.org/10.1371/journal.pone.0094602

Ding, D., Lawson, K. D., Kolbe-Alexander, T. L., Finkelstein, E. A., Katzmarzyk, P. T., van Mechelen, W., & Pratt, M. (2016). The economic burden of physical inactivity: a global analysis of major non-communicable diseases. *The Lancet*, *388*(10051), 1311–1324. https://doi.org/10.1016/S0140-6736(16)30383-X

Doan, H. T. N., & Hobday, M. B. (2019). Characteristics and severity of motorcycle crashes resulting in hospitalization in Ho Chi Minh City, Vietnam. *Traffic Injury Prevention*, *20*(7), 732–737. https://doi.org/10.1080/15389588.2019.1643460

Dons, E., Int Panis, L., Van Poppel, M., Theunis, J., & Wets, G. (2012). Personal exposure to Black Carbon in transport microenvironments. *Atmospheric Environment*, *55*, 392–398. https://doi.org/10.1016/j.atmosenv.2012.03.020

Dons, E., Laeremans, M., Orjuela, J. P., Avila-Palencia, I., Carrasco-Turigas, G., Cole-Hunter, T., … Int Panis, L. (2017). Wearable Sensors for Personal Monitoring and Estimation of Inhaled Traffic-Related Air Pollution: Evaluation of Methods. *Environmental Science and Technology*, *51*(3), 1859–1867.

https://doi.org/10.1021/acs.est.6b05782
Dons, E., Rojas-Rueda, D., Anaya-Boig, E., Avila-Palencia, I., Brand, C., Cole-Hunter, T., … Götschi, T. (2018). Transport mode choice and body mass index: Cross-sectional and longitudinal evidence from a European-wide study. *Environment International*, *119*(April), 109–116. https://doi.org/10.1016/j.envint.2018.06.023
Dora, C., & Hosking, J. (2011). *Urban Transport and Health : Module 5g. Sustainable Transport: A Sourcebook for Policy-makers in Developing Cities*.
Drakaki, E., Dessinioti, C., & Antoniou, C. V. (2014). Air pollution and the skin. *Frontiers in Envrionmental Science*, *70*(3), 156–157. https://doi.org/10.1007/s00105-018-4349-5
Dufour, D. (2010). *Presto Cycling Policy Guide-General Framework*. Retrieved from https://ec.europa.eu/transport/sites/default/files/cycling-guidance/presto_cycling_policy_guide_general_framework.pdf
EEA. (2016a). *Explaining road transport emissions - A non-technical guide*. *European Environment Agency*. https://doi.org/10.2800/71804
EEA. (2016b). Noise pollution in Europe. *EEA*, *41*(1), 65–68. https://doi.org/10.1016/s0020-7101(96)90005-7
EEA. (2017a). *Managing exposure to noise in Europe*. *European Environment Agency*. https://doi.org/10.2800/338580
EEA. (2017b). *Road traffic remains biggest source of noise pollution in Europe*. Retrieved from https://www.eea.europa.eu/highlights/road-traffic-remains-biggest-source
EEA. (2018a). *Air quality in Europe — 2018 report*. *European Environment Agency*. https://doi.org/10.2800/62459
EEA. (2018b). *Emissions of air pollutants from transport*. *European Environment Agency*. Retrieved from http://www.eea.europa.eu/data-and-maps/indicators/transport-emissions-of-air-pollutants-8/transport-emissions-of-air-pollutants-3
EEA. (2018c). *Emissions of air pollutants from transport*. *European Environment Agency*. https://doi.org/10.1088/0004-637X/705/2/L195
El-Geneidy, A. M., & Levinson, D. M. (2006). *Access to Destinations: Development of Accessibility Measures*. *Technical Report*. Retrieved from http://www.lrrb.org/PDF/200616.pdf
Elldér, E. (2020). Telework and daily travel: New evidence from Sweden. *Journal of Transport Geography*, *86*(December 2019), 102777. https://doi.org/10.1016/j.jtrangeo.2020.102777
Ellebjerg, L. (2005). *Effectiveness and Benefits of Traffic Flow Measures on Noise Control*.
Elvik, R., & Mysen, A. (1999). Incomplete Accident Reporting: Meta-Analysis of Studies Made in 13 Countries. *Transportation Research Record: Journal of the Transportation Research Board*, *1665*(1), 133–140. https://doi.org/10.3141/1665-18
Engström, E., & Forsberg, B. (2019). Health impacts of active commuters' exposure to traffic-related air pollution in Stockholm, Sweden. *Journal of Transport & Health*, *14*(July), 100601. https://doi.org/10.1016/j.jth.2019.100601
ETSC. (1999). *Reducing the severity of road injuries through post impact care*. Brussels.
ETSC. (2018). *Contraflow cycling*.
European Comission. (2010). *Illustrated glossary for transport statistics - 4th edition*. https://doi.org/10.2785/58454
European Commission. (2009). *Safety Net: Post Impact Care*.
European Commission. (2010). *Towards a European road safety area: policy orientations on road safety 2011-2020*.
European Commission. (2013). *COMMISSION STAFF WORKING DOCUMENT On the implementation of objective 6 of the European Commission's policy orientations on road safety 2011-2020 – First milestone towards an injury strategy*.
European Commission. (2014). *Special Eurobarometer 412: sport and physical activity:*

report. *European Commission*. https://doi.org/10.2766/73002
European Commission. (2018). *Road safety in the European Union Trends, statistics, and main challenges*. https://doi.org/10.2832/169706
European Environment Agency. (2018). *Total greenhouse gas emissions from transport*. Retrieved from https://www.eea.europa.eu/data-and-maps/indicators/transport-emissions-of-greenhouse-gases/transport-emissions-of-greenhouse-gases-11
European Environmental Agency. (2014). Health impacts of air pollution. Retrieved from https://www.eea.europa.eu/signals/signals-2013/infographics/health-impacts-of-air-pollution/view#tab-based-on-data)
European Union. (2016). *Review of in use factors affecting the fuel consumption and CO2 emissions of passenger cars*. https://doi.org/10.2790/74318
Fernández, A. C. (2011). *The contribution of bike-sharing to sustainable mobility in Europe Acknowledgement*. Technische Universität Wien.
Fierz, M., Houle, C., Steigmeier, P., & Burtscher, H. (2011). Design, calibration, and field performance of a miniature diffusion size classifier. *Aerosol Science and Technology*, *45*(1), 1–10. https://doi.org/10.1080/02786826.2010.516283
Flint, E., Cummins, S., & Sacker, A. (2014). Associations between active commuting, body fat, and body mass index: Population based, cross sectional study in the United Kingdom. *BMJ (Online)*, *349*(August), 1–9. https://doi.org/10.1136/bmj.g4887
Flint, E., Webb, E., & Cummins, S. (2016a). Change in commute mode and body-mass index: prospective, longitudinal evidence from UK Biobank. *The Lancet Public Health*, *1*(2), e46–e55. https://doi.org/10.1016/S2468-2667(16)30006-8
Flint, E., Webb, E., & Cummins, S. (2016b). Change in commute mode and body-mass index: prospective, longitudinal evidence from UK Biobank. *The Lancet Public Health*, *1*(2), e46–e55. https://doi.org/10.1016/S2468-2667(16)30006-8
Foley, L., Panter, J., Heinen, E., Prins, R., & Ogilvie, D. (2015). Changes in active commuting and changes in physical activity in adults: A cohort study. *International Journal of Behavioral Nutrition and Physical Activity*, *12*(1), 1–12. https://doi.org/10.1186/s12966-015-0323-0
Foraster, M., Eze, I. C., Vienneau, D., Brink, M., Cajochen, C., Caviezel, S., … Probst-Hensch, N. (2016). Long-term transportation noise annoyance is associated with subsequent lower levels of physical activity. *Environment International*, *91*, 341–349. https://doi.org/10.1016/j.envint.2016.03.011
Forsyth, A., Slotterback, C. S., & Krizek, K. (2010). Health impact assessment (HIA) for planners: What tools are useful? *Journal of Planning Literature*, *24*(3), 231–245. https://doi.org/10.1177/0885412209358047
Fritschi, L., Brown, A. L., Kim, R., Schwela, D., & Kephalopoulos, S. (2011). *Burden of disease from environmental noise: Quantification of healthy life years lost in Europe*. *World Health Organization*. https://doi.org/10.1080/13504630.2011.629519
Fu, X., Liu, J., Ban-Weiss, G. A., Zhang, J., Huang, X., Ouyang, B., … Tao, S. (2017). Effects of canyon geometry on the distribution of traffic-related air pollution in a large urban area: Implications of a multi-canyon air pollution dispersion model. *Atmospheric Environment*, *165*, 111–121. https://doi.org/10.1016/j.atmosenv.2017.06.031
Furie, G. L., & Desai, M. M. (2012). Active transportation and cardiovascular disease risk factors in U.S. adults. *American Journal of Preventive Medicine*, *43*(6), 621–628. https://doi.org/10.1016/j.amepre.2012.06.034
GDV. (2017). *Road safety of electric bicycles Compact accident research*.
George, Y., Papadimitriou, E., Lejeune, P., Treny, V., Hemdorff, S., Bergel, R., … Cardoso, J. (2005). *State of the Art Report on Risk and Exposure Data*. *SafetyNet*.
Ghekiere, A., Van Cauwenberg, J., De Geus, B., Clarys, P., Cardon, G., Salmon, J., … Deforche, B. (2014). Critical environmental factors for transportation cycling in children:

A qualitative study using bike-along interviews. *PLoS ONE*, *9*(9). https://doi.org/10.1371/journal.pone.0106696

Giallouros, G., Kouis, P., Papatheodorou, S. I., Woodcock, J., & Tainio, M. (2020). The long-term impact of restricting cycling and walking during high air pollution days on all-cause mortality: Health impact Assessment study. *Environment International*, *140*(March), 105679. https://doi.org/10.1016/j.envint.2020.105679

Giesel, F., & Nobis, C. (2016). The Impact of Carsharing on Car Ownership in German Cities. *Transportation Research Procedia*, *19*(June), 215–224. https://doi.org/10.1016/j.trpro.2016.12.082

Giles-Corti, B., Vernez-Moudon, A., Reis, R., Turrell, G., Dannenberg, A. L., Badland, H., … Owen, N. (2016a). City planning and population health: a global challenge. *The Lancet*, *388*(10062), 2912–2924. https://doi.org/10.1016/S0140-6736(16)30066-6

Giles-Corti, B., Vernez-Moudon, A., Reis, R., Turrell, G., Dannenberg, A. L., Badland, H., … Owen, N. (2016b). Urban design, transport, and health 1-City planning and population health: a global challenge. *The Lancet*, *388*(10062), 2912–2924. https://doi.org/10.1016/S0140-6736(16)30066-6

Gloerfelt, X. (2009). *Noise from automotive components*. *Aerodynamic noise from wall-bounded flows*. Retrieved from http://sin-web.paris.ensam.fr/squelettes/ref_biblio/Gloerfelt_VKI_2009b.pdf

GNHiAP. (2019). *Global Status Report on Health in All Policies*. Retrieved from https://actionsdg.ctb.ku.edu/wp-content/uploads/2019/10/HiAP-Global-Status-Report-final-single-pages.pdf

Gonzalo-Orden, H., Pérez-Acebo, H., Unamunzaga, A. L., & Arce, M. R. (2018). Effects of traffic calming measures in different urban areas. *Transportation Research Procedia*, *33*, 83–90. https://doi.org/10.1016/j.trpro.2018.10.079

Gössling, S., Humpe, A., Litman, T., & Metzler, D. (2019). Effects of perceived traffic risks, noise, and exhaust smells on bicyclist behaviour: An economic evaluation. *Sustainability (Switzerland)*, *11*(2), 1–15. https://doi.org/10.3390/su11020408

Götschi, T., Tainio, M., Maizlish, N., Schwanen, T., Goodman, A., & Woodcock, J. (2015). Contrasts in active transport behaviour across four countries: How do they translate into public health benefits? *Preventive Medicine*, *74*, 42–48. https://doi.org/10.1016/j.ypmed.2015.02.009

Granville, Laird, Barber, & Fiona Rait. (2002). *Why do parents drive their children to school? Scottish Executive Central Research Unit*.

Grundy, C., Steinbach, R., Edwards, P., Green, J., Armstrong, B., & Wilkinson, P. (2009). Effect of 20 mph traffic speed zones on road injuries in London, 1986-2006: Controlled interrupted time series analysis. *BMJ (Online)*, *339*(7736), 31. https://doi.org/10.1136/bmj.b4469

Guski, R., Schreckenberg, D., & Schuemer, R. (2017). WHO environmental noise guidelines for the european region: A systematic review on environmental noise and annoyance. *International Journal of Environmental Research and Public Health*, *15*(3), 1–39. https://doi.org/10.3390/ijerph15030519

Guthold, R., Stevens, G. A., Riley, L. M., & Bull, F. C. (2018). Worldwide trends in insufficient physical activity from 2001 to 2016: a pooled analysis of 358 population-based surveys with 1·9 million participants. *The Lancet Global Health*, *6*(10), e1077–e1086. https://doi.org/10.1016/S2214-109X(18)30357-7

Ha, N. T., Ederer, D., Vo, V. A. H., Pham, A. Van, Mounts, A., Leisha, D., … Program, I. (2019). Changes in motorcycle-related injuries and deaths after mandatory motorcycle helmet law in a district of Vietnam. *Traffic Injury Prevention*, *19*(1), 75–80. https://doi.org/10.1080/15389588.2017.1322203.Changes

Haddak, M. M. (2016). Exposure-based Road Traffic Fatality Rates by Mode of Travel in

France. *Transportation Research Procedia*, *14*, 2025–2034. https://doi.org/10.1016/j.trpro.2016.05.170

Haddon, W. (1968). The changing approach to the epidemiology, prevention, and amelioration of trauma: the transition to approaches etiologically rather than descriptively based. *American Journal of Public Health*, 1431–1438.

Haddon, W. (1972). A Logical Framework for Categorizing Highway Safety Phenomena and Activity. *The Journal of Trauma*, *Vol. 12*, *N*.

Hai, P. M. (2018). *Ho Chi Minh City SUSTAINABLE URBAN TRANSPORT INDEX (SUTI) - 2018*. Ho Chi Minh City. https://doi.org/10.1007/978-981-15-0660-4_6

Haigh, F., Harris, E., Harris-Roxas, B., Baum, F., Dannenberg, A. L., Harris, M. F., … Spickett, J. (2015). What makes health impact assessments successful? Factors contributing to effectiveness in Australia and New Zealand Health policies, systems and management in high-income countries. *BMC Public Health*, *15*(1), 1–12. https://doi.org/10.1186/s12889-015-2319-8

Haines, A., Gouveia, N., Tainio, M., Woodcock, J., Goodman, A., Monteiro, C., … Edwards, P. (2017). Health impact modelling of different travel patterns on physical activity, air pollution and road injuries for São Paulo, Brazil. *Environment International*, *108*(April), 22–31. https://doi.org/10.1016/j.envint.2017.07.009

Hakkert, A. S., & Braimaister, L. (2002). The uses of exposure and risk in road safety studies. *SWOV Institute for Road Safety Research, The Netherlands*, *R-2002-12*, 56.

Hallal, P. C., Andersen, L. B., Bull, F. C., Guthold, R., Haskell, W., Ekelund, U., … Wells, J. C. (2012). Global physical activity levels: Surveillance progress, pitfalls, and prospects. *The Lancet*, *380*(9838), 247–257. https://doi.org/10.1016/S0140-6736(12)60646-1

Ham, W., Vijayan, A., Schulte, N., & Herner, J. D. (2017). Commuter exposure to PM2.5, BC, and UFP in six common transport microenvironments in Sacramento, California. *Atmospheric Environment*, *167*, 335–345. https://doi.org/10.1016/j.atmosenv.2017.08.024

Hammersen, F., Niemann, H., & Hoebel, J. (2016). Environmental noise annoyance and mental health in adults: Findings from the cross-sectional German health update (GEDA) study 2012. *International Journal of Environmental Research and Public Health*, *13*(10), 1–12. https://doi.org/10.3390/ijerph13100954

Harris-Roxas, B., & Harris, E. (2013). The impact and effectiveness of health impact assessment: A conceptual framework. *Environmental Impact Assessment Review*, *42*, 51–59. https://doi.org/10.1016/j.eiar.2012.09.003

Harris-Roxas, B., Viliani, F., Bond, A., Cave, B., Divall, M., Furu, P., … Winkler, M. (2012). Health impact assessment: The state of the art, *30*(1), 43–52. https://doi.org/10.1080/14615517.2012.666035

Hassani, A., & Hosseini, V. (2016). An assessment of gasoline motorcycle emissions performance and understanding their contribution to Tehran air pollution. *Transportation Research Part D: Transport and Environment*, *47*(October 2002), 1–12. https://doi.org/10.1016/j.trd.2016.05.003

HEI. (2010). *Traffic-Related Air Pollution: A Critical Review of the Literature on Emissions, Exposure, and Health Effects*. *Health Effects Institute*. Retrieved from http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Traffic-Related+Air+Pollution:+A+Critical+Review+of+the+Literature+on+Emissions,+Exposure,+and+Health+Effects#0

HEI. (2013). *EXECUTIVE SUMMARY Understanding the Health Effects of Ambient Ultrafine Particles INTRODUCTION*. *Health Effects Institute*. Retrieved from https://www.healtheffects.org/system/files/Perspectives3-ExecutiveSummary.pdf

Heinen, E., & Buehler, R. (2019). Bicycle parking: a systematic review of scientific literature on parking behaviour, parking preferences, and their influence on cycling and travel behaviour. *Transport Reviews*, *39*(5), 630–656. https://doi.org/10.1080/01441647.2019.1590477

Hennessy, D. A., & Wiesenthal, D. L. (1999). Traffic Congestion, Driver Stress, and Driver Aggression. *Aggressive Behavior*, *25*(November 1998), 409–423.

Hennig, F., Quass, U., Hellack, B., Küpper, M., Kuhlbusch, T. A. J., Stafoggia, M., & Hoffmann, B. (2018). Ultrafine and fine particle number and surface area concentrations and daily cause-specific mortality in the Ruhr area, Germany, 2009–2014. *Environmental Health Perspectives*, *126*(2), 2009–2014. https://doi.org/10.1289/EHP2054

Hertel, O. (2009). *Integrated Monitoring and Assessment of air pollution*. Retrieved from http://www2.dmu.dk/pub/doktor_oh.pdf

Hieu, V. Van, Quynh, L. X., Ho, P. N., & Hens, L. (2013). Health Risk Assessment of Mobility-Related Air Pollution in Ha Noi, Vietnam. *Journal of Environmental Protection*, *04*(10), 1165–1172. https://doi.org/10.4236/jep.2013.410133

Ho, Q. B., Vu, H. N. K., Nguyen, T. T., & Nguyen, T. T. H. (2020). Traffic air emission inventory and measures to reduce air pollution in Ho Chi Minh City, Vietnam. *Journal of Urban Environment*, *38*(March), 29–38. https://doi.org/10.34154/2020-jue-0101-29-38/euraass

Hobbhahn, N., Fears, R., Haines, A., & ter Meulen, V. (2019). Urgent action is needed to protect human health from the increasing effects of climate change. *The Lancet Planetary Health*, *3*(8), e333–e335. https://doi.org/10.1016/S2542-5196(19)30114-7

Hodgson, F., & Tight, M. (1999). Raising awareness of transport issues: The potential to bring about behavioural change? *International Journal of Sustainable Development and World Ecology*, *6*(4), 281–292. https://doi.org/10.1080/13504509909470018

Hohmann, C., Grabenhenrich, L., De Kluizenaar, Y., Tischer, C., Heinrich, J., Chen, C. M., … Keil, T. (2013). Health effects of chronic noise exposure in pregnancy and childhood: A systematic review initiated by ENRIECO. *International Journal of Hygiene and Environmental Health*, *216*(3), 217–229. https://doi.org/10.1016/j.ijheh.2012.06.001

Hornikx, M. (2016). Ten questions concerning computational urban acoustics. *Building and Environment*, *106*, 409–421. https://doi.org/10.1016/j.buildenv.2016.06.028

Huang, J., Deng, F., Wu, S., & Guo, X. (2012). Comparisons of personal exposure to PM2.5and CO by different commuting modes in Beijing, China. *Science of the Total Environment*, *425*, 52–59. https://doi.org/10.1016/j.scitotenv.2012.03.007

Huang, Y., Ng, E. C. Y., Zhou, J. L., Surawski, N. C., Chan, E. F. C., & Hong, G. (2018). Eco-driving technology for sustainable road transport: A review. *Renewable and Sustainable Energy Reviews*, *93*(April), 596–609. https://doi.org/10.1016/j.rser.2018.05.030

Hudda, N., Eckel, S. P., Knibbs, L. D., Sioutas, C., Delfino, R. J., & Fruin, S. A. (2012). Linking In-Vehicle Ultrafine Particle Exposures to On-Road Concentrations. *National Institutes of Health Public Access*, *23*(1), 1–7. https://doi.org/10.1038/jid.2014.371

Humphreys, D. K., Goodman, A., & Ogilvie, D. (2013). Associations between active commuting and physical and mental wellbeing. *Preventive Medicine*, *57*(2), 135–139. https://doi.org/10.1016/j.ypmed.2013.04.008

Hung, K. V. (2006). *Traffic Management In Motorcycle Dependent Cities*.

Huong Giang, N. T., & Kim Oanh, N. T. (2014). Roadside levels and traffic emission rates of PM2.5and BTEX in Ho Chi Minh City, Vietnam. *Atmospheric Environment*, *94*(June), 806–816. https://doi.org/10.1016/j.atmosenv.2014.05.074

Hussain, L. M., & Redmond, A. D. (1994). Are pre-hospital deaths from accidental injury preventable? *The BMJ*, *308*(April), 1–4. Retrieved from papers3://publication/uuid/F0235690-13B4-47F5-9B47-B24182E1695C

Hwang, S. H., Choi, Y. H., Paik, H. J., RyangWee, W., KumKim, M., & Kim, D. H. (2016).

Potential importance of ozone in the association between outdoor air pollution and dry eye disease in South Korea. *JAMA Ophthalmology*, *134*(5), 503–510. https://doi.org/10.1001/jamaophthalmol.2016.0139
IAIA. (1999). Principles of Environmental Impact Assessment Best Practice. *International Association for Impact Assessment*, *79*, 1–4. https://doi.org/10.1016/j.eiar.2019.106289
Ibarra, D., Ramírez-Mendoza, R., & López, E. (2017). Noise emission from alternative fuel vehicles: Study case. *Applied Acoustics*, *118*, 58–65. https://doi.org/10.1016/j.apacoust.2016.11.010
IEA. (2019). *Global EV Outlook 2019*. *International Energy Agency*. Retrieved from www.iea.org/publications/reports/globalevoutlook2019/
IHME. (2020). *Health data-country profile-Vietnam*.
Int Panis, L., de Geus, B., Vandenbulcke, G., Willems, H., Degraeuwe, B., Bleux, N., … Meeusen, R. (2010). Exposure to particulate matter in traffic: A comparison of cyclists and car passengers. *Atmospheric Environment*, *44*(19), 2263–2270. https://doi.org/10.1016/j.atmosenv.2010.04.028
IPCC. (2012). *National systems for managing the risks from climate extremes and disasters*. *A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change* (Vol. 9781107025). Cambridge University Press. https://doi.org/10.1017/CBO9781139177245.009
IPCC. (2014). *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. *Cambridge University Press*.
ITF. (2019a). Improving Transport Planning and Investment Through the Use of Accessibility Indicators Case-Specific Policy Analysis. *International Transport Forum Policy Papers*, *66*. Retrieved from www.itf-oecd.org
ITF. (2019b). *ITF Transport Outlook 2019 Summary*. https://doi.org/10.1787/9789282108000-en
ITF. (2019c). *Road Safety Annual Report 2019, Germany*. *OECD Publishing*. https://doi.org/10.1787/irtad-2014-en
ITF. (2020). *Road Safety Annual Report 2020*. *International Transport Forum*. Retrieved from https://doi.org/10.1016/j.tmaid.2020.101607%0Ahttps://doi.org/10.1016/j.ijsu.2020.02.034%0Ahttps://onlinelibrary.wiley.com/doi/abs/10.1111/cjag.12228%0Ahttps://doi.org/10.1016/j.ssci.2020.104773%0Ahttps://doi.org/10.1016/j.jinf.2020.04.011%0Ahttps://doi.o
Jacobs, G., Thomas, A. A., & Astrop, A. (2000). *Estimating Global Road Fatalities*. *Transport Research Laboratory*.
Jacobsen, P. L. (2003). Safety in numbers: More walkers and bicyclists, safer walking and bicycling. *Injury Prevention*, *21*(4), 271–275. https://doi.org/10.1136/ip.9.3.205rep
Jaecker-Cueppers, M. (2011). *Noise and its Abatement Module 5c Sustainable Transport: A Sourcebook for Policy-makers in Developing Cities*. *Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH*. Retrieved from http://www.sutp.org/index.php/component/phocadownload/category/50-5c?download=100:5c-noi-en
James, S. L., Abate, D., Abate, K. H., Abay, S. M., Abbafati, C., Abbasi, N., … Murray, C. J. L. (2018). Global, regional, and national incidence, prevalence, and years lived with disability for 354 Diseases and Injuries for 195 countries and territories, 1990-2017: A systematic analysis for the Global Burden of Disease Study 2017. *The Lancet*, 1789–1858. https://doi.org/10.1016/S0140-6736(18)32279-7
Jarjour, S., Jerrett, M., Westerdahl, D., De Nazelle, A., Hanning, C., Daly, L., … Balmes, J. (2013). Cyclist route choice, traffic-related air pollution, and lung function: A scripted

exposure study. *Environmental Health: A Global Access Science Source*, *12*(1), 1–12. https://doi.org/10.1186/1476-069X-12-14
Jeremy, G., & Apparicio, P. (2019). Noise exposure of cyclists in Ho Chi Minh City: A spatio-temporal analysis using non-linear models. *Applied Acoustics*, *148*, 332–343. https://doi.org/10.1016/j.apacoust.2018.12.031
Jiang, W., Boltze, M., Groer, S., & Scheuvens, D. (2017). Impacts of low emission zones in Germany on air pollution levels. *Transportation Research Procedia*, *25*(July 2016), 3370–3382. https://doi.org/10.1016/j.trpro.2017.05.217
Jittrapirom, P., Knoflacher, H., & Mailer, M. (2017). The conundrum of the motorcycle in the mix of sustainable urban transport. *Transportation Research Procedia*, *25*, 4873–4894. https://doi.org/10.1016/j.trpro.2017.05.365
Johansson, B., & Mattsson, L.-G. (1995). *Road pricing: Theory, empirical assessment and policy*. *Transportation Research Part A: Policy and Practice* (Vol. 30). https://doi.org/10.1016/0965-8564(96)82660-7
Jung, J., & Koo, Y. (2018). Analyzing the effects of car sharing services on the reduction of greenhouse gas (GHG) emissions. *Sustainability (Switzerland)*, *10*(2), 1–17. https://doi.org/10.3390/su10020539
Kalaiselvi, R., & Ramachandraiah, A. (2016). Honking noise corrections for traffic noise prediction models in heterogeneous traffic conditions like India. *Applied Acoustics*, *111*, 25–38. https://doi.org/10.1016/j.apacoust.2016.04.003
Karra, S., Malki-Epshtein, L., & Neophytou, M. K. A. (2017). Air flow and pollution in a real, heterogeneous urban street canyon: A field and laboratory study. *Atmospheric Environment*, *165*, 370–384. https://doi.org/10.1016/j.atmosenv.2017.06.035
Kelly, P., Kahlmeier, S., Götschi, T., Orsini, N., Richards, J., Roberts, N., … Foster, C. (2014). Systematic review and meta-analysis of reduction in all-cause mortality from walking and cycling and shape of dose response relationship. *International Journal of Behavioral Nutrition and Physical Activity*, *11*(1). https://doi.org/10.1186/s12966-014-0132-x
Kemm, J. (2013). *Health Impact Assessment: Past Achievement, Current Understanding, and Future Progress*. *Oxford University Press*. https://doi.org/10.1093/acprof:oso/9780199656011.001.0001
Kenardy, J., Heron-Delaney, M., Hendrikz, J., Warren, J., Edmed, S. L., & Brown, E. (2017). Recovery trajectories for long-term health-related quality of life following a road traffic crash injury: Results from the UQ SuPPORT study. *Journal of Affective Disorders*, *214*(February), 8–14. https://doi.org/10.1016/j.jad.2017.02.031
Ketzel, M., Raaschou-Nielsen, O., Hjortebjerg, D., Pedersen, M., Langhoff-Roos, J., Halldorsson, T. I., … Grandström, C. (2017). Gestational diabetes mellitus and exposure to ambient air pollution and road traffic noise: A cohort study. *Environment International*, *108*(March), 253–260. https://doi.org/10.1016/j.envint.2017.09.003
KFH Group. (2009). *Guidelines for the Design and Placement of Transit Stops for the Washington Metropolitan Area Transit Authority*. Retrieved from http://link.springer.com/article/10.1007/s11771-012-1329-2
Khan, A., Mandic, S., & Uddin, R. (2020). Association of active school commuting with physical activity and sedentary behaviour among adolescents: A global perspective from 80 countries. *Journal of Science and Medicine in Sport*. https://doi.org/10.1016/j.jsams.2020.12.002
Khan, J., Ketzel, M., Kakosimos, K., Sørensen, M., & Jensen, S. S. (2018). Road traffic air and noise pollution exposure assessment – A review of tools and techniques. *Science of the Total Environment*, *634*, 661–676. https://doi.org/10.1016/j.scitotenv.2018.03.374
Khordagui, N. (2019). Parking prices and the decision to drive to work: Evidence from California. *Transportation Research Part A: Policy and Practice*, *130*(September), 479–

495. https://doi.org/10.1016/j.tra.2019.09.064
Khreis, H., May, A. D., & Nieuwenhuijsen, M. J. (2017a). Health impacts of urban transport policy measures: A guidance note for practice. *Journal of Transport and Health*, *6*(June), 209–227. https://doi.org/10.1016/j.jth.2017.06.003
Khreis, H., May, A. D., & Nieuwenhuijsen, M. J. (2017b). Health impacts of urban transport policy measures: A guidance note for practice. *Journal of Transport & Health*, *6*(June), 209–227. https://doi.org/10.1016/j.jth.2017.06.003
Khreis, H., Warsow, K. M., Verlinghieri, E., Guzman, A., Pellecuer, L., Ferreira, A., … Nieuwenhuijsen, M. (2016). The health impacts of traffic-related exposures in urban areas: Understanding real effects, underlying driving forces and co-producing future directions. *Journal of Transport and Health*, *3*(3), 249–267. https://doi.org/10.1016/j.jth.2016.07.002
Kim, K. E., Cho, D., & Park, H. J. (2016). Air pollution and skin diseases: Adverse effects of airborne particulate matter on various skin diseases. *Life Sciences*, *152*, 126–134. https://doi.org/10.1016/j.lfs.2016.03.039
Kim Oanh, N. T., Thuy Phuong, M. T., & Permadi, D. A. (2012). Analysis of motorcycle fleet in Hanoi for estimation of air pollution emission and climate mitigation co-benefit of technology implementation. *Atmospheric Environment*, *59*, 438–448. https://doi.org/10.1016/j.atmosenv.2012.04.057
Kleinert, S., & Horton, R. (2016). Urban design: an important future force for health and wellbeing. *The Lancet*, *388*(10062), 2848–2850. https://doi.org/10.1016/S0140-6736(16)31578-1
Knibbs, L. D., Cole-Hunter, T., & Morawska, L. (2011). A review of commuter exposure to ultrafine particles and its health effects. *Atmospheric Environment*, *45*(16), 2611–2622. https://doi.org/10.1016/j.atmosenv.2011.02.065
Koh, W. T. H. (2003). *Congestion control and vehicle ownership restriction: The choice of an optimal quota policy*. *Research Collection School Of Economics* (Vol. 38).
Konbattulwar, V., Velaga, N. R., Jain, S., & Sharmila, R. B. (2016). Development of in-vehicle noise prediction models for Mumbai Metropolitan Region, India. *Journal of Traffic and Transportation Engineering (English Edition)*, *3*(4), 380–387. https://doi.org/10.1016/j.jtte.2016.04.002
Kononov, J., Durso, C., Reeves, D., & Allery, B. (2012). Relationship between traffic density, speed, and safety and its implications for setting variable speed limits on freeways. *Transportation Research Record Journal of the Transportation Research Board*, *1*(2280), 1–9. https://doi.org/10.3141/2280-01
Kragh, J. (2011). *Traffic noise prediction with Nord2000*. *Proceedings of ACOUSTICS 2011*.
Krizek, K. J., & Stonebraker, E. W. (2011). Assessing options to enhance bicycle and transit integration. *Transportation Research Record*, (2217), 162–167. https://doi.org/10.3141/2217-20
Kumar, P., Morawska, L., Birmili, W., Paasonen, P., Hu, M., Kulmala, M., … Britter, R. (2014). Ultrafine particles in cities. *Environment International*, *66*, 1–10. https://doi.org/10.1016/j.envint.2014.01.013
Lachapelle, U., & Pinto, D. G. (2016). Longer or more frequent walks: Examining the relationship between transit use and active transportation in Canada. *Journal of Transport and Health*, *3*(2), 173–180. https://doi.org/10.1016/j.jth.2016.02.005
Lan, T. T. N., Liem, N. Q., & Binh, N. T. T. (2013). Personal exposure to benzene of selected population groups and impact of commuting modes in Ho Chi Minh, Vietnam. *Environmental Pollution*, *175*, 56–63. https://doi.org/10.1016/j.envpol.2012.12.017
Langford, B. C., Cherry, C. R., Bassett, D. R., Fitzhugh, E. C., & Dhakal, N. (2017). Comparing physical activity of pedal-assist electric bikes with walking and conventional bicycles. *Journal of Transport and Health*, *6*(July), 463–473.

https://doi.org/10.1016/j.jth.2017.06.002
Langlois, M., Wasfi, R. A., Ross, N. A., & El-Geneidy, A. M. (2016). Can transit-oriented developments help achieve the recommended weekly level of physical activity? *Journal of Transport and Health*, *3*(2), 181–190. https://doi.org/10.1016/j.jth.2016.02.006
Langrish, J. P., Mills, N. L., Chan, J. K. K., Leseman, D. L. A. C., Aitken, R. J., Fokkens, P. H. B., … Jiang, L. (2009). Beneficial cardiovascular effects of reducing exposure to particulate air pollution with a simple facemask. *Particle and Fibre Toxicology*, *6*, 1–9. https://doi.org/10.1186/1743-8977-6-8
Larouche, R., Saunders, T. J., Faulkner, G. E. J., Colley, R., & Tremblay, M. (2014). Associations between active school transport and physical activity, body composition, and cardiovascular fitness: A systematic review of 68 studies. *Journal of Physical Activity and Health*, *11*(1), 206–227. https://doi.org/10.1123/jpah.2011-0345
Laverty, A. A., Mindell, J. S., Webb, E. A., & Millett, C. (2013). Active travel to work and cardiovascular risk factors in the united kingdom. *American Journal of Preventive Medicine*, *45*(3), 282–288. https://doi.org/10.1016/j.amepre.2013.04.012
Le, L. T. P., & Leung, A. (2018). Associations between urban road-traffic emissions, health risks, and socioeconomic status in Ho Chi Minh City, Vietnam: a cross-sectional study. *The Lancet Planetary Health*, *2*, S5. https://doi.org/10.1016/s2542-5196(18)30090-1
Lee, I. M., Shiroma, E. J., Lobelo, F., Puska, P., Blair, S. N., Katzmarzyk, P. T., … Wells, J. C. (2012). Effect of physical inactivity on major non-communicable diseases worldwide: An analysis of burden of disease and life expectancy. *The Lancet*, *380*(9838), 219–229. https://doi.org/10.1016/S0140-6736(12)61031-9
Legrain, A., Eluru, N., & El-Geneidy, A. M. (2015). Am stressed, must travel: The relationship between mode choice and commuting stress. *Transportation Research Part F: Traffic Psychology and Behaviour*, *34*, 141–151. https://doi.org/10.1016/j.trf.2015.08.001
Lekaviciute, J., Kephalopoulos, S., Stansfeld, S., & Clark, C. (2013). *ENNAH-European Network on Noise and Health Report EUR*. Luxembourg. https://doi.org/10.2788/83694
Lelieveld, J., Evans, J. S., Fnais, M., Giannadaki, D., & Pozzer, A. (2015). The contribution of outdoor air pollution sources to premature mortality on a global scale. *Nature*, *525*(7569), 367–371. https://doi.org/10.1038/nature15371
Lerner, A., Fye, A., Roberts, B., Inman, A., Abraham, D., Anspacher, D., … Randall, E. (2011). *Bus Priority Treatment Guidelines*. *National Capital Region Transportation Planning Board Metropolitan Washington Council of Governments* (Vol. 204). Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/21998481
Leung, A., & Le, T. P. L. (2019). The perception of air pollution exposure from commuting in Ho Chi Minh City, Vietnam.
Li, X., Huang, S., Jiao, A., Yang, X., Yun, J., Wang, Y., … Xiang, H. (2017). Association between ambient fine particulate matter and preterm birth or term low birth weight: An updated systematic review and meta-analysis. *Environmental Pollution*, *227*, 596–605. https://doi.org/10.1016/j.envpol.2017.03.055
Liao, Y., Tsai, H. H., Wang, H. S., Lin, C. P., Wu, M. C., & Chen, J. F. (2016). Travel mode, transportation-related physical activity, and risk of overweight in Taiwanese adults. *Journal of Transport and Health*, *3*(2), 220–225. https://doi.org/10.1016/j.jth.2016.02.012
Lindström, M. (2008). Means of transportation to work and overweight and obesity: A population-based study in southern Sweden. *Preventive Medicine*, *46*(1), 22–28. https://doi.org/10.1016/j.ypmed.2007.07.012
Litman, T. (2014). *Implementing Transport Policies and Programmes toward Realizing "Bali Vision Three Zeros - Zero Congestion, Zero Pollution, and Zero Accidents towards Next Generation Transport Systems in Asia."*

Litman, T. (2016). *When Are Bus Lanes Warranted? Victoria Transportation Policy Institute*. Retrieved from http://www.vtpi.org/blw.pdf
Litman, T. (2018). *Parking Pricing Implementation Guidelines*.
Litman, T. (2019). *Evaluating Accessibility for Transport Planning: Measuring People's Ability to Reach Desired Goods and Activities*. *Victoria Transportation Policy Institute*.
Litman, T. (2020). *Evaluating Accessibility for Transportation Planning: Measuring People's Ability to Reach Desired Goods and Activities*. *Victoria Transport Policy Institute*.
Litman, T. (2021). *A new traffic safety paradigm*.
Liu, B., Ivers, R., Norton, R., Blows, S., & Lo, S. (2007). Helmets for preventing injury in motorcycle riders. *Cochrane Database of Systematic Reviews*, (4). https://doi.org/10.1002/14651858.cd004333.pub2
Liu, Y., Lan, B., Shirai, J., Austin, E., Yang, C., & Seto, E. (2019). Exposures to air pollution and noise from multi-modal commuting in a Chinese city. *International Journal of Environmental Research and Public Health*, *16*(14), 1–16. https://doi.org/10.3390/ijerph16142539
Luengo-Oroz, J., & Reis, S. (2019). Assessment of cyclists' exposure to ultrafine particles along alternative commuting routes in Edinburgh. *Atmospheric Pollution Research*, *10*(4), 1148–1158. https://doi.org/10.1016/j.apr.2019.01.020
Luo, J., Boriboonsomsin, K., & Barth, M. (2018). Reducing pedestrians' inhalation of traffic-related air pollution through route choices: Case study in California suburb. *Journal of Transport and Health*, (June 2017), 0–1. https://doi.org/10.1016/j.jth.2018.06.008
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
Luong, L. T. M., Dang, T. N., Thanh Huong, N. T., Phung, D., Tran, L. K., Van Dung, D., & Thai, P. K. (2020). Particulate air pollution in Ho Chi Minh city and risk of hospital admission for acute lower respiratory infection (ALRI) among young children. *Environmental Pollution*, *257*, 113424. https://doi.org/10.1016/j.envpol.2019.113424
Machado, C. A. S., Hue, N. P. M. de S., Berssaneti, F. T., & Quintanilha, J. A. (2018). An overview of shared mobility. *Sustainability (Switzerland)*, *10*(12), 1–21. https://doi.org/10.3390/su10124342
Madsen, K. A., Cotterman, C., Thompson, H. R., Rissman, Y., Rosen, N. J., & Ritchie, L. D. (2015). Passive commuting and dietary intake in fourth and fifth grade students. *American Journal of Preventive Medicine*, *48*(3), 292–299. https://doi.org/10.1016/j.amepre.2014.09.033
Maghrour Zefreh, M., & Torok, A. (2018). Theoretical Comparison of the Effects of Different Traffic Conditions on Urban Road Traffic Noise. *Journal of Advanced Transportation*, *2018*, 1–11. https://doi.org/10.1155/2018/7949574
Marmett, B., Carvalho, R. B., Dorneles, G. P., Nunes, R. B., & Rhoden, C. R. (2020). Should I stay or should I go: Can air pollution reduce the health benefits of physical exercise? *Medical Hypotheses*, *144*(June), 109993. https://doi.org/10.1016/j.mehy.2020.109993
Marshall, W. E., & Ferenchak, N. N. (2019). Why cities with high bicycling rates are safer for all road users. *Journal of Transport and Health*, *13*(May), 100539. https://doi.org/10.1016/j.jth.2019.03.004
Martin, A., Panter, J., Suhrcke, M., & Ogilvie, D. (2015). Impact of changes in mode of travel to work on changes in body mass index: Evidence from the British Household Panel Survey. *Journal of Epidemiology and Community Health*, *69*(8), 753–761. https://doi.org/10.1136/jech-2014-205211
Martínez-Ruiz, V., Jiménez-Mejías, E., Amezcua-Prieto, C., Olmedo-Requena, R., Luna-Del-Castillo, J. D. D., & Lardelli-Claret, P. (2015). Contribution of exposure, risk of crash

and fatality to explain age- and sex-related differences in traffic-related cyclist mortality rates. *Accident Analysis and Prevention*, *76*, 152–158. https://doi.org/10.1016/j.aap.2015.01.008
McAndrews, C., & Deakin, E. (2018). Public health sector influence in transportation decision-making: The case of health impact assessment. *Case Studies on Transport Policy*. https://doi.org/10.1016/j.cstp.2018.02.002
McCallum, L. C., Ollson, C. A., & Stefanovic, I. L. (2015). Advancing the practice of health impact assessment in Canada: Obstacles and opportunities. *Environmental Impact Assessment Review*, *55*, 98–109. https://doi.org/10.1016/j.eiar.2015.07.007
McCormack, G. R., & Virk, J. S. (2014). Driving towards obesity: A systematized literature review on the association between motor vehicle travel time and distance and weight status in adults. *Preventive Medicine*, *66*, 49–55. https://doi.org/10.1016/j.ypmed.2014.06.002
Mcguckin, N., & Fucci, A. (2018). *Summary of Travel Trends: 2017 National Household Travel Survey*. Retrieved from https://nhts.ornl.gov/.
Meng, X., Ma, Y., Chen, R., Zhou, Z., Chen, B., & Kan, H. (2013). Size-fractionated particle number concentrations and daily mortality in a Chinese City. *Environmental Health Perspectives*, *121*(10), 1174–1178. https://doi.org/10.1289/ehp.1206398
Meszler, D. (2007). *Air Emissions Issues Related to Two- and Three-Wheeled Motor Vehicles*. *International Council on Clean Transportation*.
Metcalfe, O., Higgins, C., & Lavin, T. (2009). *Health Impact Assessment Institute of Public Health in Ireland*. *Īrija*.
Mindell, J., Rutter, H., & Watkins, S. (2011). Urban Transportation and Human Health A2 - Nriagu, J.O. *Encyclopedia of Environmental Health*, 578–589. https://doi.org/http://dx.doi.org/10.1016/B978-0-444-52272-6.00320-2
Mindell, J. S. (2017a). International recognition of the links between transport, health and sustainability. *Journal of Transport and Health*, *6*(August), 5–6. https://doi.org/10.1016/j.jth.2017.08.003
Mindell, J. S. (2017b). Transport and health around the world. *Journal of Transport and Health*, *4*, 1–3. https://doi.org/10.1016/j.jth.2017.04.001
Mindell, J. S., Cohen, J. M., Watkins, S., & Tyler, N. (2011). Synergies between low-carbon and healthy transport policies. *Proceedings of the Institution of Civil Engineers - Transport*, *164*(3), 127–139. https://doi.org/10.1680/tran.2011.164.3.127
Mindell, J. S., & Karlsen, S. (2012). Community severance and health: What do we actually know? *Journal of Urban Health*, *89*(2), 232–246. https://doi.org/10.1007/s11524-011-9637-7
Minh, C. C., Long, N. X., Y, N. C., & Tu, T. T. (2016). Motorcycle ownership and use in hochiminh city.
Mirco, A., & Cocchi, D. (2013). *Measure Evaluation Results BOL 2.1 Integrated PT Fare System*. Retrieved from http://www.civitas.eu/sites/default/files/mimosa_bol_2_1_mrt_pointer-f.pdf%5Cnhttp://www.civitas.eu/content/bol-21-mrt-1225
MOH. (2016). *5-Year Plan for people’s health protection, care and promotion 2016-2020*. *Ministry of Health Vietnam*.
MOH. (2018). *Health Statistics Year Book 2018*. Ministry of Health - Vietnam.
MONRE. (2016). *BÁO CÁO HIỆN TRẠNG MÔI TRƯỜNG QUỐC GIA 2016 CHUYÊN ĐỀ: MÔI TRƯỜNG ĐÔ THỊ*.
Moradi, A., Nazari, S. S. H., & Rahmani, K. (2018). Sleepiness and the risk of road traffic accidents: A systematic review and meta-analysis of previous studies. *Transportation Research Part F: Traffic Psychology and Behaviour*. https://doi.org/10.1016/j.trf.2018.09.013

Morency, C., Trépanier Martin, M., & Demers, M. (2011). Walking to transit: An unexpected source of physical activity. *Transport Policy*, *18*(6), 800–806. https://doi.org/10.1016/j.tranpol.2011.03.010

Morency, P., Gauvin, L., Plante, C., Fournier, M., & Morency, C. (2012). Neighborhood social inequalities in road traffic injuries: The influence of traffic volume and road design. *American Journal of Public Health*, *102*(6), 1112–1119. https://doi.org/10.2105/AJPH.2011.300528

MOT. (2017). *Báo cáo đề án: Tăng cường vận tải hành khách công cộng kết hợp kiểm soát sử dụng phương tiện cá nhân tham gia giao thông nhằm giảm ùn tắc giao thông và ô nhiễm trên địa bàn thành phố HCM*. Ho Chi Minh City.

Mueller, N., Rojas-rueda, D., Basagaña, X., Cirach, M., Cole-hunter, T., Dadvand, P., … Nieuwenhuijsen, M. (2017a). Urban and Transport Planning Related Exposures and Mortality: A Health Impact Accessment for Cities, *125*(1), 89–96.

Mueller, N., Rojas-rueda, D., Basagaña, X., Cirach, M., Cole-hunter, T., Dadvand, P., … Nieuwenhuijsen, M. (2017b). Urban and Transport Planning Related Exposures and Mortality: A Health Impact Assessment for Cities. *Environmental Health Pe*, *125*(1), 89–96. https://doi.org/10.1289/EHP220

Mueller, N., Rojas-Rueda, D., Cole-Hunter, T., de Nazelle, A., Dons, E., Gerike, R., … Nieuwenhuijsen, M. (2015). Health impact assessment of active transportation: A systematic review. *Preventive Medicine*, *76*, 103–114. https://doi.org/10.1016/j.ypmed.2015.04.010

Naci, H., Chisholm, D., & Baker, T. D. (2009). Distribution of road traffic deaths by road user group: A global comparison. *Injury Prevention*, *15*(1), 55–59. https://doi.org/10.1136/ip.2008.018721

NACTO. (2014). *Urban Bikeway Design Guide* (Second Edi). National Association of City Transportation Officials. Retrieved from https://rd.springer.com/content/pdf/10.5822%2F978-1-61091-582-3.pdf%0Ahttp://nacto.org/publication/urban-bikeway-design-guide/

Nam, N. Van. (2013). *Bus Prioritisation in Motorcycle Dependent Cities*. Technische Universität Darmstadt Fachgebiet.

naneos particle solutions gmbh. (2016). *Lung-deposited surface area*. Retrieved from www.naneos.ch

National Academies of Sciences Engineering and Medicine. (2004). *Traveler Response to Transportation System Changes Handbook, Third Edition: Chapter 9, Transit Scheduling and Frequency*. The National Academies Press. https://doi.org/10.17226/23433

National Academies of Sciences Engineering and Medicine. (2007). *Elements Needed to Create High-Ridership Transit Systems*. https://doi.org/10.17226/23175

Neves, A., & Brand, C. (2019). Assessing the potential for carbon emissions savings from replacing short car trips with walking and cycling using a mixed GPS-travel diary approach. *Transportation Research Part A: Policy and Practice*, *123*(August 2018), 130–146. https://doi.org/10.1016/j.tra.2018.08.022

Ngoc, A. M. (2015). *Quality Management for Public Transport in Motorcycle Dependent Cities*. Technische Universität Darmstadt. Retrieved from http://tuprints.ulb.tu-darmstadt.de/5015/1/An_Minh_Ngoc_Quality_Management_for_Public_Transport_in_MDCs.pdf

Nguyen, H., Ivers, R. Q., Jan, S., Martiniuk, A. L. C., Li, Q., & Pham, C. (2013). The economic burden of road traffic injuries: Evidence from a provincial general hospital in Vietnam. *Injury Prevention*, *19*(2), 79–84. https://doi.org/10.1136/injuryprev-2011-040293

Nguyen, T. H., Tang, H. K., Kelly, P., Van Der Ploeg, H. P., & Dibley, M. J. (2010).

Association between physical activity and metabolic syndrome: A cross sectional survey in adolescents in Ho Chi Minh City, Vietnam. *BMC Public Health, 10*. https://doi.org/10.1186/1471-2458-10-141

Nguyen, T. T. Q., Takeuchi, W., & Misra, P. (2020). Technical note: Emission mapping of key sectors in Ho Chi Minh city, Vietnam using satellite derived urban land-use data. *Atmospheric Chemistry and Physics*, (October), 1–37. https://doi.org/10.5194/acp-2020-895

NHTSA. (2017). *Traffic Safety Facts: Speeding*. Retrieved from https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812687

NHTSA. (2019). *Traffic Safety Facts*. *U.S Department of Transportation, National Highway Traffic Safety Administration* (Vol. 076). https://doi.org/http://dx.doi.org/10.1016/j.annemergmed.2013.12.004

Nhung, N. T. T., Schindler, C., Chau, N. Q., Hanh, P. T., Hoang, L. T., Dien, T. M., … Künzli, N. (2020). Exposure to air pollution and risk of hospitalization for cardiovascular diseases amongst Vietnamese adults: Case-crossover study. *Science of the Total Environment*, *703*(1), 134637. https://doi.org/10.1016/j.scitotenv.2019.134637

Nhung, N. T. T., Schindler, C., Dien, T. M., Probst-Hensch, N., Perez, L., & Künzli, N. (2018). Acute effects of ambient air pollution on lower respiratory infections in Hanoi children: An eight-year time series study. *Environment International*, *110*(June 2016), 139–148. https://doi.org/10.1016/j.envint.2017.10.024

Nicholson, L. M., Turner, L., Slater, S. J., Abuzayd, H., Chriqui, J. F., & Chaloupka, F. (2014). Developing a measure of traffic calming associated with elementary school students' active transport. *Transportation Research Part D: Transport and Environment*, *33*, 17–25. https://doi.org/10.1016/j.trd.2014.08.022

Nieuwenhuijsen, M. J. (2016). Urban and transport planning, environmental exposures and health-new concepts, methods and tools to improve health in cities. *Environmental Health: A Global Access Science Source*, *15*(Suppl 1). https://doi.org/10.1186/s12940-016-0108-1

Nieuwenhuijsen, M. J. (2020). Urban and transport planning pathways to carbon neutral, liveable and healthy cities; A review of the current evidence. *Environment International*, (March), 105661. https://doi.org/10.1016/j.envint.2020.105661

Nieuwenhuijsen, M. J., & Haneen, K. (2020). *Advances in Trasnportation and Health-Tools, technologies, policies, and developments*. (M. J. Nieuwenhuijsen & K. Haneen, Eds.). Elsevier.

Nieuwenhuijsen, M. J., Khreis, H., Mueller, N., & Rojas-Rueda, D. (2020). *ADVANCES IN TRANSPORTATION AND HEALTH Tools, Technologies, Policies, and Developments*. (M. J. Nieuwenhuijsen & H. Khreis, Eds.). Elsevier Inc.

Nieuwenhuijsen, M. J., Khreis, H., Verlinghieri, E., Mueller, N., & Rojas-Rueda, D. (2017). Participatory quantitative health impact assessment of urban and transport planning in cities: A review and research needs. *Environment International*, *103*(November), 61–72. https://doi.org/10.1016/j.envint.2017.03.022

Oberdorster, G., Ferin, J., & Lehnert, B. E. (1994). Correlation between particle size, in vivo particle persistence, and lung injury. *Environmental Health Perspectives*, *102*(SUPPL. 5), 173–179. https://doi.org/10.1289/ehp.102-1567252

Oberdörster, G., Oberdörster, E., & Oberdörster, J. (2005). Nanotoxicology: An emerging discipline evolving from studies of ultrafine particles. *Environmental Health Perspectives*, *113*(7), 823–839. https://doi.org/10.1289/ehp.7339

OECD/ITF. (2010). *Reporting on Serious Road Traffic Casualties*. *International Transport Forum*. Retrieved from http://www.internationaltransportforum.org/irtadpublic/pdf/Road-Casualties-Web.pdf

OECD/ITF. (2017). *Real-world Vehicle Emissions*. Retrieved from

https://doi.org/10.1787/70178aa1-en
Office for Cycle Superhighways. (2018). *Cycle Superhighways. Capital Region of Denmark*. Retrieved from www.supercykelstier.dk/english
Öhrström, E., Skånberg, A., Svensson, H., & Gidlöf-Gunnarsson, A. (2006). Effects of road traffic noise and the benefit of access to quietness. *Journal of Sound and Vibration*, *295*(1–2), 40–59. https://doi.org/10.1016/j.jsv.2005.11.034
Oja, P., Vuori, I., & Paronen, O. (1998). Daily walking and cycling to work: Their utility as health-enhancing physical activity. *Patient Education and Counseling*, *33*(SUPPL.1), 87–94. https://doi.org/10.1016/S0738-3991(98)00013-5
Okokon, E. O., Yli-Tuomi, T., Turunen, A. W., Taimisto, P., Pennanen, A., Vouitsis, I., … Lanki, T. (2017a). Particulates and noise exposure during bicycle, bus and car commuting: A study in three European cities. *Environmental Research*, *154*(November 2016), 181–189. https://doi.org/10.1016/j.envres.2016.12.012
Okokon, E. O., Yli-Tuomi, T., Turunen, A. W., Taimisto, P., Pennanen, A., Vouitsis, I., … Lanki, T. (2017b). Particulates and noise exposure during bicycle, bus and car commuting: A study in three European cities. *Environmental Research*, *154*(January), 181–189. https://doi.org/10.1016/j.envres.2016.12.012
Okokon, E. O., Yli-Tuomi, T., Turunen, A. W., Tiittanen, P., Juutilainen, J., & Lanki, T. (2018). Traffic noise, noise annoyance and psychotropic medication use. *Environment International*, *119*(November 2017), 287–294. https://doi.org/10.1016/j.envint.2018.06.034
Orban, E., McDonald, K., Sutcliffe, R., Hoffmann, B., Fuks, K. B., Dragano, N., … Moebus, S. (2016). Residential road traffic noise and high depressive symptoms after five years of follow-up: Results from the heinz nixdorf recall study. *Environmental Health Perspectives*, *124*(5), 578–585. https://doi.org/10.1289/ehp.1409400
Østergaard, L., Kolle, E., Steene-Johannessen, J., Anderssen, S. A., & Andersen, L. B. (2013). Cross sectional analysis of the association between mode of school transportation and physical fitness in children and adolescents. *International Journal of Behavioral Nutrition and Physical Activity*, *10*, 1–7. https://doi.org/10.1186/1479-5868-10-91
Otero, I., Nieuwenhuijsen, M. J., & Rojas-Rueda, D. (2018). Health impacts of bike sharing systems in Europe. *Environment International*, *115*(April), 387–394. https://doi.org/10.1016/j.envint.2018.04.014
Ow, L. F., & Ghosh, S. (2017). Urban cities and road traffic noise: Reduction through vegetation. *Applied Acoustics*, *120*, 15–20. https://doi.org/10.1016/j.apacoust.2017.01.007
Pacitto, A., Amato, F., Salmatonidis, A., Moreno, T., Alastuey, A., Reche, C., … Querol, X. (2019). Effectiveness of commercial face masks to reduce personal PM exposure. *Science of the Total Environment*, *650*, 1582–1590. https://doi.org/10.1016/j.scitotenv.2018.09.109
PAHO. (2013). *Health, Environment and Sustainable Development: The Future We Want*. *Pan American Health Organization*.
Palmieri, L., Andrianou, X., Barbariol, P., Bella, A., Bellino, S., Benelli, E., … Brusaferro, S. (2020). *Characteristics of SARS-CoV-2 patients dying in Italy Report based on available data on April 23 th , 2020 (Istituto Superiore di Sanità)*.
Panter, J., Heinen, E., Mackett, R., & Ogilvie, D. (2016). Impact of New Transport Infrastructure on Walking, Cycling, and Physical Activity. *American Journal of Preventive Medicine*, *50*(2), e45–e53. https://doi.org/10.1016/j.amepre.2015.09.021
Papadakaki, M., Ferraro, O. E., Orsi, C., Otte, D., Tzamalouka, G., von-der-Geest, M., … Chliaoutakis, J. (2017). Psychological distress and physical disability in patients sustaining severe injuries in road traffic crashes: Results from a one-year cohort study from three European countries. *Injury*, *48*(2), 297–306.

https://doi.org/10.1016/j.injury.2016.11.011
Patterson, R., Panter, J., Vamos, E. P., Cummins, S., Millett, C., & Laverty, A. A. (2020). Associations between commute mode and cardiovascular disease, cancer, and all-cause mortality, and cancer incidence, using linked Census data over 25 years in England and Wales: a cohort study. *The Lancet Planetary Health*, *4*(5), e186–e194. https://doi.org/10.1016/S2542-5196(20)30079-6
Peden, M., Scurfield, R., Sleet, D., Mohan, D., Hyder, A. A., Jarawan, E., & Mathers, C. (2004). World report on road traffic injury prevention. *World Health Organization*, 244. https://doi.org/10.1016/j.puhe.2005.09.003
Peeters, B., & Blokland, G. v. (2007). *Improved Methods for the Assessment of the Generic Impact of Noise in the Environment The Noise Emission Model For European Road Traffic*. Retrieved from www.imagine-project.org
Pérez, K., Olabarria, M., Rojas-Rueda, D., Santamariña-Rubio, E., Borrell, C., & Nieuwenhuijsen, M. (2017). The health and economic benefits of active transport policies in Barcelona. *Journal of Transport and Health*, *4*, 316–324. https://doi.org/10.1016/j.jth.2017.01.001
Petridou, E., & Moustaki, M. (2001). Human factors in the causation of road traffic crashes. *European Journal of Epidemiology*, *16*(9), 819–826. https://doi.org/10.1023/A:1007649804201
Pham, N. K., Sepehri, A., Le, T. M., & Tran, V. T. (2020). Correlates of body mass index among primary school children in Ho Chi Minh City, Vietnam. *Public Health*, *181*, 65–72. https://doi.org/10.1016/j.puhe.2019.12.007
Pham, N. M., & Eggleston, K. (2016). Prevalence and determinants of diabetes and prediabetes among Vietnamese adults. *Diabetes Research and Clinical Practice*, *113*, 116–124. https://doi.org/10.1016/j.diabres.2015.12.009
Pham, T., Riley, E., & Harris, P. (2018). Inclusion of Health in Environmental Impact Assessment of Major Transport Infrastructure Projects in Vietnam. *International Journal of Health Policy and Management*, *7*(9), 828–835. https://doi.org/10.15171/ijhpm.2018.36
Pham, T. T. P., Matsushita, Y., Dinh, L. T. K., Do, T. Van, Nguyen, T. T. T., Bui, A. T., … Kajio, H. (2019). Prevalence and associated factors of overweight and obesity among schoolchildren in Hanoi, Vietnam. *BMC Public Health*, *19*(1), 1–9. https://doi.org/10.1186/s12889-019-7823-9
Phan, H. Y. T., Yano, T., Phan, H. A. T., Nishimura, T., Sato, T., & Hashimoto, Y. (2010). Community responses to road traffic noise in Hanoi and Ho Chi Minh City. *Applied Acoustics*, *71*(2), 107–114. https://doi.org/10.1016/j.apacoust.2009.08.004
Phan, H. Y. T., Yano, T., Sato, T., & Nishimura, T. (2010). Characteristics of road traffic noise in Hanoi and Ho Chi Minh City, Vietnam. *Applied Acoustics*, *71*(5), 479–485. https://doi.org/10.1016/j.apacoust.2009.11.008
Phung, D., Thi, T., Nhut, H., Luong, L. M. T., Morawska, L., Chu, C., … Thai, P. K. (2016). Science of the Total Environment 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
Plankermann, K. (2013). *Human Factors as Causes for Road Traffic Accidents in the Sultanate of Oman under Consideration of Road Construction Designs*.
Posada, F. (2009). *CNG Bus Emissions Roadmap : from Euro III to Euro VI. The International Council on Clean Transportation*.
Posada, F., Wagner, D. V., Bansal, G., & Fernandez, R. (2015). *Survey of best practices in reducing emissions through vehicle replacement programs*. *The International Council on Clean Transportation*. Retrieved from http://www.indiaenvironmentportal.org.in/files/file/ICCT_HDVreplacement_bestpractice

.pdf
PRESTO Project. Give Cycling a Push - Implementation fact sheet - Trafic light intersections (2010).
PRESTO Project. (2010b). *Give Cycling a Push Implementation Fact Sheet-Cycle Lanes*.
PRESTO Project. (2010c). *PRESTO Cycling Policy Guide - Cycling Infrastructure*. Retrieved from https://ec.europa.eu/energy/intelligent/projects/sites/iee-projects/files/projects/documents/presto_policy_guide_cycling_infrastructure_en.pdf
PRESTO Project. (2012). *Cycle Tracks Implementation Fact Sheet*.
Prüss-Ustün, A., Wolf, J., Corvalán, C., Bos, R., & Neira, M. (2016). *Preventing disease through healthy environments: A global assessment of the environmental burden of disease*. *World Health Organisation* (Vol. 259). https://doi.org/10.1016/j.toxlet.2016.07.028
PSO.HCMC. (2020). *Thực trạng dân số thành phố Hồ Chí Minh*.
Pucher, J., & Buehler, R. (2008). Making cycling irresistible: Lessons from the Netherlands, Denmark and Germany. *Transport Reviews*, *28*(4), 495–528. https://doi.org/10.1080/01441640701806612
Pucher, J., Dill, J., & Handy, S. (2010). Infrastructure, programs, and policies to increase bicycling: An international review. *Preventive Medicine*, *50*(SUPPL.), S106–S125. https://doi.org/10.1016/j.ypmed.2009.07.028
Qiu, Z., Wang, W., Zheng, J., & Lv, H. (2019). Exposure assessment of cyclists to UFP and PM on urban routes in Xi’an, China. *Environmental Pollution*, *250*, 241–250. https://doi.org/10.1016/j.envpol.2019.03.129
Quigley, R., den Broeder, L., Furu, P., Bond, A., Cave, B., & Bos, R. (2006). Health Impact Assessment International Best Practice Principles. *Special Publication Series 5 USA: International Association for Impact Assessment*, (5), 1–4.
Quigley, R. J., & Taylor, L. C. (2004). Evaluating health impact assessment. *Public Health*, *118*(8), 544–552. https://doi.org/10.1016/j.puhe.2003.10.012
Ragettli, M. S., Corradi, E., Braun-Fahrländer, C., Schindler, C., de Nazelle, A., Jerrett, M., … Phuleria, H. C. (2013). Commuter exposure to ultrafine particles in different urban locations, transportation modes and routes. *Atmospheric Environment*, *77*, 376–384. https://doi.org/10.1016/j.atmosenv.2013.05.003
Raja, K. S., Crane, L. A., & Dellavalle, R. P. (2009). The benefits and risks of ultraviolet (UV) tanning and its alternatives: the role of prudent sun exposure. *NIH Public Access*, *23*(1), 1–7. https://doi.org/10.1038/jid.2014.371
Raser, E., Gaupp-Berghausen, M., Dons, E., Anaya-Boig, E., Avila-Palencia, I., Brand, C., … Gerike, R. (2018). European cyclists’ travel behavior: Differences and similarities between seven European (PASTA) cities. *Journal of Transport and Health*, *9*(October 2017), 244–252. https://doi.org/10.1016/j.jth.2018.02.006
Rhodus, J., Fulk, F., Autrey, B., O’Shea, S., Roth, A., Wrnham, A., & Harris, C. (2013). *A Review of Health Impact Assessments in the U.S.: Current State-of-Science, Best Practices, and Areas for Improvement*. *United States Environmental Protection Agency*. Retrieved from http://www.epa.gov/research/healthscience/docs/review-hia.pdf%5Cnpapers2://publication/uuid/1F470629-8846-4EED-8623-FD9D35B45C7D
Rissanen, R., Berg, H. Y., & Hasselberg, M. (2017). Quality of life following road traffic injury: A systematic literature review. *Accident Analysis and Prevention*, *108*(March), 308–320. https://doi.org/10.1016/j.aap.2017.09.013
Rodríguez, R. A., Virguez, E. A., Rodríguez, P. A., & Behrentz, E. (2016). Influence of driving patterns on vehicle emissions: A case study for Latin American cities. *Transportation Research Part D: Transport and Environment*, *43*, 192–206. https://doi.org/10.1016/j.trd.2015.12.008
Rolison, J. J., Regev, S., Moutari, S., & Feeney, A. (2018). What are the factors that

contribute to road accidents? An assessment of law enforcement views, ordinary drivers' opinions, and road accident records. *Accident Analysis and Prevention, 115*(February), 11–24. https://doi.org/10.1016/j.aap.2018.02.025

Roswall, N., Ammitzbøll, G., Christensen, J. S., Raaschou-Nielsen, O., Jensen, S. S., Tjønneland, A., & Sørensen, M. (2017). Residential exposure to traffic noise and leisure-time sports – A population-based study. *International Journal of Hygiene and Environmental Health*, *220*(6), 1006–1013. https://doi.org/10.1016/j.ijheh.2017.05.010

Rudolf, P. (2004). *Land Use Planning and Urban Transport*. *Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH*. Retrieved from http://www.sutp.org/en-dn-th2

Runkel, M., Mahler, A., Beermann, A.-C., & Hittmeyer, A. (2018). *Fair & low carbon vehicle taxation in Europe, a comparison of CO2-based car taxation in EU-28, Norway and Switzerland*. Berlin. Retrieved from www.foes.de

Saelens, B. E., Moudon, A. V., Kang, B., Hurvitz, P. M., & Zhou, C. (2014). Relation between higher physical activity and public transit use. *American Journal of Public Health*, *104*(5), 854–859. https://doi.org/10.2105/AJPH.2013.301696

Sahlqvist, S., Song, Y., & Ogilvie, D. (2012). Is active travel associated with greater physical activity? The contribution of commuting and non-commuting active travel to total physical activity in adults. *Preventive Medicine*, *55*(3), 206–211. https://doi.org/10.1016/j.ypmed.2012.06.028

Sallis, J. F. (2016). New evidence for the role of transportation in health. *The Lancet Public Health*, *1*(2), e38–e39. https://doi.org/10.1016/s2468-2667(16)30008-1

Sallis, J. F., Bull, F., Burdett, R., Frank, L. D., Griffiths, P., Giles-Corti, B., & Stevenson, M. (2016a). Use of science to guide city planning policy and practice: how to achieve healthy and sustainable future cities. *The Lancet*, *388*(10062), 2936–2947. https://doi.org/10.1016/S0140-6736(16)30068-X

Sallis, J. F., Bull, F., Burdett, R., Frank, L. D., Griffiths, P., Giles-Corti, B., & Stevenson, M. (2016b). Use of science to guide city planning policy and practice: how to achieve healthy and sustainable future cities. *The Lancet*, *388*(10062), 2936–2947. https://doi.org/10.1016/S0140-6736(16)30068-X

Santacreu, A. (2018a). *Cycling Safety - Summary and Conclusions*. Paris. Retrieved from www.itf-oecd.org

Santacreu, A. (2018b). *Safer City Streets Global Benchmarking for Urban Road Safety*. *International Transport Forum Working Document, OECD Publishing*. Paris.

Scheepers, C. E., Wendel-Vos, G. C. W., den Broeder, J. M., van Kempen, E. E. M. M., van Wesemael, P. J. V, & Schuit, A. J. (2014). Shifting from car to active transport: A systematic review of the effectiveness of interventions. *Transportation Research Part A: Policy and Practice*, *70*, 264–280. https://doi.org/10.1016/j.tra.2014.10.015

Schepers, J. P., Fishman, E., Den Hertog, P., Wolt, K. K., & Schwab, A. L. (2014). The safety of electrically assisted bicycles compared to classic bicycles. *Accident Analysis and Prevention*, *73*, 174–180. https://doi.org/10.1016/j.aap.2014.09.010

Schneider, R. J. (2013). Theory of routine mode choice decisions: An operational framework to increase sustainable transportation. *Transport Policy*, *25*, 128–137. https://doi.org/10.1016/j.tranpol.2012.10.007

Schoeters, A., Wijnen, W., Carnis, L., & Weijermars, W. (2018). *Costs related to serious road injuries, deliverable 7.3 of teh H2020 project Safety Cube*.

Scholes, S., Wardlaw, M., Anciaes, P., Heydecker, B., & Mindell, J. S. (2018). Fatality rates associated with driving and cycling for all road users in Great Britain 2005–2013. *Journal of Transport and Health*, *8*(September 2017), 321–333. https://doi.org/10.1016/j.jth.2017.11.143

Schraufnagel, D. E. (2020). The health effects of ultrafine particles. *Experimental and*

Molecular Medicine, *52*(3), 311–317. https://doi.org/10.1038/s12276-020-0403-3
Schraufnagel, D. E., Balmes, J. R., Cowl, C. T., De Matteis, S., Jung, S.-H., Mortimer, K., … Wuebbles, D. J. (2019a). Air Pollution and Noncommunicable Diseases. *CHEST*, *155*(2), 409–416. https://doi.org/10.1016/j.chest.2018.10.042
Schraufnagel, D. E., Balmes, J. R., Cowl, C. T., De Matteis, S., Jung, S. H., Mortimer, K., … Wuebbles, D. J. (2019b). Air Pollution and Noncommunicable Diseases: A Review by the Forum of International Respiratory Societies' Environmental Committee, Part 1: The Damaging Effects of Air Pollution. *CHEST*, *155*(2), 409–416. https://doi.org/10.1016/j.chest.2018.10.042
Sener, I. N., Lee, R. J., & Elgart, Z. (2016). Potential health implications and health cost reductions of transit-induced physical activity. *Journal of Transport and Health*, *3*(2), 133–140. https://doi.org/10.1016/j.jth.2016.02.002
Sengoelge, M., Leithaus, M., Braubach, M., & Laflamme, L. (2019). Are there changes in inequalities in injuries? A review of evidence in the WHO european region. *International Journal of Environmental Research and Public Health*, *16*(4). https://doi.org/10.3390/ijerph16040653
Setyawan, A., Kusdiantoro, I., & Syafi'i. (2015). The effect of pavement condition on vehicle speeds and motor vehicles emissions. *Procedia Engineering*, *125*, 424–430. https://doi.org/10.1016/j.proeng.2015.11.111
Shah, P. S., & Balkhair, T. (2011). Air pollution and birth outcomes: A systematic review. *Environment International*, *37*(2), 498–516. https://doi.org/10.1016/j.envint.2010.10.009
Shaheen, S., Chan, N., Bansal, A., & Cohen, A. (2015). Shared Mobility: Definitions, Industry Developments, and Early Understanding. *Transportation Sustainability Research Center (TSRC)*, 30. Retrieved from http://innovativemobility.org/wp-content/uploads/2015/11/SharedMobility_WhitePaper_FINAL.pdf
Shaheen, S., Cohen, A., & Zohdy, I. (2016). *Shared Mobility: Current Practices and Guiding Principles*. *U.S. Department of Transport*.
Shaw, C., Keall, M., & Guiney, H. (2017). What modes of transport are associated with higher levels of physical activity? Cross-sectional study of New Zealand adults. *Journal of Transport and Health*, *7*(May), 125–133. https://doi.org/10.1016/j.jth.2017.09.010
Shi, J., Lin, Z., Chen, R., Wang, C., Yang, C., Cai, J., … Kan, H. (2017). Cardiovascular benefits of wearing particulate-filtering respirators: A randomized crossover trial. *Environmental Health Perspectives*, *125*(2), 175–180. https://doi.org/10.1289/EHP73
Short, J. (1999). Transport Accessibility. *Japan Railway & Transport Review*, (June), 4–8.
Sikka, N., Vila, C., Stratton, M., Ghassemi, M., & Pourmand, A. (2019). Sharing the sidewalk: A case of E-scooter related pedestrian injury. *American Journal of Emergency Medicine*, *37*(9), 1807.e5-1807.e7. https://doi.org/10.1016/j.ajem.2019.06.017
Siman-Tov, M., Radomislensky, I., Peleg, K., Bahouth, H., Becker, A., Jeroukhimov, I., … Weiss, M. (2018). A look at electric bike casualties: Do they differ from the mechanical bicycle? *Journal of Transport and Health*, *11*(October), 176–182. https://doi.org/10.1016/j.jth.2018.10.013
Simonnet, A., Chetboun, M., Poissy, J., Raverdy, V., Noulette, J., Duhamel, A., … Verkindt, H. (2020). High Prevalence of Obesity in Severe Acute Respiratory Syndrome Coronavirus-2 (SARS-CoV-2) Requiring Invasive Mechanical Ventilation. *Obesity*, *28*(7), 1195–1199. https://doi.org/10.1002/oby.22831
Singh, T., Biggs, T., Crossley, E., Faoury, M., Mahmood, A., Salamat, A., … Brown, P. (2020). Noise Exposure on the London Underground, an Observational Study over a Decade. *Laryngoscope*, (February). https://doi.org/10.1002/lary.28547
Sivak, M., & Schoettle, B. (2012). Eco-driving: Strategic, tactical, and operational decisions of the driver that influence vehicle fuel economy. *Transport Policy*, *22*, 96–99. https://doi.org/10.1016/j.tranpol.2012.05.010

Śliwińska-Kowalska, M., & Zaborowski, K. (2017). WHO environmental noise guidelines for the European region: A systematic review on environmental noise and permanent hearing loss and tinnitus. *International Journal of Environmental Research and Public Health*, *14*(10). https://doi.org/10.3390/ijerph14101139

Smart, M. J. (2018). Walkability, transit, and body mass index: A panel approach. *Journal of Transport & Health*, (August 2017), 0–1. https://doi.org/10.1016/j.jth.2017.12.012

Smith, H. R., & Hemily, Brendon, Ivanovic, Miomir, Fleming, G. (2005). *Transit Signal Priority: A Planning and Implementation Handbook*. *Transportation Research* (Vol. 4).

Smith, K. R., Woodward, A., Campbell-Lendrum, D., Chadee, D. D., Honda, Y., Liu, Q., … Rocklov, J. (2014). Human health: Impacts, adaptation, and co-benefits. In *Cambridge University Press* (pp. 709–754). Cambridge, United Kingdom and New York. https://doi.org/10.1017/CBO9781107415379.016

Stevenson, M., Thompson, J., de Sá, T. H., Ewing, R., Mohan, D., McClure, R., … Woodcock, J. (2016a). Land use, transport, and population health: estimating the health benefits of compact cities. *The Lancet*, *388*(10062), 2925–2935. https://doi.org/10.1016/S0140-6736(16)30067-8

Stevenson, M., Thompson, J., de Sá, T. H., Ewing, R., Mohan, D., McClure, R., … Woodcock, J. (2016b). Urban design, transport, and health 2-Land use, transport, and population health: estimating the health benefits of compact cities. *The Lancet*, *388*(10062), 2925–2935. https://doi.org/10.1016/S0140-6736(16)30067-8

Stieb, D. M., Chen, L., Eshoul, M., & Judek, S. (2012). Ambient air pollution, birth weight and preterm birth: A systematic review and meta-analysis. *Environmental Research*, *117*, 100–111. https://doi.org/10.1016/j.envres.2012.05.007

Strak, M., Boogaard, H., Meliefste, K., Oldenwening, M., Zuurbier, M., Brunekreef, B., & Hoek, G. (2010). Respiratory health effects of ultrafine and fine particle exposure in cyclists. *Occupational and Environmental Medicine*, *67*(2), 118–124. https://doi.org/10.1136/oem.2009.046847

Sugiyama, T., Ding, D., & Owen, N. (2013a). Commuting by car: Weight gain among physically active adults. *American Journal of Preventive Medicine, 44*(2), 169–173. https://doi.org/10.1016/j.amepre.2012.09.063

Sugiyama, T., Ding, D., & Owen, N. (2013b). Commuting by car: Weight gain among physically active adults. *American Journal of Preventive Medicine, 44*(2), 169–173. https://doi.org/10.1016/j.amepre.2012.09.063

Sugiyama, T., Wijndaele, K., Koohsari, M. J., Tanamas, S. K., Dunstan, D. W., & Owen, N. (2016). Adverse associations of car time with markers of cardio-metabolic risk. *Preventive Medicine*, *83*, 26–30. https://doi.org/10.1016/j.ypmed.2015.11.029

Sustrans. (2014). *Cycle Streets - Technical information note No. 32*.

SUTP. (2010). *Fact Sheet H-02 – cycling Facilities on the Road Overview*.

SUTP. Fact Sheet H-04-Intersecstion (2014).

Tainio, M., de Nazelle, A. J., Götschi, T., Kahlmeier, S., Rojas-Rueda, D., Nieuwenhuijsen, M. J., … Woodcock, J. (2016). Can air pollution negate the health benefits of cycling and walking? *Preventive Medicine*, *87*, 233–236. https://doi.org/10.1016/j.ypmed.2016.02.002

Tajalli, M., & Hajbabaie, A. (2017). On the relationships between commuting mode choice and public health. *Journal of Transport and Health*, *4*, 267–277. https://doi.org/10.1016/j.jth.2016.12.007

Targino, A. C., Rodrigues, M. V. C., Krecl, P., Cipoli, Y. A., & Ribeiro, J. P. M. (2018). Commuter exposure to black carbon particles on diesel buses, on bicycles and on foot: a case study in a Brazilian city. *Environmental Science and Pollution Research*, *25*(2), 1132–1146. https://doi.org/10.1007/s11356-017-0517-x

Taylor, I., & Hiblin, B. (2017). *Typical Costs of Cycling Interventions: Interim analysis of*

Cycle City Ambition schemes. Retrieved from http://www.transportforqualityoflife.com
te Velde, S. J., Haraldsen, E., Vik, F. N., De Bourdeaudhuij, I., Jan, N., Kovacs, E., … Bere, E. (2017). Associations of commuting to school and work with demographic variables and with weight status in eight European countries: The ENERGY-cross sectional study. *Preventive Medicine*, *99*, 305–312. https://doi.org/10.1016/j.ypmed.2017.03.005
Thaker, P., & Gokhale, S. (2015). The impact of traffic-flow patterns on air quality in urban street canyons. *Environmental Pollution*, *208*, 161–169. https://doi.org/10.1016/j.envpol.2015.09.004
Thanh, T. T. M. (2017). *Parking Management Strategies for Asian Developing Countries*.
The U.S. Department of Health and Human Services. (2008). *Physical Activity Guidelines for Americans*. *The U.S. Department of Health and Human Services*.
The U.S. Department of Health and Human Services. (2018). *Physical Activity Guidelines for Americans*. Washington, DC.
Thomas, P., Chambers-Smith, D., Morris, A., Yannis, G., Evgenikos, P., Duchamp, G., … Martensen, H. (2009). *Building the European Road Safety Observatory*.
Thompson, J., Stevenson, M., Wijnands, J. S., Nice, K. A., Aschwanden, G. D., Silver, J., … Morrison, C. N. (2020). A global analysis of urban design types and road transport injury: an image processing study. *The Lancet Planetary Health*, *4*(1), e32–e42. https://doi.org/10.1016/S2542-5196(19)30263-3
Thomson, R., Fagerlind, H., Lannér, G., Dupré, G., Bisson, O., García, J. M., & López, F. (2005). *European Best Practice for Roadside Design: Guidelines for Roadside Infrastructure on New and Existing Roads*. *Chalmers University of Technology*. Retrieved from http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:European+Best+Practice+for+Roadside+Design:+Guidelines+for+Roadside+Infrastructure+on+New+and+Existing+Roads#0%5Cnhttp://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Roadside+Infrastr
Thu, N. T. A., Hang, T. V. D., & Blume, L. (2019). *Air Quality Report 2018*. *Green Innovation and Development Center (GreenID)* (Vol. 234).
Timmers, V. R. J. H., & Achten, P. A. J. (2016). Non-exhaust PM emissions from electric vehicles. *Atmospheric Environment*, *134*, 10–17. https://doi.org/10.1016/j.atmosenv.2016.03.017
To, Q. G., Gallegos, D., Do, D. V., Tran, H. T. M., To, K. G., Wharton, L., & Trost, S. G. (2018). The level and pattern of physical activity among fifth-grade students in Ho Chi Minh City, Vietnam. *Public Health*, *160*, 18–25. https://doi.org/10.1016/j.puhe.2018.03.021
Trang, N. H. H. D., Hong, T. K., & Dibley, M. J. (2012). Active commuting to school among adolescents in Ho Chi Minh City, Vietnam: Change and predictors in a longitudinal study, 2004 to 2009. *American Journal of Preventive Medicine*, *42*(2), 120–128. https://doi.org/10.1016/j.amepre.2011.10.006
Transport for London. (2016). Chapter 8 Cycle Parking. In *London Cycling Design Standards* (Vol. 8). Retrieved from http://content.tfl.gov.uk/lcds-chapter8-cycleparking.pdf
TRB. (1996). *TCRP Report 19: Guidelines for the Location and Design of Bus Stops*.
TRB. (1999). *TCRP Report 46: The Role of Transit Amenities and Vehicle Characteristics in Building Transit Ridership - Amenities for Transit Handbook and the Transit Game Design*. *TCRP Report 46*. Retrieved from http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_46-a.pdf
TRB. (2004). Traveler Response to Transportation System Changes Handbook, Third Edition: Chapter 10, Bus Routing and Coverage. In *Traveler Response to Transportation System Changes Handbook, Third Edition*. Transportation Research Board. https://doi.org/10.17226/23330

Trinh, O. T. H., Nguyen, N. D., Dibley, M. J., Phongsavan, P., & Bauman, A. E. (2008). The prevalence and correlates of physical inactivity among adults in Ho Chi Minh City. *BMC Public Health*, *8*, 1–11. https://doi.org/10.1186/1471-2458-8-204

Truong, L. T., Sarvi, M., & Currie, G. (2016). An investigation of multiplier effects generated by implementing queue jump lanes at multiple intersections. *Journal of Advanced Transportation*, *50*(8), 1699–1715. https://doi.org/10.1002/atr.1424

Tsuda, A., Henry, F. S., & Butler, J. P. (2013). Particle transport and deposition: Basic physics of particle kinetics. *Comprehensive Physiology*, *3*(4), 1437–1471. https://doi.org/10.1002/cphy.c100085

Tuan, V. A., & Son, D. T. (2015). Accessibility to Public Transport Systems in Developing Countries - An Empirical Study in Ho Chi Minh City, Vietnam. *Journal of the Eastern Asia Society for Transportation Studies*, *11*(0), 1240–1258.

Turrell, G., Hewitt, B. A., Rachele, J. N., Giles-Corti, B., & Brown, W. J. (2017). Prospective trends in body mass index by main transport mode, 2007-2013. *Journal of Transport and Health*, (March), 0–1. https://doi.org/10.1016/j.jth.2017.12.004

U.S Environmental Protection Agency. (2019). *U.S. Transportation Sector Greenhouse Gas Emissions, 1990-2017*. Retrieved from https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100WUHR.pdf

UBA. (2018). *Air Quality 2017 Preliminary Evaluation*.

UN. (1992). *Report of the United Nations Conference on Environment and Development*. *Rio de Janeiro* (Vol. l). Rio de Janeiro. Retrieved from http://legal.icsf.net/icsflegal/uploads/pdf/instruments/rio0201.pdf

UN. (2015). *United nations general assembly-Transforming our world: The 2030 Agenda for Sustainable Development*. *United Nations* (Vol. 25). https://doi.org/10.1163/157180910X12665776638740

UN. (2017). *World Population Prospects*. New York.

UN. (2018). *World Urbanization Prospects: The 2018 Revision*.

United Nations. (2013). *The future we want, Resolutions Adopted by the General Assembly on 27 July 2012, 123rd plenary meeting*. *United Nations* (Vol. 13). https://doi.org/10.1017/s0251107x00015583

United Nations. (2018). *Road Safety Performance Review Viet Nam*. *United Nations Development* (Vol. 1).

United Nations Department of Global Communications. (2020). *Sustainable Development Goals: Guidelines for the Use of the SDG Logo*. Retrieved from https://www.un.org/sustainabledevelopment/news/communications-material/

Urbanczyk, R. (2010). *PRESTO Cycling Policy Guide Promotion*.

US National Research Council. (2011). *Improving Health in the United States: The Role of Health Impact Assessment Committee on Health Impact Assessment*. Retrieved from http://www.iom.edu/~/media/Files/Activity Files/Environment/EnvironmentalHealthRT/2011-Nov-RT/132291.pdf

Van Bui, T., Blizzard, C. L., Luong, K. N., Van Truong, N. Le, Tran, B. Q., Otahal, P., … Gall, S. (2015). Physical activity in Vietnam: Estimates and measurement issues. *PLoS ONE*, *10*(10), 1–14. https://doi.org/10.1371/journal.pone.0140941

Van Do, V., Jancey, J., Pham, N. M., Nguyen, C. T., Van Hoang, M., & Lee, A. H. (2019). Objectively measured physical activity of Vietnamese adults with type 2 diabetes: Opportunities to intervene. *Journal of Preventive Medicine and Public Health*, *52*(2), 101–108. https://doi.org/10.3961/jpmph.18.213

Van Elslande, P., & Fouquet, K. (2007). *Analyzing "human functional failures" in road accidents*. *Traffic Accident Causation in Europe* (Vol. 5). Retrieved from http://www.trace-project.org/publication/archives/trace-wp5-d5-1.pdf

van Kempen, E., Casas, M., Pershagen, G., & Foraster, M. (2018). WHO environmental noise guidelines for the European region: A systematic review on environmental noise and cardiovascular and metabolic effects: A summary. *International Journal of Environmental Research and Public Health*, *15*(2), 1–59. https://doi.org/10.3390/ijerph15020379

Van, N. T. C. (2018). *Strategies for Integrated Transport and Urban Development in Asian Developing Countries*.

Van, N. T. C., Boltze, M., & Tuan, V. A. (2013). Urban Accessibility in Motorcycle Dependent Cities – Case Study in Ho Chi Minh City , Vietnam. *WCTR 13th*, (19 99), 1–19.

Vanderslice, E., Brown, M., Senechal, J., Murase, R., Issacson, K., Hinshaw, M., … Evans, D. (1998). *Portland Pedestrian design guide*. *Pedestrian Transportation Program*.

Velasco, E., & Tan, S. H. (2016). Particles exposure while sitting at bus stops of hot and humid Singapore. *Atmospheric Environment*, *142*, 251–263. https://doi.org/10.1016/j.atmosenv.2016.07.054

VGTRC. (2016). *Nguyên nhân tai nạn giao thông liên quan đến trẻ em và giải pháp cho thành phố hồ chí minh*.

VGTRC. (2018). *Vai trò của xe máy trong hiện tại và tương lai tại việt nam*.

Vlieger, I. De. (1997). Influence of traffic conditions on fuel consumption and emissions - Brussels as a case study. *Transactions on the Built Environment*, *30*, 1–3. https://doi.org/10.1016/j.cattod.2011.03.061

Vu, A. T., & Man Nguyen, D. V. (2018). Analysis of Child-related Road Traffic Accidents in Vietnam. *IOP Conference Series: Earth and Environmental Science*, *143*(1). https://doi.org/10.1088/1755-1315/143/1/012074

Vu, T. (2016). *Road traffic accidents involving children and safety improvement measures in HCMC*.

Vuchic, V. R. (2005). *Urban Transit-Operations, Planning, and Economics*. John wiley & Sons, Inc. Retrieved from https://www.amazon.com/Urban-Transit-Operations-Planning-Economics/dp/0471632651

Waheed, F., Ferguson, G. M., Ollson, C. A., MacLellan, J. I., McCallum, L. C., & Cole, D. C. (2018). Health Impact Assessment of transportation projects, plans and policies: A scoping review. *Environmental Impact Assessment Review*, *71*(March 2017), 17–25. https://doi.org/10.1016/j.eiar.2017.12.002

Walker, L., Tresidder, M., Birk, M., Wiegand, L., & Dill, J. (2009). *Fundamentals of bicycle boulevard planning & design*. *Center for Transportation Studies, Portland State University*. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.468.1184&rep=rep1&type=pdf

Wallas, A., Ekström, S., Bergström, A., Eriksson, C., Gruzieva, O., Sjöström, M., … Pershagen, G. (2019). Traffic noise exposure in relation to adverse birth outcomes and body mass between birth and adolescence. *Environmental Research*, *169*(July 2018), 362–367. https://doi.org/10.1016/j.envres.2018.11.039

Wanner, M., Götschi, T., Martin-Diener, E., Kahlmeier, S., & Martin, B. W. (2012). Active transport, physical activity, and body weight in adults a systematic review. *American Journal of Preventive Medicine*, *42*(5), 493–502. https://doi.org/10.1016/j.amepre.2012.01.030

Wappelhorst, S., Mock, P., & Yang, Z. (2018). *Using Vehicle Taxation Policy to Lower Transport Emissions: An Overview for Passenger Cars in Europe*.

Watkins, K. E., Ferris, B., Borning, A., Rutherford, G. S., & Layton, D. (2011). Where Is My Bus? Impact of mobile real-time information on the perceived and actual wait time of transit riders. *Transportation Research Part A: Policy and Practice*, *45*(8), 839–848. https://doi.org/10.1016/j.tra.2011.06.010

Watts, N., Adger, W. N., & Agnolucci, P. (2015). Health and climate change: Policy responses to protect public health. *Environnement, Risques et Sante, 14*(6), 466–468. https://doi.org/10.1016/S0140-6736(15)60854-6

Webb, E., Netuveli, G., & Millett, C. (2012). Free bus passes, use of public transport and obesity among older people in England. *Journal of Epidemiology and Community Health, 66*(2), 176–180. https://doi.org/10.1136/jech.2011.133165

Weber, T., Scaramuzza, G., & Schmitt, K. U. (2014). Evaluation of e-bike accidents in Switzerland. *Accident Analysis and Prevention, 73*, 47–52. https://doi.org/10.1016/j.aap.2014.07.020

Weijermars, W., Meunier, J.-C., Bos, N., P., C., Hours, M., Johannsen, H., & Barnes, W. (2016). *Physical and psychological consequences of serious road traffic injuries, Deliverable 7.2 of the H2020 Project SafetyCube*. *SWOV institute for road safety research, The Netherlands*. https://doi.org/10.1088/0143-0807/3/2/001

Weijermars, Wendy, Bos, N., Filtness, A., Brown, L., Bauer, R., Dupont, E., … Thomas, P. (2018). Burden of injury of serious road injuries in six EU countries. *Accident Analysis and Prevention, 111*(November 2017), 184–192. https://doi.org/10.1016/j.aap.2017.11.040

Wener, R. E., & Evans, G. W. (2007). A morning stroll: Levels of physical activity in car and mass transit commuting. *Environment and Behavior*, *39*(1), 62–74. https://doi.org/10.1177/0013916506295571

WHO. Declaration of Alma-Ata (1978).

WHO. (1999). *Guidelines for community noise*. *World Health Organization* (Vol. 5(2)(a)).

WHO. (2005a). *Health Effects of Transport-related Air Pollution: Summary for policy-makers*. *World Health Organization*.

WHO. (2005b). *Health effects of transport-related air pollution*. *World Health Organization*. Retrieved from http://www.bvsde.paho.org/bvsacd/cd63/e86650/conten.pdf%5Cnpapers2://publication/uuid/0896BDA1-6025-41A0-A320-420490564B66

WHO. (2009). *Night noise guidelines for Europe*. *World Health Organization* (Vol. 100). https://doi.org/10.1093/ejechocard/jer095

WHO. (2010a). *Global Recommendations on Physical Activity for Health*. *World Health Organization*.

WHO. (2010b). *Why urban health matters*.

WHO. (2011). *Health in the green economy - Health co-benefits of climate change mitigation - Transport sector*. https://doi.org/978 92 4 150291 7

WHO. (2013a). *Global status report on road safety 2013*. Retrieved from http://www.who.int/about/licensing/copyright_form/en/index.html

WHO. (2013b). *Health Effects of Particulate Matter: Policy implications for countries in eastern Europe, Caucasus and central Asia*. *World Health Organization* (Vol. 50). https://doi.org/10.5124/jkma.2007.50.2.175

WHO. (2013c). *The 8th Global Conference on Health Promotion, Helsinki, Finland, 10-14 June 2013 The Helsinki Statement on Health in All Policies*. *Health promotion international*.

WHO. (2014a). *Health in all policies: Helsinki statement. Framework for country action*. *World Health Organisation*. Helsinki. Retrieved from https://www.who.int/healthpromotion/frameworkforcountryaction/en/

WHO. (2014b). *Quantitative risk assessment of the effects of climate change on selected causes of death, 2030s and 2050s*. Retrieved from http://www.who.int/globalchange/publications/quantitative-risk-assessment/en/

WHO. (2017). *Health economic assessment tools (HEAT) for walking and for cycling: Methods and user guide on physical activity, air pollution, injuries and carbon impact*

assessments. *World Health Organization*.
WHO. (2018a). *Environmental Noise Guidelines for the European Region*. World Health Organization, Regional Office for Europe. https://doi.org/10.3390/ijerph14080873
WHO. (2018b). *Global status report on road safety 2018*. *World Health Organization*. World Health Organization. https://doi.org/10.1590/s1809-98232013000400007
WHO. (2018c). *Noncommunicable Diseases-Country Profiles 2018*. *World Health Organization (WHO)*. https://doi.org/10.1002/9781119097136.part5
WHO. (2018d). *Technical Series on Primary health Care: Health in All Policies as part of the primary health care agenda on multisectoral action*.
WHO. (2019a). *Evidence and resources to act on health inequities, social determinants and meet the SDGs*.
WHO. (2019b). *Healthy, prosperous lives for all: the European Health Equity Status Report*. *WHO Regional Office for Europe*. Retrieved from http://www.euro.who.int/en/publications/abstracts/health-equity-status-report-2019
Winters, M., & Cooper, A. (2008). *What Makes a Neighbourhood Bikeable: Reporting on the Results of Focus Group Sessions*. Retrieved from http://cyclingincities.spph.ubc.ca/files/2011/10/WhatMakesNeighbourhoodsBikeable.pdf ? ?
Wismar, M., Blau, J., Ernst, K., Figueras, J., Williams, G., Collins, K., … Siliquini, R. (2007). *The effectiveness of health impact assessment: Scope and limitations of supporting decision-making in Europe*. *World Health Organization*. Retrieved from http://www.euro.who.int/__data/assets/pdf_file/0003/98283/E90794.pdf
Woodcock, J., Edwards, P., Tonne, C., Armstrong, B. G., Ashiru, O., Banister, D., … Roberts, I. (2009). Public health benefits of strategies to reduce greenhouse-gas emissions: urban land transport. *The Lancet*, *374*(9705), 1930–1943. https://doi.org/10.1016/S0140-6736(09)61714-1
Woodcock, J., Givoni, M., & Morgan, A. S. (2013). Health Impact Modelling of Active Travel Visions for England and Wales Using an Integrated Transport and Health Impact Modelling Tool (ITHIM). *PLoS ONE*, *8*(1). https://doi.org/10.1371/journal.pone.0051462
Woodcock, J., Tainio, M., Cheshire, J., O'Brien, O., & Goodman, A. (2014). Health effects of the London bicycle sharing system: Health impact modelling study. *BMJ (Online)*, *348*(February), 1–14. https://doi.org/10.1136/bmj.g425
World Commission on Environment and Development. (1987). *Report of the World Commission on Environment and Development: Our Common Future* (Vol. 4). https://doi.org/10.1080/07488008808408783
Wright, P. H., & Baker, E. J. (1976). Factors which contribute to traffic accidents. *Transportation Planning and Technology*, *3*(2), 75–79. https://doi.org/10.1080/03081067608717094
Wu, D. L., Lin, M., Chan, C. Y., Li, W. Z., Tao, J., Li, Y. P., … Bu, C. W. (2013). Influences of commuting mode, air conditioning mode and meteorological parameters on fine particle (PM2.5) exposure levels in traffic microenvironments. *Aerosol and Air Quality Research*, *13*(2), 709–720. https://doi.org/10.4209/aaqr.2012.08.0212
Xu, K., Soucat, A., Kutzin, J., Brindley, C., Maele, N. Vande, Toure, H., … Cherilova, V. (2018). *Public Spending on Health: A Closer Look at Global Trends*. *World Health Organization*. Retrieved from https://www.who.int/health_financing/documents/health-expenditure-report-2018/en/
Yan, F., Winijkul, E., Jung, S., Bond, T. C., & Streets, D. G. (2011). Global emission projections of particulate matter (PM): I. Exhaust emissions from on-road vehicles. *Atmospheric Environment*, *45*(28), 4830–4844. https://doi.org/10.1016/j.atmosenv.2011.06.018

Yao, C. M. K. L., Ma, A. K., Cushing, S. L., & Lin, V. Y. W. (2017). Noise exposure while commuting in Toronto - A study of personal and public transportation in Toronto. *Journal of Otolaryngology - Head and Neck Surgery*, *46*(1), 4–11. https://doi.org/10.1186/s40463-017-0239-6

Zaharna, M., & Guilleminault, C. (2010). Sleep, noise and health: Review. *Noise and Health*, *12*(47), 64–69. https://doi.org/10.4103/1463-1741.63205

Zare Sakhvidi, M. J., Zare Sakhvidi, F., Mehrparvar, A. H., Foraster, M., & Dadvand, P. (2018). Association between noise exposure and diabetes: A systematic review and meta-analysis. *Environmental Research*, *166*(January), 647–657. https://doi.org/10.1016/j.envres.2018.05.011

Zegeer, C. V., Badgett, A., Boyd, J. C., J, M., PE, C., Daubert, D. B., … Zimmer, W. (1998). *Design and Safety Pedestrian Facilities*. *Institute of Transport Engineers*.

Zein, S. R., & Navin, F. P. D. (2003). Improving Traffic Safety: A New Systems Approach. *Transportation Research Record: Journal of the Transportation Research Board*, *1830*(1), 1–9. https://doi.org/10.3141/1830-01

Zhang, L., Long, R., & Chen, H. (2019). Do car restriction policies effectively promote the development of public transport? *World Development*, *119*, 100–110. https://doi.org/10.1016/j.worlddev.2019.03.007

Zheng, Z., Peng, F., Xu, B., Zhao, J., Liu, H., Peng, J., … Tang, W. (2020). Risk factors of critical & mortal COVID-19 cases: A systematic literature review and meta-analysis. *Journal of Infection*, *81*(2), e16–e25. https://doi.org/10.1016/j.jinf.2020.04.021

Zhu, Y., Eiguren-Fernandez, A., Hinds, W. C., & Miguel, A. H. (2007). In-cabin commuter exposure to ultrafine particles on Los Angeles freeways. *Environmental Science and Technology*, *41*(7), 2138–2145. https://doi.org/10.1021/es0618797

Zlatkovic, M., Stevanovic, A., & Reza, R. M. Z. (2013). Effects of Queue Jumpers and Transit Signal Priority on Bus Rapid Transit. *Transportation Research Board 92th Annual Meeting*, *489*(5), 1–19.

Zuurbier, M., Hoek, G., Oldenwening, M., Lenters, V., Meliefste, K., van den Hazel, P., & Brunekreef, B. (2010). Commuters' exposure to particulate matter air pollution is affected by mode of transport, fuel type, and route. *Environmental Health Perspectives*, *118*(6), 783–789. https://doi.org/10.1289/ehp.0901622

Appendix A - Reviewed Studies Measured Air Pollution Concentration Across Transport Modes

A1. Reviewed studies measured UFP number concentration across transport modes

No	Study	City	Measurement period	Instrument	Transport mode	Mean concentration
UFP number concentration						
1	(Grana et al., 2017)[1]	Rome, Italy	December 2013-March 2014	P-Trak (TSI Model 8525, TSI Incor-	Car	20509
					Motorcycle	73168
					Subway	14134
2	(de Nazelle et al., 2012b)[2]	Barcelona, Spain	May–June 2009	CPC Model 3007, TSI	Car	123000
					Bus	55200
					Bike	77500
					Walk	52700
3	(Boogaard et al., 2009)[3]	11 Dutch cities, Netherlands	August-October 2006	TSI CPC Model 3007	Car	25545
					Bike	24329
4	(Int Panis et al., 2010)[4]	Brussels, Belgium	June, 2009	TSI P-Track Model 8525	Car	31472
					Bike	30214
5	(Moreno et al., 2015)[5]	Barcelona, Spain	October and November 2014	NanoTracer (Philips Aerasense Nanotracer, NT	Bus	54000
					Tram	30000
					Subway	23000
					Walk	48000
6	(Ragettli et al., 2013)[6]	Basel, Switzerland	December 2010-September 2011	MiniDiSC CPC	Car	31784
					Bus	14055
					Bike	22660
					Walk	19481
7	(Zuurbier et al., 2010b)[7]	Arnhem, Netherlands	June 2007 - June 2008	CPCs; model 3007, TSI, Inc., Shoreview, MN, USA)	Car	38827
					Diesel bus	43235
					Electric bus	28602
					Bike	44257
8	(Ham et al., 2017)[8]	Sacramento, California, USA	April 2014 and November 2015	DiSCmini	Car	7900
					Bus	13000
					Bike	22000
					Tram	5500
					Train	42000
9	(Shokeen, 2019)[9]	Darmstadt, Germany	December, 2018 to March, 2019	Naneos, UFP	Car	11273
					Bus	16536
					Bike	53090
					Tram	16836
10	(Qiu et al., 2019)[10]	Xi'an, China	July to October 2018	P-Track Ultrafine Particle Counters (Model 8525, TSI, USA)	Bike	18172

11	(Gu et al., 2015)[11]	Augsburg, Germany	March 2007 to December 2008	CPC, model 3007, TSI Inc., Shoreview, MN, USA)	Car	28425
					Bike	35844
					Walk	23209
12	(Both, Westerdahl, Fruin, Haryanto, & Marshall, 2013)[12]	Jakarta, Indonesia:	2005, from May through October	CPCModel 3007, TSI Inc., Shore-view, MN	Car	294000
					Bus	401000
13	(Tsang, Kwok, & Miguel, 2008)[13]	Hong Kong	Jul-05	TSI Inc. Model 3785, Saint Paul, MN	Walk	63415
14	(Peters et al., 2014)[14]	Antwerp, Belgium	February – March 2012	P-Trak ultrafine particle counter (model number 8525)	Bike	32210
15	(Apte et al., 2011)[15]	New Delhi, India	February 22 to May 26, 2010	(CPC, model CPC 3007, TSI Inc., Shoreview	Auto-Rickshaw	290000
16	(Suárez et al., 2014)[16]	Santiago, Chile	From June 13th to October 13th, 2011 and from March 6th to May 15th, 2012	P-TRAK Model 8525, TSI	Car	54500
					Bus	70900
					Bike	63900
					Subway	42500
17	(Rivas et al., 2017)[17] (*)	London, UK	25 February and 17 June 2016	P-Trak model 8 525 (TSI Inc., USA)	Car	8879
					Bus	9663
					Walk	7331
					Subway	6300
18	This study	Ho Chi Minh city, Vietnam	November, 2019	Naneos, UFP	Car	15930
					Bus	51514
					Bike	308963
					Motorcycle	360903
					Walk	177135
19	(Kaur, Nieuwenhuijsen, & Colvile, 2005)[18]	London, UK	April 2004 to June 2004	P-TRAKs Ultrafine Particle Counters (Model 8525)	Walk	80009

[1] Exposure to ultrafine particles in different transport modes in the city of Rome*
[2] A travel mode comparison of commuters’ exposures to air pollutants in Barcelona
[3] Exposure to ultrafine and fine particles and noise during cycling and driving in 11 Dutch cities
[4] Exposure to particulate matter in traffic: A comparison of cyclists and car passengers
[5] Urban air quality comparison for bus, tram, subway and pedestrian commutes in Barcelona
[6] Commuter exposure to ultrafine particles in different urban locations, transportation modes and routes
[7] Commuters’ Exposure to Particulate Matter Air Pollution Is Affected by Mode of Transport, Fuel Type, and Route
[8] Commuter exposure to PM2.5, BC, and UFP in six common transport microenvironments in Sacramento, California
[9] Multi-metric Exposure Assessment of Ultrafine Particulate Matter in Various Modes of Transportation in Darmstadt
[10] Exposure assessment of cyclists to UFP and PM on urban routes in Xi'an, China*
[11] Personal day-time exposure to ultrafine particles in different microenvironments
[12] Exposure to carbon monoxide, fine particle mass, and ultrafine particle number in Jakarta, Indonesia: Effect of commute mode Adam
[13] Pedestrian exposure to ultrafine particles in Hong Kong under heavy traffic conditions
[14] Cyclist exposure to UFP and BC on urban routes in Antwerp, Belgium
[15] Concentrations of fine, ultrafine, and black carbon particles in auto-rickshaws in New Delhi, India
[16] Personal exposure to particulate matter in commuters using different transport modes (bus, bicycle, car and subway) in an assigned route in downtown Santiago, Chile
[17] Determinants of black carbon, particle mass and number concentrations in London transport microenvironments
[18] Pedestrian exposure to air pollution along a major road in Central London, UK

A2. Reviewed studies measured $PM_{2.5}$ concentration across transport modes

No	Study	City	Measurement period	Instrument	Transport mode	Mean concentration
PM2.5 (Microgram/m3)						
1	(Qiu et al., 2019)[1]	Xi'an, China	July to October 2018	Dust Monitors (Model 11-A, GRIMM, Germany)	Bike	38.6
2	(de Nazelle et al., 2012b)[2]	Barcelona, Spain	May–June 2009	DustTrak Model 8520, TSI	Car	35.5
					Bus	25.9
					Bike	35
					Walk	21.6
3	(Both et al., 2013)[3]	Jakarta, Indonesia	2005, from May through October	DustTrak 8520, TSI Inc., Shoreview, MN	Car	91
					Bus	117
4	(Boogaard et al., 2009)[4]	11 Dutch cities, Netherlands	August-October 2006	DustTrak (TSI Inc, MN, USA)	Car	49.4
					Bike	44.5
5	(Int Panis et al., 2010)[5]	Brussels, Belgium	June, 2009	TSI DustTrak DRX model 8534 (TSI Inc, USA)	Car	14.4
					Bike	18.9
6	(Suárez et al., 2014)[6]	Santiago, Chile	From June 13th to October 13th, 2011 and from March 6th to May 15th, 2012	DUST-TRAK II, Model 8532, TSI, Shoreview, MN, USA	Car	46.5
					Bus	60.4
					Bike	50.9
					Subway	62.4
7	(Ham et al., 2017)[7]	Sacramento, California, USA	April 2014 and November 2015	DustTrak (PM2.5, TSI 8 520),	Car	7.1
					Bus	7.47
					Bike	9.56
					Tram	5.69
					Train	32.46
8	(Rivas et al., 2017)[8] (*)	London, UK	25 February and 17 June 2016	GRIMM EDM 107 aerosol spectrometer (GRIMM Technologies Inc., Germany)	Car	7.4
					Bus	13.2
					Walk	13.6
					Subway	50.7
9	(Zuurbier et al., 2010b)[9]	Arnhem, Netherlands	June 2007 - June 2008	DataRAMs (model 1200; MIE Inc., Bedford, MA, USA	Car	108.5
					Diesel bus	68.7
					Electric bus	40.5
					Bike	72
10						200

	(Apte et al., 2011)[10]	New Delhi, India	February 22 to May 26, 2010	DustTrak aerosol monitors (model 8520, TSI, Inc., Shoreview, MN).	Auto-Rickshaw	
11	(McNabola, Broderick, & Gill, 2008)[11]	Dublin, Ireland	January 2005 – June 2006	Adams'sampler	Car	85.8
					Bus	115.8
					Bike	80.5
					Walk	64.8
12	(Moreno et al., 2015)[12]	Barcelona, Spain	October and November 2014	DustTrack monitor (DT: Model 8533, TSI)	Bus	45
					Tram	30
					Subway	43
					Walk	28
13	(Kaur et al., 2005b)[13]	London, UK	April 2004 to June 2004	high-flow personal sampler (HFPS)	Walk	37.7
14	(Pant, Habib, Marshall, & Peltier, 2017)[14]	New Delhi, India	December 2014 and May 2016	scattering nephelometer (pDR-1500,	Bus	69.1
				Thermo Fisher, Franklin, MA, USA)	Autoriskshaw	88.7
15	(Shen & Gao, 2019)[15]	Nanjing, China	7-13 May, 2017 and 11-18 December, 2017	TSI DustTrak II Aerosol Monitors	Subway (in cabin)	54.4
				(Model 8532, TSI Inc., USA)	Bus	74.7
					Bike	79
					Walk	80.3
16	(Yan et al., 2015)[16]	Beijing, China	between December 10 and 23, 2011	DustTrak Photometer (Model 8520, TSI Inc. St. Paul,	Subway	61.8
					Train	42.4
					Bus (Air condition bus)	38.9
					Bus (non Air condition bus)	38.4
					Walk	49.9
17	(Huang, Deng, Wu, & Guo, 2012)[17]	Beijing, China	between Decem-	model LD-6S, Beijing Green Technology Digital Co., Ltd, China)	Car	31.6
			between 2010 and February 2011		Bus	42.4
					Bike	49
18	(Okokon et al., 2018)[18]	Lagos, Nigeria	End of 2015-early 2016	DustTrak DRX 8533 (TSI Inc., Shoreview,	Car	151
					Bus	173

				Minnesota, USA) was		
19	(Okokon et al., 2017)[19]	Helsinki, Finland	7-17 June, 2011	TSI DustTrak DRX 8533 (TSI Inc., Shoreview, Minnesota, USA)	Car	23.5
					Bus	29
					Bike	27
20	(Okokon et al., 2017)[20]	Rotterdam, the Netherlands;	10-19, May, 2011	TSI DustTrak DRX 8533 (TSI Inc., Shoreview, Minnesota, USA)USA)	Car	22.5
					Bus	21
					Bike	32
21	(Okokon et al., 2017)[21]	Thessaloniki, Greece	5-13 April, 2011	TSI DustTrak DRX 8533 (TSI Inc., Shoreview, Minnesota, USA)	Car	40
					Bus	85
					Bike	41
22	(Kaur & Nieuwenhuijsen, 2009)[22]	London	between 28th April 2003 and 23 May 2003.	gravimetric high-flow personal sampler developed by Adams et	Car	33.4
					Bus	33.1
					Bike	33.8
					Walk	27.1
23	(Onat et al., 2019)[23]	Istanbul, Turkey	between June 2016 and September 2017	pDR 1200 portable real-time aerosol monitor (Thermo-Fisher Scientific, USA)	Car	22
					Bus	31.1
24	(Kaur et al., 2005a)[24]	London, UK	between 28th April 2003 and 23rd May2003	a high-flow personal sampler (HFPS) developed by Adams et al.	Car	38
					Bus	34.5
					Bike	33.5
					Walk	27.5
25	(Morabia et al., 2009)[25]	New York City	between October 2007 and February 2008	AM510 SidePakTM	Car	21.4
					Subway	30.6
					Walk	26.7

[1] Exposure assessment of cyclists to UFP and PM on urban routes in Xi'an, China*
[2] A travel mode comparison of commuters' exposures to air pollutants in Barcelona
[3] Exposure to carbon monoxide, fine particle mass, and ultrafine particle number in Jakarta, Indonesia: Effect of commute mode Adam
[4] Exposure to ultrafine and fine particles and noise during cycling and driving in 11 Dutch cities
[5] Exposure to particulate matter in traffic: A comparison of cyclists and car passengers
[6] Personal exposure to particulate matter in commuters using different transport modes (bus, bicycle, car and subway) in an assigned route in downtown Santiago, Chile
[7] Commuter exposure to PM2.5, BC, and UFP in six common transport microenvironments in Sacramento, California
[8] Determinants of black carbon, particle mass and number concentrations in London transport microenvironments
[9] Commuters' Exposure to Particulate Matter Air Pollution Is Affected by Mode of Transport, Fuel Type, and Route
[10] Concentrations of fine, ultrafine, and black carbon particles in auto-rickshaws in New Delhi, India
[11] Relative exposure to fine particulate matter and VOCs between transport microenvironments in Dublin: Personal exposure and uptake
[12] Urban air quality comparison for bus, tram, subway and pedestrian commutes in Barcelona
[13] Pedestrian exposure to air pollution along a major road in Central London, UK
[14] PM2.5 exposure in highly polluted cities: A case study from New Delhi, India
[15] Commuter exposure to particulate matters in four common transportation modes in Nanjing
[16] Commuter exposure to particulate matter and particle-bound PAHs in three transportation modes in Beijing, China
[17] Comparisons of personal exposure to PM2.5 and CO by different commuting modes in Beijing, China
[18] Particulate air pollution and noise: Assessing commuter exposure in Africa's most populous city
[19] Particulates and noise exposure during bicycle, bus and car commuting: A study in three European cities
[20] Particulates and noise exposure during bicycle, bus and car commuting: A study in three European cities
[21] Particulates and noise exposure during bicycle, bus and car commuting: A study in three European cities
[22] Determinants of Personal Exposure to PM2.5, Ultrafine Particle Counts, and CO in a Transport Microenvironment
[23] Determinants of exposure to ultrafine particulate matter, black carbon, and PM2.5 in common travel modes in Istanbul
[24] Personal exposure of street canyon intersection users to PM2.5, ultrafine particle counts and carbon monoxide in Central London, UK
[25] Air Pollution and Activity During Transportation by Car, Subway, and Walking

A3. Reviewed studies measured BC concentration across transport modes

No	Study	City	Measurement period	Instrument	Transport mode	Mean concentration
BC (Microgram/m^3)						
1	(Ham et al., 2017)[1]	Sacramento, California, USA	April 2014 and November 2015	Micro-Aethalometer (BC, Magee/AethLabs AE51)	Car	0.5
					Bus	0.95
					Bike	0.71
					Tram	0.25
					Train	2.54
2	(Rivas et al., 2017)[2] (*)	London, UK	25 February and 17 June 2016	MicroAeth AE51 (AethLabs, USA)	Car	4.4
					Bus	5.6
					Walk	2
3	(Apte et al., 2011)[3]	New Delhi, India	February 22 to May 26, 2010	portable aethalometers (model AE-51 "micro- Aeth," Magee Scientific, Berkeley, CA)	Auto-Rickshaw	43
4	(Peters et al., 2014)[4]	Antwerp, Belgium	February – March 2012	micro- aethalometer Model AE51 (Aethlabs)	Bike	5.9
5	(Moreno et al., 2015)[5]	Barcelona, Spain	October and November 2014		Bus	5.5
					Tram	3.4
					Subway	7
					Walk	6.45
6	(Pant et al., 2017)[6]	New Delhi, India	December 2014 and May 2016	microAethalometer AE51 (AethLabs, San Francisco,	Bus	17.1
				CA, USA)	Autoriskshaw	29
7	(Merritt et al., 2019)[7]	Stockholm, Sweden	2013	MicroAeth Model AE51, AethLabs, San Francisco, CA, USA)	Bus	2.69
					Walk	1.69
8	(Okokon et al., 2018)[8]	Lagos, Nigeria	End of 2015-early 2016	AE51 microaethalometers (Magee Scientific Corp. Berkely, California, USA)	Car	37
9	(Okokon et al., 2017)[9]	Helsinki, Finland	7-17 June, 2011	AE51 microaethalometers (Magee Scientific	Car	5.3
				Corp. Berkely, California, USA)	Bus	4.6
					Bike	3.2

10	(Okokon et al., 2017)[10]	Rotterdam, the Netherlands;	10-19, May, 2011	AE51 microaethalometers (Magee Scientific	Car	6.35
				Corp. Berkely, California, USA)	Bus	4.3
					Bike	3.1
11	(Okokon et al., 2017)[11]	Thessaloniki, Greece	5-13 April, 2011	AE51 microaethalometers (Magee Scientific	Car	7.8
				Corp. Berkely, California, USA)	Bus	8.5
					Bike	6.9
12	(Onat et al., 2019)[12]	Istanbul, Turkey	between June 2016 and September 2017	microAeth	Car	10.25
				AE51, a portable aethalometer (AethLabs, USA)	Bus	10.3
13	(Li et al., 2015)[13]	Shanghai, China	August, 2014	MicroAeth Black Carbon monitors (model AE-51, Magee Scien-	Car	9.39
					Bus	8.66
					Subway	10.96
					Bike	6.58
					Walk	5.59
14	(Williams & Knibbs, 2016)[14]	Brisbane, Australia	April to October, 2015	AethLabs model AE51, San Francisco, USA).	Car	3.032
					Bus	2.353
					Train	0.488
					Bike	1.042
					Walk	1.242
15	(de Nazelle et al., 2012b)[15]	Barcelona, Spain	May–June 2009		Car	19.5
					Bus	7.58
					Bike	9.53
					Walk	6.31
16	(Dons, Int Panis, Van Poppel, Theunis, & Wets, 2012)[16]	Flanders, Belgium	summer 2010	microAeth Model AE51, (AethLabs, 2011)	Car	6.3
					Bus	6.6
					Train	2.4
					Bike	3.6
					Walk	3.2
17	(Brand et al., 2019)[17]	London	December, 2017	MicroAeth AE51 (AethLabs)	Bike	4.7
		Rotterdam	October, 2017	MicroAeth AE51 (AethLabs)	Bike	1.7
		São Paulo	February, 2018	MicroAeth AE51 (AethLabs)	Bike	5.5

[1] Commuter exposure to PM2.5, BC, and UFP in six common transport microenvironments in Sacramento, California
[2] Determinants of black carbon, particle mass and number concentrations in London transport microenvironments
[3] Concentrations of fine, ultrafine, and black carbon particles in auto-rickshaws in New Delhi, India
[4] Cyclist exposure to UFP and BC on urban routes in Antwerp, Belgium
[5] Urban air quality comparison for bus, tram, subway and pedestrian commutes in Barcelona
[6] PM2.5 exposure in highly polluted cities: A case study from New Delhi, India
[7] Personal exposure to black carbon in Stockholm, using different intra- urban transport modes
[8] Particulate air pollution and noise: Assessing commuter exposure in Africa's most populous city
[9] Particulates and noise exposure during bicycle, bus and car commuting: A study in three European cities
[10] Particulates and noise exposure during bicycle, bus and car commuting: A study in three European cities
[11] Particulates and noise exposure during bicycle, bus and car commuting: A study in three European cities
[12] Determinants of exposure to ultrafine particulate matter, black carbon, and PM2.5 in common travel modes in Istanbul
[13] Personal exposure to black carbon during commuting in peak and off-peak hours in Shanghai
[14] Daily personal exposure to black carbon: A pilot study
[15] A travel mode comparison of commuters’ exposures to air pollutants in Barcelona
[16] Personal exposure to Black Carbon in transport microenvironments
[17] Impact of route choice and period of the day on cyclists' exposure to black carbon in London, Rotterdam and São Paulo

Appendix B - Measurement survey

B1. Reviewed studies for estimating minute ventilation when commuting by different modes

No.	Studies	Sitting	Walking	Standing	Cycling	Car driving	Bus commuting
1	Int Panis, et al., 2010[1]				52.7	12.4	
2	Zuurbier, Hoek, Hazel, & Brunekreef, 2009[12]				23.5	11.8	12.7
3	Nyhan, Mcbola, & Misstear, 2013 [3]		22.5		30.5		13.7
4	de Nazelle et al., 2012 [4]		34.1		41	19.9	20.1
5	Huang, Deng, Wu, & Guo, 2012[5]				26	11	11
6	O'Donoghue, Gill, McKevitt, & Broderick, 2007[6]				28		11
7	Ramos, Wolterbeek, & Almeida, 2016[7]				55.9	13.9	13.9
8	Beals, Funk, Fountain, & Sedman, 1996[8]	8.5	23.6	9.5		9.9	
9	Shimer, Jenkins, Hui, & Adams, 1995[9]	8.5	22.2	9.5		9.0	
10	Alexander Y. Bigazzi & Miguel A. Figliozzi (2014) [10]				40.5		

[1] Exposure to particulate matter in traffic: A comparison of cyclists and car passengers
[2] Minute ventilation of cyclists, car and bus passengers: An experimental study
[3] Comparison of particulate matter dose and acute heart rate variability response in cyclists, pedestrians, bus and train passengers
[4] Benefits of shift from car to active transport
[5] Comparisons of personal exposure to PM2.5 and CO by different commuting modes in Beijing, China
[6] Exposure to hydrocarbon concentrations while commuting or exercising in Dublin
[7] Air pollutant exposure and inhaled dose during urban commuting: a comparison between cycling and motorized modes
[8] Quantifying the distribution of inhalation exposure in human populations: Distribution of minute volumes in adults and children
[9] Measurement of Breathing Rate and Volume in Routinely Performed Daily Activities
[10] Review of Urban Bicyclists' Intake and Uptake of Traffic-Related Air Pollution

B2. Measurement devices

- **Partector 2: air pollution measurement**

For air pollution, a portable device named naneos partector 2 manufactured by naneos particle solutions GmbH in Switzerland was used. The partector 2 is in conformity with the provisions of the two European Directives (2011/65/EU and 2014/53/EU). This device is characterized by small size, low weight and long battery lifetime, thus it is well suited for mobile measurement. This device measures number of particle concentration (UFP), average particle diameter, and lung-deposited surface area (LDSA) simultaneously. In addition, ultrafine particle (UFP) surface and ultrafine particle mass concentrations are calculated and displayed by using the measured diameter of the particles.

The java data analysis tool was provided by manufacturer to work with the data from partector 2. This tool allows users to easily combine partector data with GPS data to generate a Google Earth file plotting air qualiy as function of location.

In order to know the location of exposure, a GPS (global positioning system) application (name GPS tracker) for smartphone was used to track the information of times and locations. Then, these data were combined with with the data of air pollution from partector 2. The 5 steps to combine the GPS data and partector 2 data include (1) turn on GPS tracker and partector 2 simultaneously while start a measurement, (2) turn of GPS tracker and partector 2 at the same time, (3) export GPS data in the gpx file format, (4) load both partector and GPS data in the java-based partector data analysis tool, (5) select “export KMZ file” in the menu, the program wills ave the data file in Google Earth format and automatically open Google Earth for viewing.

Because of the nature of the work and unavailability of laboratory equipment for this device, the calibration of device was done by the supplier itself with error range in the industry standards. Calibration certification was provided by the supplier.

Specification:

- Measurement indicators: LDSA, particle number, average particle size, surface area, UFP mass (PM0.3)
- LDSA concentration range: from 0 – 12,000 µm²/cm³
- Measured particle diameter range: from 10 – 300 nm (PM0.01-PM0.3)
- Number particle concentration range: from 0 - 10^6 cm^{-3}
- Surface area concentration range: 0 – 50,000 µm²/cm³
- UFP mass range (PM0.3): 0 – 2,500 µg/m³
- Typical accuracy: 30%
- Data storage on a µSD-Card

- **Noise measurement device: Sound level meter PCE 432**

For measuring level of noise exposure, a decibel meter PCE 432 manufacture by PCE instruments GmbH in Germany was used. The device complies with ICE 61672-1:2013, ANSI S1.4-1983, and ANSI S1.43-1997. The device has three measurement modes including level meter, 1/1 octave, 1/3 octave. For the purpose of this study (measuring the average sound pressure levels while commuting by different transport modes), the level meter mode was selected, which measuring sound pressure level with A frequency weighting and the data-logging interval was set 1 second. The measuring range was from 22 to 136 db (A), at a frequency of 3 Hz … 20 kHz. The calibration of device was conducted by manufacturer. This device was powered by battery, and recorded data to a micro SD card memory. A post-process software of sound level meter was provided by manufacturer, which allow to work with data easily.

Specification:

- Measuring range: 22 … 136 dB (A)
- Accuracy: Class 1
- Frequency range: 3 Hz … 20 kHz
- Frequency analysis:
  - 1/1 Octave band filter: 8 Hz … 16 kHz
  - 1/3 Octave band filter: 6.3 Hz … 20 kHz
- Data-logging interval: 1 s … 24 h
- Frequency weightings: A, B, C, Z

- **Descriptive statistics**

Distribution of monitoring trips by transport modes, measuring times, and routes

Transport mode	**Route 1**			**Route 2**			**Total**
	Morning peak hour	**Off-peak hour**	**Afternoon peak hour**	**Morning peak hour**	**Off-peak hour**	**Afternoon peak hour**	
Car	5	6	4	5	6	3	29
Bus	4	8	6	4	8	6	36
MC	6	7	6	6	7	6	38
BC	6	6	7	6	6	7	38
141							

Distribution of walking trips by sections and measuring time

Walking	**Section 1**	**Section 2**	**Section 3**	**Section 4**	
Morning peak	3	4	4	4	
Off peak	9	5	5	4	
Afternoon peak	5	3	3	4	
Total	17	12	12	12	**53**

Distribution of waiting times by bus stops and measuring time

Waiting	**Bus stop 1**	**Bus stop 2**	**Bus stop 3**	**Bus stop 4**	**Bus stop 5**	**Total**
Morning peak	3	4	3	4	2	16
Off peak	4	4	5	4	4	21
Afternoon peak	4	3	3	4	3	17
Total	11	11	11	12	9	**54**

Average travelling time by transport mode and by measuring periods

Transport microenvironment	All (min)	Morning peak hour (min)	Off-peak hour (min)	Afternoon peak hour (min)
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Car	29 (11)	26 (4)	23 (3)	43 (13)
Bus (time on bus)	28 (6)	27 (2)	25 (5)	32 (7)
MC	22 (6)	20 (2)	18 (1)	28 (7)
BC	29 (5)	27 (5)	26 (2)	32 (6)

.

Appendix C – Interview's questionnaire

I: Vehicle ownership and transport mode use

Q1: Vehicle ownership/available vehicle for use

(1) □ None (4) □ Motorcycle (7) □ Other
(2) □ Bicycle (5) □ Electric motorcycle
(3) □ Electric bicycle (6) □ Car

Q2: The most frequent and regular transport mode do you use for daily travelling from the last 12 months? (only in the weekdays)

(1) □ Walk (4) □ Motorcycle (7) □ Public transport (bus)
(2) □ Bicycle (5) □ Electric motorcycle (8) □ Other
(3) □ Electric bicycle (6) □ Car

Q3: Main trip purpose by using transport mode <u>in question 2</u>?

(1) □ To work (4) □ Eating (breakfast, lunch, dinner)
(2) □ To study (5) □ Meeting friends, family
(3) □ Shopping/Entertaining (6) □ Other

Q4: Average daily travel distance with the transport mode <u>in question 2</u>? (only in the weekdays)

(1) □ Less than 1 km (4) □ 5-10 km (7) □ More than 20 km
(2) □ 1-2 km (5) □ 10-15 km
(3) □ 2-5 km (6) □ 15-20 km

Q5: Average daily travel time with the transport <u>mode in question 2</u>? (only in the weekdays)
If you travel by bus, please add both waiting time and accessing time (from home to bus stop, from bus stop to your destination)

(1) □ Less than 10 minutes (3) □ 30-60 minutes (5) □ More than 90 minutes
(2) □ 10-30 minutes (4) □ 60- 90 minutes

<u>Question 5.1 to 5.3 for bus users only</u>

Q5.1: Average walking time from your home to bus stop?

(1) □ Less 5 minutes (3) □ 10-15 minutes (5) □ More than 20 minutes
(2) □ 5-10 minutes (4) □ 15- 20 minutes

Q5.2: Average walking time from bus stop to your destination?

(1) □ Less 5 minutes (3) □ 10-15 minutes (5) □ More than 20 minutes
(2) □ 5-10 minutes (4) □ 15- 20 minutes

Q5.3: Average waiting time at bus stop?

(1) □ Less 5 minutes
(2) □ 5-10 minutes
(3) □ 10-15 minutes
(4) □ 15- 20 minutes
(5) □ More than 20 minutes

II: Health status

Q6: In general, how do you evaluate your health?

Very poor	Poor	Normal	Good	Very good
(1) □	(2) □	(3) □	(4) □	(5) □

Q7: In overall, how satisfied are you with your health, your social relationship, and your family relationship?

	Completely dissatisfied	Dissatisfied	Neither dissatisfied nor satisfied	Satisfied	Completely satisfied
Q7.1: How satisfied are you with your health?	(1) □	(2) □	(3) □	(4) □	(5) □
Q7.2: How satisfied are you with your social relationships?	(1) □	(2) □	(3) □	(4) □	(5) □
Q7.3: How satisfied are you with your family relationships?	(1) □	(2) □	(3) □	(4) □	(5) □

Q8: How tall are you? (in centimes)

…………………………………

Q9: How much do you weight? (in kilograms)

…………………………………

Q10: Have you ever been told by a doctor, nurse, or other health professionals that you have the following health problems from the last 12 months (or currently have)?

Health problems	(1) Yes	(2) No
1. Respiratory diseases (e.g., asthma, throat irritation, bronchoconstriction, chronic obstructive pulmonary, etc)		
2. Cardiovascular diseases (e.g., hypertension, heart failure, stroke, arrhythmia, heart attack, etc)		
3. Type 2 diabetes		
4. Lung cancer		
5. Breast cancer		
6. Colon cancer		
7. Skin diseases (e.g., acne, skin ageing, atopic dermatitis, skin cancer, etc)		

8. Eye diseases (e.g., eye irritation, dry eye, redness, watery eyes, sore eyes, etc)		
9. Sleep problems (e.g., sleepiness, sleep disorder, insomnia, etc)		
10. Hearing problems (e.g., tinnitus, hearing loss, etc)		
11. Mental health problems (e.g., depression, bipolar affective disorder, etc)		
12. Other (please classify) ………………………………………………………..		

Q11: How often do you feel that you have the following problems from the last 12 months (or currently have)?

Health problems	Never	Rarely	Sometimes	Often	Very often
	(1) □	(2) □	(3) □	(4) □	(5) □
1. Respiratory problems (e.g. difficult to breathe, wheezing, coughing, runny nose, etc.)					
2. Cardiovascular problems (e.g., chest tightness, difficult to breathe, dizziness, etc)					
3. Skin problems (e.g., ageing skin, acne, skin irritation, etc)					
4. Eye problems (e.g., itchy eyes, watery eyes, redness, etc)					
5. Sleep problems (e.g., sleepiness, insomnia, difficult to fall asleep, etc)					
6. Hearing problems (e.g., tinnitus, hearing loss, hearing impairment, etc)					
7. Mental health problems (e.g., depression, cannot control your mood/behaviour, etc)					
8. Other (please classify) ………………………………………					

Q12: How often do you have these feelings from the last 12 months?

Feeling	Never	Rarely	Sometimes	Often	Very often
	(1) □	(2) □	(3) □	(4) □	(5) □
(1) Stress					
(2) Sad					
(3) Nervous or anxious					
(4) Loneliness					
(5) Angry					
(6) Difficult to think and/or concentration					

Q13: How often do you feel stress when you are travelling with the transport mode in question 2?

Never	Rarely	Sometimes	Often	Very often
(1) □	(2) □	(3) □	(4) □	(5) □

Q14: In general, how do you rate your level of annoyance due to traffic-related problems (traffic congestion, traffic noise, traffic accident, ...) when you are travelling with the transport mode in question 2?

	Extremely annoyed	Quite a lot	Moderately	slightly	Not annoyed at all
Q14.1: Level of annoyance due to traffic-related problems in general?	(1) □	(2) □	(3) □	(4) □	(5) □
Q14.2: Level of annoyance due to traffic noise?	(1) □	(2) □	(3) □	(4) □	(5) □
Q14.3: Level of annoyance due to traffic-related air pollution?	(1) □	(2) □	(3) □	(4) □	(5) □

Q15: How do you rate your feeling of safety when you are travelling with the transport mode in question 2?

Very unsafe	Unsafe	Fair	Safe	Very safe
(1) □	(2) □	(3) □	(4) □	(5) □

III: The perception of impacts of transport on health

Q16: If you have to select another transport mode to replace your mode in question 2, please, rate level of importance by following factors that may influence your transport mode choice? With 1 is not important and 10 is very important

Not important → **Very important**

Factors	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1. Short travel time										
2. Low travel cost										
3. Comfort										
4. Safety										
5. Convenient										
6 Reduce exposure to air pollution										

7. Reduce exposure to noise pollution										
8. Increase physical activity/fitness										
9. Reduce exposure to UV radiation										
10. Reduce psychological stress										
11. Reduce CO2 emission										
12. Reduce land consumption for transport										

Q 17: If you know that your current transport mode choice has negative impacts on your health, are you willing to change to the other transport modes that may better for your health?

(1) □ Yes (2) □ No (3) □ Will be considered

For car users and motorcyclists:

Q18: If you know that travelling by public transport, bicycle, and walking is better for your health, are you willing to change to these transport modes?

(1) □ Yes (2) □ No (3) □ Will be considered

For public transport users, cyclist, and pedestrians:

Q19: If you know that your current transport modes are better for your health (compared to cars, and motorcycles), will you continue to use these transport modes in the future?

(1) □ Yes (2) □ No (3) □ Change to cars/motorcycles when possible

V: General information of interviewee

Q20. Gender:

(1) □ Male (2) □ Female (3) □ Others

Q21. Age:

(1) □ Under 18 (3) □ 25-35 (5) □ 51-60 (7) □ 71-80
(2) □ 18-24 (4) □ 36-50 (6) □ 61-70 (8) □ above 80

Q22: Home address

(1) □ District 1 (6) □ District 6 (11) □ District 11 (16) □ Tan Phu

(2) □ District 2 (7) □ District 7 (12) □ District 12 (17) □ Phu Nhuan

(3) □ District 3 (8) □ District 8 (13) □ Thu Duc (18) □ Binh Tan

(4) □ District 4 (9) □ District 9 (14) □ Binh Thanh (19) □ Go Vap

(5) □ District 5 (10) □ District 10 (15) □ Tan Binh (20) □ Others

Q23. Occupation:

(1) □ Office worker/Gov officer
(2) □ Worker
(3) □ Farmer
(4) □ Self-employed
(5) □ Student
(6) □ Pupil (primary to high school)
(7) □ Part-time employee
(8) □ Housewife/ Jobless
(9) □ Retired
(10) □ Others

Q24. Education level

(1) □ Not attending school
(2) □ Primary/Secondary school
(3) □ High school
(4) □ College/University
(5) □ Master/PhD
(6) □ Other

Q25. Income level

(1) □ No income
(2) □ <6 Mil.VND/month
(3) □ 6~10 Mil.VND/month
(4) □ 10~30 Mil.VND/month
(5) □ 30~50 Mil.VND/month
(6) □ > 50 Mil.VND/month

VI: Drinking and smoking behaviours

Q26: How often do you smoke?

Never	Rarely	Sometimes	Often	Very often
(1) □	(2) □	(3) □	(4) □	(5) □

Q27: In average, how many units of alcohol do you drink per week? (see in the table at the end of questionnaire for calculation)

None	Less than 10 units	More than 10 units
(1) □	(2) □	(3) □

Calculation of standard drink

1 beer, 330ml, 5% of alcohol
= 1.3 units

100 ml of wine, 12% of alcohol
= 1 unit

30 ml of wine, 40 % of alcohol
= 1 unit

$$\text{Number of unit drink} = \frac{\text{amount of drink in litres} * \text{percent of alcohol by volume} * 0.789}{10}$$