


THE ROAD FORWARD

Cost-Effective Policy Measures to Decrease Local and Global Emissions from Passenger Land Transport

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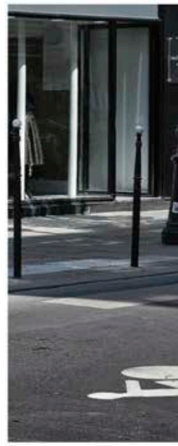

Centre for the Future of Places
KTH Royal Institute of Technology
Copenhagen Centre on Energy Efficiency
UNEP DTU Partnership

As we work to find effective solutions to the related challenges of climate change, environmental degradation and urban livability, we know that streets and other surface transport corridors must play a central role. These transport systems drive a large percentage of total global emissions, not only from vehicle operations, but also from the embodied and operating energy of their infrastructure, and from the behavioural patterns of consumption, emissions and depletion that they reinforce.

This is a particularly urgent topic in a time of historically unprecedented rapid urbanisation. Increased economic activity and welfare in many developing countries and emergent economies is giving rise to increased demand for transportation and thereby, increased level of emissions and resource depletion. Yet in many of these countries, expensive technical solutions are not yet realistic — at least not in the near future. It is therefore imperative to look also at affordable technical and non-technical solutions to curb pollutant emissions from road transport.

There is an urgent need, then, for cost-effective alternatives to capital-intensive and costly technical solutions. These are often not even the best options for the global environment, and other options — including land use changes, behavioural changes, and attractive non-motorised and public alternatives to private transport — are often more effective solutions.

Here, in a concise and accessible format, is a book outlining many of those solutions. It is written for political leaders, decision-makers, practitioners, and other stakeholders in the transport sector, as well as for those responsible for land-use and community planning. It provides them with the required information and analysis necessary to make decisions on sustainable and cost-effective transport and land-use solutions to reduce emissions. It is not meant to be an exhaustive compendium of solutions — many more will be needed in the years ahead — but a "road map" toward significant progress for the challenges ahead.

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THE ROAD FORWARD:
COST-EFFECTIVE POLICY MEASURES TO DECREASE EMISSIONS FROM PASSENGER LAND TRANSPORT

WITH

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PREFACE

This book is a resource for that perennial challenge of all urban policy: implementation. The policies in this case are those aimed at reducing passenger transport emissions on land, and especially (but not exclusively) in urban areas.

The reduction of transport emissions has become a key priority for many cities and towns, particularly as we seek effective action to mitigate the disastrous effects of global climate change. Transport emissions reductions are also essential to improve air and water quality, to promote human health and well-being, to support urban liveability and quality of life, and even to enhance economic performance and competitiveness.

The reality is that high levels of transport emissions impose increasingly high and unbearable costs on governments and citizens. What once seemed a reasonable trade-off for economic development is now looking more like a "road to disaster," economically as well as in other important ways. So-called externality costs, once ignored as hidden subsidies, are increasingly manifesting as heavy transaction costs, affecting cities' and citizens' bottom lines. We can't grow on like this.

It is true that many of the available methods to reduce emissions are capital-intensive and costly (e.g., new generation technologies, mass fleet electrification, etc.). However, in many cities and countries, expensive technical solutions are not yet feasible - at least not in the near future. It is therefore imperative to find and share locally affordable technical and non-technical solutions to curb pollutant emissions from road transport.

Luckily, there are many such solutions available, as this book explores. They occur at a range of scales and costs, and also at a range of implementation scales of time. In many cases, changes made carefully now can pave the way for more dramatic changes later. Relatively modest alterations can help to "future-proof" the transport system for later improvements, like set-aside areas for future pathways, transport stations and vehicle rights of way.

The more expensive technical solutions are often not even the best options for the global environment, and other options – including land use changes,

behavioural changes, and attractive non-motorised and public alternatives to private transport – are often better solutions, at least in the short term.

This is particularly true because only part of the emissions from transport comes from the vehicles themselves – the so-called "tailpipe emissions." We must also consider the embodied energy and emissions of vehicle manufacturing, as well as the embodied and operating energy of transport infrastructure – the streets, bridges, rail lines, signals, and other elements of the system. The fuel extraction, refining and delivery system is another important source of emissions generated for transport end use. For electric vehicles, we must consider the power source and its emissions, as well as the infrastructure for its delivery, and transmission losses and other impacts that contribute to emissions.

Often less well understood are the behavioural patterns of consumption that drive emissions, not only from the vehicles themselves, but also from the relatively high-emissions "choice architecture" of car-dependent places. Research shows that higher emissions from automobiles is closely associated with higher emissions from those who live car-dependent "drive-through" lifestyles. It seems that consumption and emissions drive more consumption and emissions, in a positive feedback loop.

The reduction of transport emissions is a particularly urgent topic in a time of historically unprecedented rapid urbanisation. Increased economic activity and welfare in many developing countries and emergent economies is lifting millions out of poverty and expanding well-being, but also giving rise to increased demand for transportation, and with it, increased level of emissions and resource depletion. There is an urgent need, then, to identify and share effective low-emissions alternatives.

This book is one resource in addressing that need. It is written for political leaders, decision-makers, practitioners, and other stakeholders in the transport sector, as well as for those responsible for land-use and community planning. It provides them with required information and analysis necessary to make decisions on sustainable and cost-effective transport and land-use solutions to reduce emissions. It is not meant to be an exhaustive compendium of solutions – many more will be needed in the years ahead – but rather, a useful contribution toward significant progress on the path ahead.

The book is organized into eight primary chapters. After discussing transport emissions trends and their impacts, we examine a number of low-cost technical options. We then examine demand-side reductions, including pricing signals and other feedback measures. The next section considers land use planning and allocation – a slower form of change, but a more powerful one over time. The optimum allocation of paths and rights of way is discussed in

detail. We conclude with financing and business models, certainly critical implementation topics.

The final chapter provides additional links and references, and further reading and resources.

As the title indicates, we are speaking only of land-based passenger transport, meaning that freight is excluded, as are air and sea passenger lines. Private automobiles and light trucks are included, as are taxis, buses, subway and passenger rail, ride share and TNCs, motorcycles, scooters, bicycles, and of course, pedestrians – those creatures who must begin and end every trip, even if only to a garage or car park. One cannot reduce emissions much from bicycles, of course; however, one *can* reduce emissions a great deal indeed, by shifting modes from private automobiles to bicycles, or to rail and bus. One can also reduce emissions by increasing the number of passengers per trip in private automobiles and decreasing the number of trips.

The emissions from passenger transport are complex, depending on the fuels used and other factors. They carry a range of impacts including damage to human health, ecological damage, and of course, contribution to global climate change. The latter comes from so-called greenhouse gases, of which carbon dioxide (CO_2) is the most prevalent, but by no means the only greenhouse gas emitted by transport sources. Roughly speaking, CO_2 is about eighty percent of all greenhouse gases. It is common in the research literature to combine all greenhouse gases into a "CO_2 equivalent," abbreviated as CO_2e. Herein we will either refer to measurements of CO_2e, or to CO_2 alone, with the understanding that another twenty percent or so of other greenhouse gases should be added to convert CO_2 to CO_2e.

When referring to greenhouse gas measurements specifically, we will generally adhere to research by the United Nations' Intergovernmental Panel on Climate Change (IPCC), peer-reviewed research vetted by them, or inventories measured according to their protocols. One must be very careful, however, to compare apples to apples, and this can be difficult. Inventories reflect different points of time, different definitions of sectors, different national and continental borders, and different kinds of measurements, such as per capita versus aggregate, and sector-based (measured where the activity occurs) versus consumption-based (measured where the consumption occurs that drives the activity). What is important is that all these measurements are aggregated in a consistent way, and in the case of transport, in a way that accurately reflects individual behaviours and consumption patterns. These are, after all, the ultimate drivers of emissions and their impacts.

Finally, the book is aimed at helping to expand the range of solutions to the problem of transport emissions, and to provide more modest-cost alternatives at the local level. It is not looking for "silver bullets" that may never come,

but rather, for "silver buckshot" – for multiple tools and strategies available now, that can not only reduce emissions, but improve quality of life for the residents of cities and towns. It aims to assist in the evolution of a new generation of transport and of its surrounding land use, that is safer, cleaner, more walkable, more transport-supportive, and offering a greater variety of choices in mobility. That, to us, is the road forward.

- The Editors


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1. INTRODUCTION

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1.1 ROAD TRANSPORT EMISSIONS TRENDS

Increased economic activity in both developed as well as developing countries along with globalisation is leading to higher income levels and thereby to changes in lifestyle, new patterns of mobility and comfort. This is in turn leading to increased car ownership, kilometres driven, increased levels of fossil fuel combustion and thereby, to increased levels of both local and global emissions. According to the 2021 World Energy Outlook (WEO), the transport sector has had the fastest growth in CO_2 emissions of any sector during the last years. In the WEO report it is mentioned also that transport emissions are nearly 2.5 Gt higher in the announced pledges scenario (APS) compared to the net zero emissions by 2050 scenarios (NZE), with road transport standing for around three quarters of the gap between the APS and the NZE scenarios [1].

Figure 1.1 shows the development of fuel consumption for both gasoline and diesel during the last decade. The steadily increasing trend in fuel consumption from 2010 to 2019 is disrupted in 2020, which is most likely the result of the pandemic that started in the beginning of 2020 and continued through 2021, though it showed signs of waning with the development and deployment of vaccines during 2021. The trend shown in Figure 1.1 corresponds to gasoline and diesel consumption for land transport including freight transport and passenger transport (both public and private). Therefore, the decrease in fuel consumption from land transport observed in 2020 does not necessarily mean that the consumption of gasoline and diesel for private car passenger transport decreased too. On the contrary, there are all the reasons to believe it may have even increased because of the recommendations given by the health authorities in many countries not to use public transport to avoid the spreading of the virus. In a similar way, the pandemic had also a significant impact on economic activity, which led to a decreased demand for freight transport and hence to a decreased demand for fuel, especially diesel.

It makes sense to believe that the increase in private car driving may persist or even increase in the coming years. The rationale behind this is that in the same way it takes some time for people to adapt to new habits; it takes also some time for them to leave the newly adopted habits; particularly if these new habits are associated with increased flexibility and comfort. It is therefore

believed that in most of the countries wherein owners of private cars that were not using their cars before the pandemic (yet started to drive their cars following the recommendations of health authorities) will continue to use their private cars even after the ongoing pandemic is over-- and for some time to come. Although there are yet no data available to support this assumption, it makes sense to believe this could be the case.

In the absence of appropriate incentives/disincentives, policies and regulations that can prevent the expected development described above, and at the same time speed up the deployment of cleaner and more fuel efficient vehicles, this development is likely to continue.

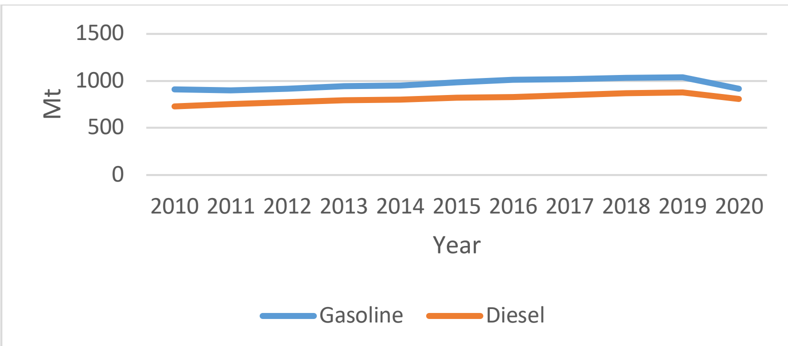

Figure 1.1 Road transport gasoline and diesel consumption (ethanol and biodiesel excluded), 2010-2020. Source: compiled by the author using data from ENERDATA.

The amount of fossil fuel consumed is directly proportional to the amount of both local and global emissions, of CO_2, this being one of the main precursors of climate change. In times of increased global temperature and the irreversible consequences it may have on our planet, these emissions are of particular concern. The direct relationship between fossil fuel consumption and CO_2 emissions is also reflected in the development of global CO_2 emissions over the same period from land transport as shown in Figure 1.2.

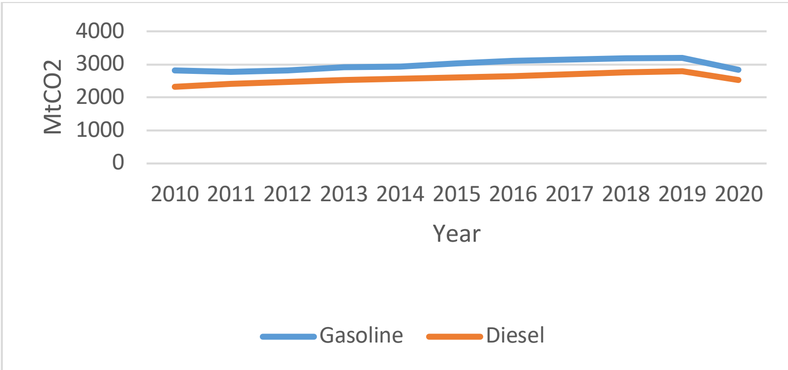

Figure 1.2 Global CO_2 emissions from land transport gasoline and diesel consumption (ethanol and biodiesel excluded), 2010-2020.Source: compiled by the author using data from ENERDATA.

Although the share of electric vehicles (EVs) in the global vehicle fleet has been steadily increasing during the last years, this is taking place mostly in high-income developed countries and not in poor developing countries. To expect EVs to be the solution to a global problem is still far from realistic for many low-income developing countries, where EVs are still not affordable. Much of the generation of electricity is also from fossil fuels, meaning that fleet electrification is far from a complete solution, even where it occurs. Therefore, more affordable technologies that can mitigate emissions are needed. In addition to this, policies and incentives leading to changed behaviour are needed. Reducing the level of emissions from land transport is not an easy task, nor there is a one size fits all solution. Nevertheless, there are a number of affordable options that could be applied to achieve this objective. These options will be presented in this chapter, and further elaborated in following chapters of this book.

The transport sector, and in particular the land transport sector, can play a crucial role in the objective of slowing down the current development due to its great emissions reduction potential, as nearly a quarter of the total emissions of CO_2 are originating from this sector (Figure 1.3). To exploit its full potential, a combination of policy measures, low-cost technical and non-technical solutions must be considered. These policy measures and solutions must take into consideration also the prevailing conditions of the particular country or city where those will be implemented. In this context, it is also very important to consider the specific social and cultural circumstances prevailing in the particular country.

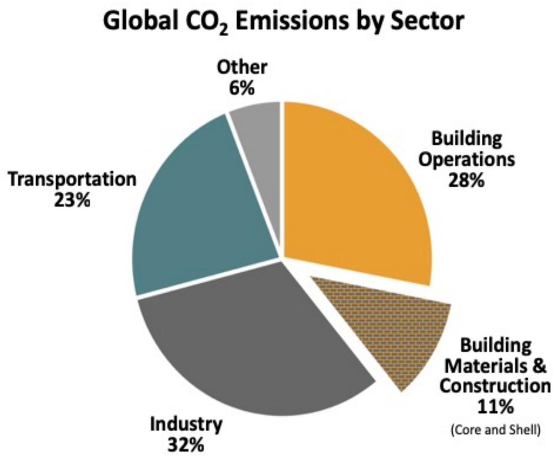

Figure 1.3 Share of CO_2 emissions by sector in 2018. Source: Global Alliance for Buildings and Construction, 2018 Global Status Report.

Of the total amount of the emissions from the transport sector as a whole, around 80% are originated by land transport alone (Figure 1.4).

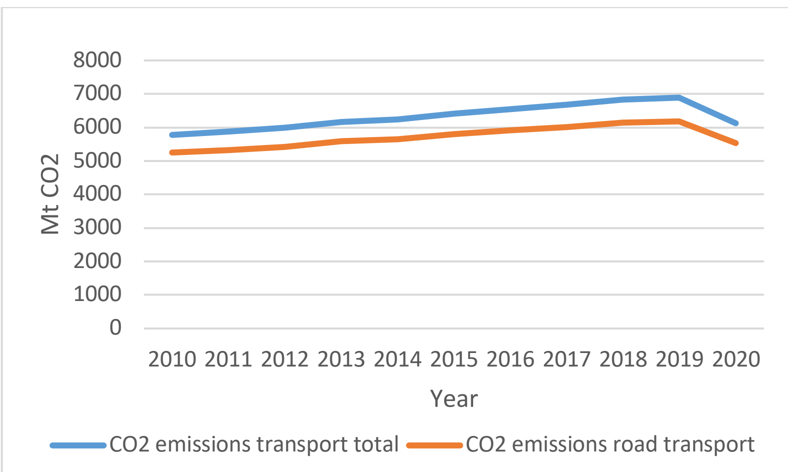

Figure 1.4 CO_2 emissions transport sector (total and land), 2010-2020. Source: compiled by the author using data from ENERDATA.

Currently, and in contrast to other sectors, which have been decreasing the levels of emissions during the last decade, with exception of 2020, emissions from land transport have been steadily increasing. For instance, the share of

land transport emissions in the EU increased from 13% in 1990 to around 20% in 2013 [2]. Global CO_2 emissions from the transport sector increased from approximately 5,300 Mt in 2010 to around 6,200 Mt in 2019, which is an increase equivalent to 17%.

1.2 WHY IT IS IMPORTANT TO REDUCE EMISSIONS FROM LAND TRANSPORT

Despite the fact that the negative impacts of air pollution on the environment (both local and global) are well known by the majority of people, and even directly perceived by many, there is still a minority of people and governments all over the world that are not fully aware of the consequences of it. Air pollution can be defined as the presence or concentration of substances in the atmosphere emanating from activities like fossil fuel combustion at levels that are harmful to human health and damaging for both the local and global environment. At the local level, these substances seriously affect human health and cause deterioration to cultural heritage by damaging, amongst others, materials, monuments and buildings. Some of the local land transport pollutants to which the mentioned impacts can be attributed to are: nitrogen oxides (NOx), sulphur oxide (SOx), particulate matter (PM), carbon oxides (CO) and volatile organic compounds (VOCs). These pollutants affect the local environment and human health in different ways with increased mortality and loss of productivity being some of the impacts. At the global level, the most known impact from the release of greenhouse gas (GHG) emissions into the atmosphere causing atmospheric pollution is climate change. Some of the impacts caused by these emissions on ecosystems and on the global climate system may be already irreversible-- and if emissions are not significantly reduced, further damages may be irreversible and of an unprecedented magnitude. One of the largest GHG contributors to climate change is CO_2. The increasing level of CO_2 emissions in the atmosphere over time is contributing to increased average temperature on our planet with consequences such as melting glaciers, increased frequency and intensity of extreme events. Some of the extreme events are storms and flooding, as recently observed in in the USA and Central America, and droughts and forest fires, as observed in recent years in Australia and the USA, in some European countries like Portugal and Spain, as well as in some Nordic countries like Sweden.

At the same time, transport, and in particular road transport, is vital for societies by providing a series of benefits. It allows the movement of people and goods, which are essential for life; it supports economic growth, which gives rise to increased employment, improved wellbeing, standards of living and comfort. However, for all these benefits not to be outweighed by the negative impacts, transport systems need to be planned in an integrated and sustainable manner, and emissions from this sector (both local and global)

significantly reduced. In 2018, motorised road transport (cars, trucks and light-duty vehicles) stood for over 80 percent of the total CO_2 emissions originating from the transport sector as a whole (Figure 1.3).

1.3 HOW IT CAN BE DONE, WITH MINIMAL COST AND MAXIMUM BENEFITS

Despite the fact that low cost measures such as regulations (mandated by law) and policies in the form of economic incentives/disincentives are sometime seen as less effective instruments to achieve emission reductions from the transport sector, experience shows, however, they can be effective and generate a number of benefits at the same time. Today there is evidence showing, for example, that the introduction of vehicle environmental standards like more fuel efficient and cleaner vehicles have resulted in reduced emissions in Europe. This thanks to the fact that most car manufacturers are complying with the imposed environmental standards and manufacturing more fuel-efficient and hence, low emission vehicles. The fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change, points out improved energy efficiency as one of the most important instruments to combat climate change. The transport sector is one of the largest energy consuming sectors and can, therefore, through improved fuel efficiency, play a significant role in reducing fuel consumption-- thereby combating climate change.

The International Council on Clean Transportation (ICCT) has been reviewing the impacts resulting from EU's fuel economy standards since 2001, and has found that, compared to the baseline scenario without mandatory CO_2 standards, CO_2 emissions have decreased on average by 18% thus reducing the total amount of annual emissions across Europe by 40 million tonnes [3]. Environmental standards, including improved fuel efficiency, constitute often a very low-cost measure for car buyers, since apparently, not much of the extra cost has been passed on to car owners.

Another low-cost policy measure that has proven to give rise to multiple benefits besides reducing emissions is Eco-driving. It has been already incorporated as an additional component in car driver courses in many countries, thus implying a marginal incremental cost. Eco-driving has been increasingly recognised as having a significant potential to reduce fuel consumption and thereby, both local and global emissions. Other benefits that can be mentioned are economic savings for car drivers (because of a more friendly driving style), and decreased level of noise pollution (due to more smooth acceleration and deceleration). Another important benefit of Eco-driving, because of a more friendly and relaxed driving style, is reduced number of accidents and hence reduced health care costs and saved lives. Eco-driving programmes have been introduced in countries outside Europe with

Japan and the USA being some of the examples. The multiple benefits have been observed when training has been given to private-car drivers as well as to bus and truck drivers. The main principles of Eco-driving will be covered more in detail in Chapter 3.

Fuel pricing policies constitute another effective policy measure. As mentioned earlier, they are an effective economic incentive/disincentive to achieve decreased fuel consumption and thereby reduced emissions. Although the impact of fuel taxes is slow, and sometimes insignificant in the short run – mainly due to the fact that car owners need some time for adaptation – the effect is more significant in the long run. A considerable number of studies on price elasticities show a positive price elasticity of between 0.5 and 1.5 [4]. For instance, estimations on fuel price elasticities for the Latin American region show a long-run price elasticity of around -0.6, which means a 10% increase in the price of fuel will give rise to a 6% decrease in the consumption of fuel [5]. Even though these elasticities were estimated more than a decade back, changes in fuel consumption due to fuel price increases are still prevailing, which can be confirmed by a number of studies undertaken later. A more extended explanation of how fuel-pricing policies work and the impact they may have in reducing private motorisation and fuel consumption is provided in Chapter 5.

There are a number of other measures that can be adopted by car drivers at a very low cost and which have significant benefits. One example is anti-idling, which has proven to have significant positive impacts by reducing both local and global emissions. There are several examples where anti-idling regulations have been introduced. The way anti-idling regulations are put in place and how they work will be further elaborated in Chapter 3. The introduction of low rolling resistance tyres (LRT) constitutes another example of low-cost measures. Other low-cost policy measures that have been implemented elsewhere are the introduction of car labelling. Massive campaigns to promote the use of bicycles including information about the multi benefits of biking is another example of a low-cost measure. These types of campaigns have been successfully implemented in a number of Latin American cities like, Bogota, Colombia; Quito, Ecuador; Santiago, Chile; Lima, Peru, and Concepción, Chile. In these cities, the implementation of massive campaigns promoting the use of the bicycle and its associated health and environmental benefits have resulted in a significant increase in the number of people starting to bike and that have started to consider the bicycle a valid and healthy mode of transportation. Below a massive campaign to promote the use of the bicycle in Concepción, Chile.

Figure 1.5 Massive campaign to promote the use of the bicycle in Concepción, Chile. Source: Solutiva Consultores

Like with many other policy measures, the effects of a campaign aimed at promoting the use of non-motorised transportation (NMT) takes some time before they are observed. However, in the campaign conducted in Concepción to promote the use of bicycles, the effects could be observed already after a short period. Soon after the implementation of the campaign, the need to focus efforts on younger generations that have yet to make their modal selection was recognised by the Chilean authorities. The campaign thus managed to change the perception of cycling and besides, create the necessary awareness of the benefits of NMT among politicians and decision makers. This way, the campaign led to gain the attention of the national government, which passed a bill to Congress to promote cycling in Chile. This materialised in the commitment of the National Government of Chile to programs encouraging the use of bicycles, not only in Concepción, but in other cities of the country where cycling is being intensely promoted [6]. The campaign conducted in Concepción, Chile, was one of the components of the GEF funded project implemented by the UNEP DTU Partnership aimed at promoting sustainable transport in Latin America.

REFERENCES

[1] World Energy Outlook, International Energy Agency, 2021.
[2] Explaining Road Transport Emissions: A non-technical guide. European Environment Agency, 2016.
[3] Online source: www.globalfueleconomy.org/blog/2018/december/progress-on-eu-fuel-economy-standards-for-2030.
[4] Online source: https://scholar.harvard.edu/files/alada/files/price_elasticity_of_demad_handout.pdf
[5] Journal article: Rogat, J. and Sterner, T. "The Determinants of Gasoline Demand in some Latin American Countries". International Journal of Global energy Issues, 1998.
[6] Report: United Nations Environment Programme. Terminal Evaluation of the UNEP/GEF Project "Promoting Environmentally Sustainable Transport in Latin America (PSTLA)", October 2011.

2. THE NEGATIVE IMPACTS OF PASSENGER ROAD TRANSPORT EMISSIONS

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2.1 OVERVIEW OF ROAD TRANSPORT EMISSIONS AND SCOPE OF DAMAGES

Emissions from the road transport sector have a number of negative externalities on the local as well as on the global environment. At the local level, pollutant emissions have negative impacts on urban places (buildings and monuments), on agriculture productivity (decreased crops yields), and most importantly, on human health. At the global level, they contribute to increased temperature and climate change. All these impacts (both local and global) have considerable impacts on the economy in terms of increased expenses due to, for example, restoration of buildings and monuments (because of deterioration of materials by smog), and increased health care expenses (due to deteriorated health among children and the elderly).

Air pollutants like particulate matter (PM), sulphur oxides (SOx) and volatile organic compounds (VOCs), to mention a few, severely affect human health. This can be observed already in a number of megacities of the developing world, with Delhi, Mexico City, and Santiago, Chile being some of the examples. Concentrations of pollutants such as PM and SOx have been steadily increasing in many cities of the world. The impacts of high concentrations of these emissions may vary depending on a number of local circumstances such as geographical location (cities surrounded by mountains), meteorological conditions (cities characterised by anticyclonic conditions), and whether the cities are affected by inversion or not. Inversion is an atmospheric phenomenon during which cold air is closer to ground level than warm air. This makes the temperature of the air rise as it gets further from ground keeping pollutants between the air layers at an altitude of about 600 to 900 meters above the city [1]. During these episodes, human health is seriously affected. This phenomenon occurs often during wintertime in cities which are situated at low altitude and locked by surrounding mountains like Santiago, Chile and Mexico City. The negative effects of this phenomenon may be significantly worsened under the presence of anticyclonic meteorological conditions, which is the case of many places. Exposure to

these conditions by unhealthy people, the elderly and children, may have a deadly outcome.

Other factors which can be directly associated with air pollution, and in particular with high concentration levels of air pollution are age of the existing vehicle fleet, type of fuel used, and vehicle maintenance. Evidence shows that in cities with poorly maintained older vehicles, the levels of pollution are much higher. This particularly applies to cities in low income countries in Africa, and parts of Asia and Latin America. For instance, in poor African cities with poorly maintained vehicles, which besides are predominantly driven by diesel as the main combustion fuel, extremely high levels of air pollution are observed. In these cities, where the smog can be clearly seen, the allowed concentrations levels are exceeded often by far.

At the global level, and as mentioned in Chapter 1, the transport sector, as a whole, stands for around a quarter of the CO_2 emissions. Notably, out of this, 80% can be attributed to road transportation, and a significant percentage of this (roughly half) is attributable to passenger transport. These emissions are having detrimental impacts on the climate, which will be discussed in Section 2.4. This section focuses mainly on the local impacts of air pollution, particularly on human health and the economy.

2.2 LOCAL IMPACTS ON HUMAN HEALTH

As mentioned earlier, the various pollutants emitted by road transportation have a series of impacts on the local environment and human health, and as mentioned above, the magnitude of their impacts will vary depending on the prevailing conditions of a particular city. Below a more detailed description of the impacts the various pollutants from road transportation may have on human health.

NOx: these gases affect mainly the respiratory system where nitrogen dioxide (NO_2) is one of the most toxic gases, with symptoms such as increased airway resistance at concentration levels of about 0.5 ppm. Acute exposure to NO_2 decreases gaseous exchanges in the blood and increases respiratory symptoms leading to lower lung-function values. At the global level, NOx is one of the main contributors to acid rain and eutrophication.

Ozone (O_3): even though not often mentioned, this pollutant may have serious impacts on human health. This gas is created in the lower atmosphere by the effect of sunlight on hydrocarbons and nitrogen oxides, which are released from incomplete burning of fossil fuels. Even low concentrations of this gas can give rise to throat irritation, producing cough. It may also produce headaches and even cause asthma attacks. Besides the described effects on human health, it has also negative impacts on agriculture, namely, on plants and crops.

SOx: these emissions are formed when sulphur is burnt through combustion. SOx emissions have impacts on the respiratory system, impacts that can be severe in inner cities. One well-known example is the episode of the "London Smog" which took place after the war period. Subsequent studies showed that the premature death of thousands of people in London during the 5 days in December of 1952 could be related to the high concentrations of SOx and PM, episode that was worsened by the occurrence of inversion.

Figure 2.1 London smog episode of 1952. Source: RV1864 via Flickr.

PM: also known as suspended particulate matter, refers to a wide range of finely divided solids or liquids emitted into the air from combustion processes such as fossil fuel combustion in vehicles. They can vary in size and be between 0.1 and 0.25 μm in diameter. These are dispersed into the air and if of small enough size (10 μm) they will bypass the respiratory system's own mucus filtering process and penetrate the lungs, causing illnesses such as bronchitis. PM are especially harmful for children, the elderly and pregnant women.

CO: colourless and odourless gas resulting from the incomplete combustion of carbons in fossil fuels. It combines with haemoglobin over 200 times faster than oxygen and blocks its function which restricts the supply of oxygen to the blood. If 50% or more of the haemoglobin is transformed into carboxyl haemoglobin, it can cause death. Some of the most common symptoms of CO contamination are headache and dizziness, these symptoms may appear at levels of 10%, which corresponds to concentrations of around 100 parts per million (ppm) of CO.

HCs: These gases, and in particular volatile organic compounds, (VOCs) are normally the result of incomplete combustion in vehicles. They give rise to the formation of ozone and photochemical smog in the atmosphere. Besides, these gases cause impacts in the lungs and affect the respiratory system.

Table 2.1 shows projections made by the OECD on the global health impacts on human health as a consequence of air pollution in 2010 respectively 2060. The projections are based on forecasted concentration levels of PM (PM of 2.5 μg) and ozone, and although these concentration levels correspond to outdoor pollution as a whole, they are indicative for the road transport sector, having in mind the sector's significant contribution to air pollution.

	2010	**2016**
Bronchitis in children aged 6 to 12	12	36
Chronic bronchitis in adults	4	10
Asthma symptom days (children aged 5 to 19)	118	360
Hospital admissions	4	11
Lost working days	1240	3750
Restricted activity days	4930	14900
Minor restricted activity days (asthma symptom days)	630	2580

Table 2.1. Projected global impacts of outdoor pollution on human health (million cases). Source: Adapted from OECD Policy Highlights The Economic Consequences of Outdoor Pollution, June 2016.

2.3 ECONOMIC IMPACTS

Most of the impacts local air pollution has on urban areas (buildings and monuments), on agriculture (crop yields), and most importantly, on human health have, in one way or another, consequences on the economy. Currently, the negative impacts on human health are leading to deteriorated health, lost working days and thereby, decreased productivity. Projections show that globally by 2060, the annual number of lost working days are expected to reach 3.7 billion. Globally, air pollution-related healthcare costs are projected to increase from USD 21 billion (using constant 2010 USD and PPP exchange rates) in 2015 to USD 176 billion in 2060 [2].

In the absence of the appropriate measures to stop this development, the consequences of air pollution will continue to worsen in the coming years and decades. This is mainly due to increasing economic activity and hence increasing income levels, which in turn leads to increased car ownership, demand for transport fuels and kilometres driven. It is well known that increased income levels in many parts of the world are leading to increased demand for comfort and mobility. This relationship can be illustrated in figure 2.2.

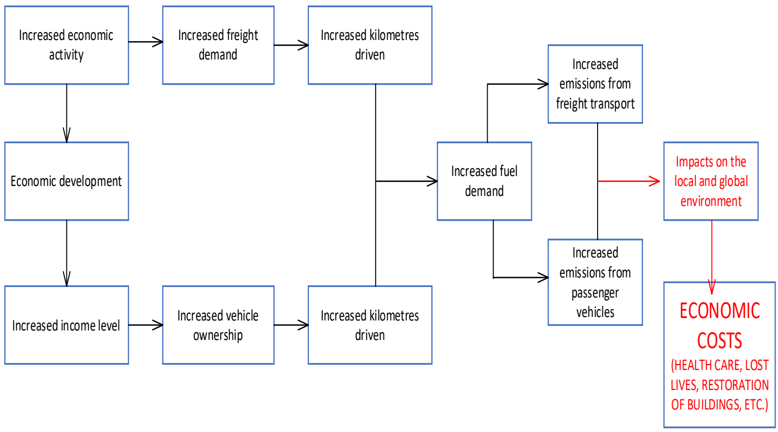


Figure 2.2 Relationship between economic activity and impacts. Source: The authors.

Figure 2.2 shows the direct relationship between increased economic activity and the impact it may have on the environment and ultimately on the economy, if the necessary measures that can enable a sustainable growth are not taken. Therefore, in the absence of more stringent regulations, policies, incentives and disincentives aimed at reducing pollution, the current development taking place in many countries will likely continue. This section deals with the economic consequences of local air pollution, while section 2.4 deals with the impacts on the global climate.

At the local level, pollutant emissions like SOx and PM contribute to deterioration of buildings, monuments and depletion of materials. These impacts lead to direct costs for societies since buildings and monuments need to be restored. They have also direct economic consequences on agriculture as more resistant crops need to be developed. In addition to this, local air pollution has severe impacts on human health, giving rise to cardiovascular and respiratory diseases and premature deaths. All these impacts pose significant costs on society in terms of lost lives and healthcare costs.

	OECD		**World**	
	2015	2060	2015	2060
Total market impacts	90	390	330	3300
Share of income	0.3%	0.5%	0.6%	1.5%
Total non-market impacts	1 550	3 750 - 3 850	3 440	20 540 - 27 570
Share of income	5%	5%	6%	9 - 12%

Table 2.1 Welfare costs of air pollution (billions USD). Source: Adapted from OECD Policy Highlights The Economic Consequences of Outdoor Pollution, June 2016.

2.4 IMPACTS ON THE CLIMATE

As we discussed in Chapter 1, the transport sector as a whole accounts for a sizeable and growing share of all greenhouse gas emissions and is thus the principal contributor to global climate change [3]. Furthermore, the true contribution of the transport sector must reflect a full life cycle analysis including construction, operation and maintenance of roadways, railways, vehicles, fuel production facilities and other components of the transport system. Depending on the inventory and the methods of assessment, the magnitude is in the range of one-quarter of all GHG emissions [4].

Within this sector, the contribution of passenger surface transport – cars, taxis, buses, ferries, rail, motorbikes and scooters – is also sizable and growing, up to 10% of all emissions. Clearly, some of these modes are more efficient than others when it comes to a key metric: the emissions per person. When measured in this way, it becomes clear that private motorized vehicles (cars, taxis and motorbikes) are making an outsize contribution, and one that is growing alarmingly in many parts of the world. This is simply not a sustainable path.

In addition to the already discussed emissions impacts on health and economic productivity, the projected impacts on the global climate are nothing short of catastrophic. While the science is less clear about the specific impacts of global climate change for different regions of the world, there is now an unequivocal consensus within atmospheric science and related disciplines that the phenomenon is occurring, and that it is already beginning to bring – and without urgent remedy is likely to bring with increasing severity – a growing series of human disasters [3].

In August, 2021, the Intergovernmental Panel on Climate Change, an intergovernmental body of the United Nations' 195 members, issued a report titled *Climate Change 2021: The Physical Science Basis*. This 3,949 page report was authored by 234 scientists from 66 countries, reflecting research from more than 14,000 scientific papers. Among the report's assessment of impacts:

- Sea-level rise of one-half to one metre is likely by 2100, but two to five metres is not ruled out;
- Extreme weather is likely to increase in correspondence with rising temperatures, with compound effects (e.g. heat and drought together) impacting many, including vulnerable populations;

- There is likelihood of “an increasing occurrence of some extreme events unprecedented in the observational record," such as catastrophic heat waves, high winds, flooding, and wildfires.

On 12 October 2021, the World Health Organization also issued the “COP26 Special Report on Climate Change and Health,” noting a number of severe impacts on human health including extreme heat, the increased spread of infectious food-, water- and vector-borne diseases, the disruption of food systems, and secondary impacts on mental health. Furthermore, the report notes, climate change undermines many of the social determinants for good health, and “threatens to undo the last fifty years of progress in development, global health, and poverty reduction” [5].

Among other goals, the report sets a goal to “promote sustainable, healthy urban design and transport systems, with improved land-use, access to green and blue public space, and priority for walking, cycling and public transport.” Included in its action points are:

1. Phase out the internal combustion engine and reduce private car use. End the sale of petrol and diesel vehicles and support a shift away from private car use.
2. Prioritise walking, cycling and public transport. Prioritise walking and cycling as healthy low-carbon modes of transport.
3. Create people-centred cities. Integrate health and equity and nature considerations into urban and transport planning to create compact and future-proof cities.

While many impacts from climate change are already emerging and are likely to become more serious, it is also clear that actions taken now can have dramatic benefits, at least relatively speaking. For one thing, we may lessen the severity of future impacts. For another, we may be able to build a more resilient and adaptive world in which changes in climate have a lesser impact than they otherwise might.

These and other reports note that action now is particularly urgent because of a phenomenon known as “path dependency.” The path we choose today shapes the choices we will find available tomorrow, and this effect is magnified over time. The more we build fragmented and auto-dependent street networks now, for example, the harder it will be to change those streets later, and the more we will increase our dependence on high-emissions private automobiles, and related disruptive systems. Furthermore, emissions are not eliminated when vehicle fleets are electrified, since embodied energy and materials tend to generate emissions, as do many fuel sources for electric energy – at least for the foreseeable future.

Research has shown that alternative models of practice and supporting policy – particularly in the transport sector – *can* achieve significant GHG emissions reductions from current baselines [6]. By contrast, "business as usual" development models are likely to result in dramatic *increases* of rates of emissions, causing even greater negative impacts in the decades and centuries ahead.

We have seen encouraging examples of successful collective action from the recent past. For example, in just the last two decades, concerted international action has arrested the emissions of dangerous chlorofluorocarbons, resulting in the recovery of the Earth's critical ozone layer [7]. We *can* take effective action now – sometimes large-scale international changes in transport systems or technologies, but sometimes too, small-scale, cost-effective shifts in the ways we get around, as this book discusses. In that and other ways, we *can* put ourselves on the path of reducing emissions impacts on our health, on our economies, and on our global climate.

REFERENCES

[1] Doctoral thesis: The Value of Improved Air Quality in Santiago de Chile. Jorge Rogat, 1998.
[2] Report: OECD Policy Highlights the Economic Consequences of Outdoor Pollution, June 2016.
[3] IPCC AR6 WG1 (2021). "Technical Summary." Arias, Paola A.; Bellouin, Nicolas; Coppola, Erika; Jones, Richard G.; et al.
[4] IPCC (2021). Sixth Assessment Report, "Climate Change: The Physical Science Basis." Available on the Web at https://www.ipcc.ch/report/sixth-assessment-report-working-group-i/
[5] World Health Organisation (2021). COP26 Special Report on Climate Change and Health. Available on the Web at https://reliefweb.int/report/world/cop26-special-report-climate-change-and-health-health-argument-climate-action
[6] Mehaffy, M. (2009). The factors of urban morphology in greenhouse gas emissions: A research overview. IOP Conference Series: Earth and Environmental Science, Volume 6, Issue 20, pp. 202-203.
[7] United Nations Environment Programme (2014), Ozone Layer on Track to Recovery: Success Story Should Encourage Action on Climate. 10 September 2014. Available on the web at http://www.unep.org/newscentre/Default.aspx?DocumentID=2796&ArticleID=10978&l=en


Lime-S
GPS Tracked

3. LOW-COST TECHNICAL OPTIONS, DRIVING TECHNIQUES AND REGULATIONS

TALAT MUNSHI, JORGE ROGAT
UNEP DTU PARTNERSHIP

3.1 MICRO-MOBILITY OPTIONS FOR FIRST AND LAST MILE CONNECTIVITY

Growing cities, changes in urban form and travel patterns have led to an increase in the demand for transport and distances that people travel [1]. In dense urban settings, individual automobiles are no longer considered as sustainable modes [2] as space is finite and use of individual automobiles have large economic environmental and social costs associated with it [3]. There is a limit to investments in the construction of new transport infrastructure, especially the transport network, to meet this growing demand. Supply of new public transport infrastructure is costly, and therefore theoretically there is a limit to how many destinations a public transport network can reach by itself. Instead, there is a need to optimise cost by making use of existing infrastructure [3]. Vehicles that can carry one or two passengers, also termed as micro-mobility solutions, are increasingly taking the central stage and have led to a fundamental change in the manner in which urban residents travel in many cities across the world.

When residents choose between modes and routes, they consider the entire journey. That is, in the case of public transport mode, the access (first mile), the line haul (the primary public transport mode including transfers if required) and the egress (the last mile) [4]. Thus, the public transport mode is always multi-modal, and the first and the last mile connectivity more-or-less describes the difficulty or the ease of completing a journey using the public transport system. The first mile and the last mile issue can plague the cities with good public transport infrastructure [5]. In practice, public transport loses on efficiency when compared to privately owned automobiles as there are limited options available once a person leaves the line haul (public transport infrastructure, for example, Bus Rapid Transport System). In table 3.1, statistics of access and egress mode and distances residents travel while accessing and egressing from the public transport system are presented. From the data presented in table 3.1, it is clear that most first and the last mile trips are made by walking. The distance that residents are willing to or can physically walk from the public transport system is limited, so, the first and the last mile of public transport systems becomes a barrier to use public transport modes. These barriers also limit the geographic coverage of public

transport as urban transport planners cannot keep adding public transport routes and stops. This transport conundrum is not very good for the efficiency of the transport system; moreover, the use of private automobiles contributes to increasing air pollution.

		Walk	Cycle	E-Cycle	Private Automobile	Bus	Para-Transport
Delhi Metro	Access	40			11	12	37
	Egress	56			3	9	32
Beijing	Access	54.4	8.3	3.8	4.2	29.3	
Metro	Egress	73.5	1.1			25.4	
Copenhagen	Access	51	24	3.8	10	15	
	Egress	77	6		3	14	

Table 3.1 Modes and travel time and distance to public transport mode.
Source: Compiled by the authors

Most studies in the past have assumed walking to be the most preferred mode for the public transport user and have recommended demand-side measures that require changes in urban form around the station areas to support it by measures such as increasing the density, land use mix, and better street design. These interventions ensure more opportunities are available around the transport stations, and it is easy for residents to access them by walking. However, there are limits to demand-side measure. For better optimisation of the public transport system and increasing its geographic reach there is a need to introduce access and egress modes that allow public transport users to access an egress from and to the system from longer travel distances without compromising time and effort [6].

An integrated transport system which combines public transportation and micro-mobility solutions like e-bikes and e-scooters can help to solve the first and last mile connectivity problem to an extent. Thus, vehicle sharing is among the several concepts that are being considered as an option to reduce the barriers that public transport users face during the first and last miles of their connectivity.

With the advancement in digital technology and flexible payment options, the bike-sharing market has developed [7]. Growing categories of transport options are available that provided on-demand mobility to an individual, particularly at the locations that have crowded and narrow streets. These micro-mobility services are usually docked/dockless, use the mobile phone-GPS connectivity to track vehicle locations, and are designed for the first and the last mile connectivity [8]. These modes provide the simplicity of sharing vehicles with others while saving on cost and increasing flexibility, especially in the case of shared electric scooters. However, as we see in most similar initiatives, these micro-mobility solutions are facing many problems with issues like unsustainable business models, fleet management, public safety and vandalism [9].

3.2 E-BIKE SHARING FOR THE FIRST OR LAST MILE

Public bike-sharing has been promoted by several platforms in the last decade as a sustainable mobility solution to improve the first and the last mile connectivity of public transport systems. Globally there has been a rapid increase in both technologies (e-bikes and e-scooters). These technologies allow sharing of bikes and the use of electric bikes with a general hope that e-bikes can help in decarbonising the transport system. E-bikes have been a popular mode of transport in Asia, mainly China, since the 2000s, and it is gaining popularity in Europe in recent years [10]. Because e-bikes require much less effort when compared to the conventional bike, they improve the capacity and the ability of the residents to reach and access the public transport system. However, they are more expensive compared to the conventional bike and are not a natural replacement for walking and conventional bicycles.

Nevertheless, they can be looked at as a replacement for the automobile both private and shared (autorickshaws and taxis). Although speed paddled, e-bikes can have speed up to 45 km/h, shared e-bikes have maximum speeds in the range between 15-25 km/h. A typical trip distance by walking is less than 1.5 km, and average walking speed is around 4-6 km/h, this can increase to 0.5-8 km trip distance in the case of bicycles, and 0.5-15 km in the case of e-bicycles.

Bike hire schemes have long been in operation. The first bike-sharing programs were in the form of free bikes in an area which anyone could share and use. The next group of shared bikes were like the once introduced in Denmark in 1991, which used coin deposit stations; these were later replaced with automated stations. The docking station was introduced which allowed bikes to be borrowed and rented from an automated station or the docking stations and returned to the same or any other docking station. Till 1990 there were only ten cities across the globe that had bike-share schemes, by early 2000, the number of bike-sharing schemes globally has grown to more than 2900 which includes e-bike sharing schemes [11].

3.3 ELECTRIC SCOOTERS

Two different types of e-scooters are currently entering the market, that is, the (stand-up) e-scooter and the ev-scooter (a moped on which the driver sits.) The scooter has been an essential mode of transport in many parts of the world, especially in the tropic and in urban areas with congested streets [13, 14]. Till recently these were only available as mopeds with Internal Combustion Engines (ICE) and were mostly privately owned except few cities like Bangkok where there is a long history of using a motorbike as a public transport mode.

Development of e-scooters started in the 1980s, but the market for e-scooters has picked up in the last decade. Two types of e-scooters are currently entering

the market, that is, the (stand-up) e-scooter and the ev-scooter [12]. Most electric scooter manufacturers are from China, Taiwan and Japan; China is the leading producer and user of e-scooters. The market for e-scooters outside the Asia-Pacific region is very small now. However, the e-scooter global market is projected to grow at a very rapid rate. In most cities, the residents do not always have to purchase their own micro-mobility solution as the electric kick scooter (stand up) has recently grown in popularity with the introduction of rideshare companies that use apps allowing users to rent scooters by minutes. The trend of using e-scooters for micro-mobility was re-energised in 2018 when they were available as shared and dockless electric scooters-- pioneered by Lime and Bird in the US [8, 15]. The e-scooters, as can be seen from figure 3.1, are present worldwide and are expected to increase their presence, as more and more rental companies will get funds to introduce these into cities [16].

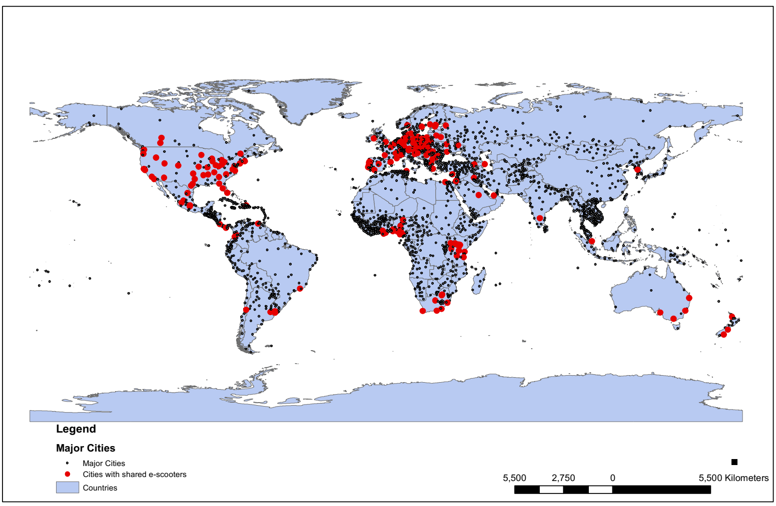


Figure 3.1: Cities with the presence of e-scooters as a micro-mobility solution (source: compiled by the authors)

However, recently there have been growing concerns regarding public safety that have led to problems not anticipated by the city planners [13]. As e-bikes and e-scooters are easy to access and exit, there are problems related to conflict of space (where they are parked) and have necessitated the need to reorganise road spaces in urban areas. They have also forced city planners to introduce segregated bicycle lanes which can also be used by e-scooters. The traditional bicycle lanes also need modification to accommodate requirements for higher speeds. There are issues regarding speed limits, and dangerous manoeuvres around pedestrians and bicyclists, which have raised safety concerns. Cities have also observed issues such as vandalism. Micro mobility

solutions that are dockless (which include dockless bikes and e-scooters) tend to litter footpaths, parks and other spaces like water bodies. Even though companies providing micro-mobility solutions pledge daily pickups, littering stills remains an issue. E-scooters signalling while turning or stopping is also an issue as it makes the rider unstable while riding, moreover abuse of e-scooters, like use by more than one rider, has been observed. The nuisance caused by e-scooters has resulted in a ban on its use in many cities like Copenhagen. In Stockholm, Rachmanto (2020) observes that e-scooters have decreased the level of comforts of pedestrians, yet the e-scooter riders themselves feel that bike lanes are not conducive for e-scooter use and several solutions especially in urban design are needed to solve the pedestrian and e-scooters conflict. The Swedish Transport Agency has also called for electric scooters to be banned after an accident involving e-scooters.

Questions are raised regarding environmental benefits from e-scooters. Life-cycle analysis by Hollingsworth and Copeland [17] show that life cycle global warming impact (GWI) of 125 g CO_2-eq/passenger-km. A large portion of this, 43%, comes from the daily collection for charging. Life-cycle GWI of internal combustion petrol engine vehicle (ICEV) is the range between 240 - 300 g CO_2-eq/km[18], per person impact would be around 165 g CO_2-eq/passenger-km (considering a vehicle occupancy of 1.45)[19, 20], the life-cycle GWI of a two-wheel motorcycle is 176 g CO_2-eq/ km (146 g CO_2-eq/passenger-km). These numbers indicate there are only marginal GWI benefits when using e-scooters over petrol two-wheelers and cars. E-scooters could replace walking trips for the first and the last mile connectivity to public transport, therefore, the introduction of e-scooters to the transport system could end up having adverse climate change impact and the business-as-usual case (with no e-scooters).

However, micro-mobility solutions like e-scooters also increase the reach to public transport, which could result in most mode shifts from intermittent public transport system like autorickshaws to e-scooter in cities like Ahmedabad. Better access to public transport system can also result in shifts from other modes to public transport. Public transport modes like buses have less than half global warming impact compared to a petrol car. The end GWI of e-scooters will of course depend upon travel behaviour of the residents before and after its introduction. Nevertheless, there are many health and safety concerns as suggested by Comer et al. (2020) E-scooter introduction should therefore be done with caution, and with appropriate state and local law and regulations. A widespread awareness-raising and education of end users might also be required, if they are to be introduced as a mainstream vehicle.

3.4 FIRST AND LAST MILE CONNECTIVITY

Figure 3.2 is a conceptual diagram, which explains how micro-mobility solutions like the e-scooter are integrated into the public transport system and help in the first and the last mile connectivity. Public transport users can walk to nearest available e-scooter. The location of which can be easily found out using an app which in most cases should not be more than 100 m as e-scooter are plenty available in cities where they have been introduced. Once the user is able to access the e-scooter they use it till the public transport stops-- this can be a Metro, BRTS or a regular bus stop. The public transport user drops the scooter (exits) near the public transport stop and accesses the public transport main mode. Likewise, while egressing from the public transport mode, the public transport user finds a scooter close to the public transport stop and rides it till his/her destination. Many public transport systems also allow the scooters to be folded and carried on the system, so it should also be possible for the public transport users to get on the public transport mode, where allowed, with the scooter and use the same scooter as the egress mode.

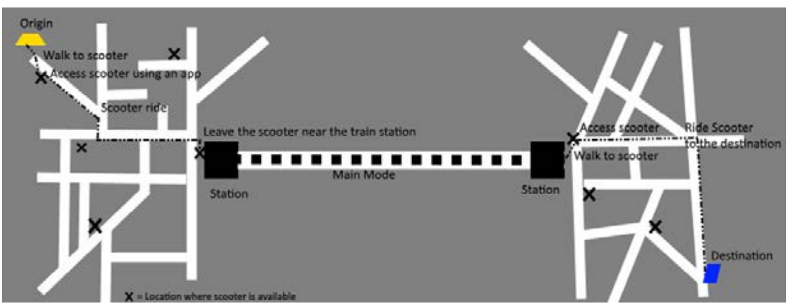


Figure 3.2: Schematic representation of how standalone e-scooters can be integrated with public transport

Figure 3.3 is the computation of accessibility to the public transport system in the city Ahmedabad for two scenarios. The first is when all public transport users walk to the nearest public transport stop, and the second scenario is when all public transport stop (BRTs+metro) user use e-scooters to the nearest public transport stop. Less than 5 minutes of access and egress time is generally accepted thresholds for public transport indicating good accessibility to the public transport system. From figure 3.2, it is clear that a large section of the walled city part of Ahmedabad will have to walk for more than 5 minutes to access either BRTS or the proposed Metro system in the city. However, if Ahmedabad was to introduce e-scooters to access public transport then most parts of the walled city could access a public transport stop in 5 minutes and the entire walled city area in less than 7.5 minutes. This indicates that if e-scooters were integrated into the public transport system, the accessibility to the public transport system and thereby to the location using the public transport system would increase substantially.

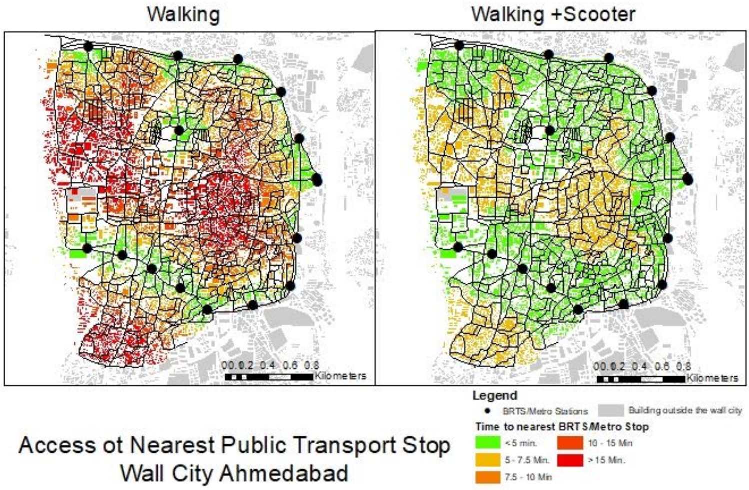


Figure 3.3: Access to nearest public transport stop in Walled city of Ahmedabad

From figure 3.3, it is evident that if residents use faster access and egress mode, the time required to access public transport is reduced, and the e-scooter (because of its flexibility of getting on and off in standing position) can be a good option. Likewise, e-bikes can be manoeuvred easily and provide a good option for first and last-mile connectivity. Thus, similar benefits can also be assumed for e-bike users; the only difference would be the requirement for bicycle docking station at both ends of the first mile and the last mile trips which can add inconvenience and increase travel time of the trips. E-scooters need to be collected as stated which adds to its overall operating and maintaining cost.

3.5 ECO DRIVING

Eco-driving is being increasingly recognised as a cost-effective and immediate measure with a significant potential to improve fuel efficiency in vehicles and thereby fuel consumption. Reduced fuel consumption means in turn emissions reductions with the known benefits for both the local and global environment. Eco-driving is essentially about a driving technique which is more fuel efficient and environment-friendly, and that can be easily adopted by any driver. It is of particular interest since the technological improvements in new vehicles are not enough to, on their own, achieve the necessary emissions reductions. According to IRU Academy, eco-driving can improve fuel efficiency by up to 15% [21]. The principles of eco driving are quite simple and can be implemented by any driver of a vehicle, whether it is a car, a bus,

a light or heavy duty vehicle. Eco driving is basically about a series of measures that can be taken by the driver such as maintaining a constant speed (avoiding sudden acceleration or deceleration), shifting gears optimally, and avoiding high speeds since this will inevitably increase fuel consumption. Optimal gear shifting is particularly relevant when it comes to cars with manual transmission. Most, if not all, of today's new vehicles indicate in the front panel when it is time for shifting to a lower or a higher gear. For owners of older cars, which are not equipped with this technology, it's important to listen to the sound of the engine. For instance, louder engine sound means the engine is working at unnecessarily high RPM (revolutions per minute) which leads to higher fuel consumption, and therefore shifting to a higher gear is needed. This may not be easy to notice at high speeds, but it is definitely possible at lower speeds. Another technique that can be used to reduce fuel consumption is "block changing", which means gear shifting does not need to be in sequence but that the driver can skip next gear and jump to a higher gear instead [22]. This has benefits such as increased fuel efficiency and preserves the life of the car's clatch. Although all these eco-driving techniques may appear trivial, not providing significant benefits in terms of reduced fuel consumption, in fact they do. Therefore, eco-driving programmes should be introduced at a larger scale to take advantage of the multiple benefits of eco driving. This especially because eco-driving programmes constitute a very low-cost measure since the training can be added as an additional training component in already existing driver training programmes, and this is normally the way it has been introduced in many countries.

Evidence from a number of EU countries where eco-driving programmes have been introduced shows it has given rise to multiple benefits for the environment as well as for car owners' economy, this since decreased fuel consumption leads to reduced fuel expenses. Another benefit for the local environment and human health is reduced exposure to pollutants like NOx, SOx and particulate matter. For the global environment, the main benefits are in terms of CO_2 emissions reductions since these emissions are directly proportional to fuel combustion. Furthermore, there are also benefits for society at large in terms of reduced number of car accidents, with corresponding benefits such as reduced need of health care and costs related to car repair. These are all benefits that can be attributed to a more friendly and relaxed driving style. Table 3.2 below shows a taxonomy of some of the benefits eco-driving give rise to.

Area benefitted	**Benefit**
Safety	• Increased road safety • Improved driving skills
Environment (local/global)	• CO_2 emissions reductions • Local air pollution reduction • Noise pollution reduction
Economics	• Reduced fuel consumption • Reduced maintenance expenses • Reduced healthcare expenses due to car accidents
Social	• More responsible and relaxed driving • Stress reduction while driving • Increased ride comfort for both driver and passen

Table 3.2 Benefits of eco-driving. Source: The authors.

One example of the positive impacts of eco-driving is the programme introduced in the EU, the ECOWILL (Widespread Implementation for Learner Driver and Licensed Drivers) project. The programme, which was supported by the European Commission Intelligent Energy Programme, was implemented during 2010 and 2013 in 13 EU countries [23]. Among the results that could be observed is an average reduction in fuel consumption of between 9.2 and 18% among the drivers that attended the short duration training. The weighted average fuel consumption reduction found in the 13 countries of the ECOWILL programme was 14%. Other benefits from the programme were reduced levels of emissions and decreased number of accidents.

Achieving a more economic and friendly driving style can be facilitated with newly developed technological devices that can guide drivers (prior to driving, while driving or post driving) on how to do it thus achieving the expected benefits of eco-driving. Figure 3.4 shows an example of an eco-driving device. A similar device was used in a study conducted in the Riverside area, California, USA in 2010. In this study, 20 drivers used the eco-driving device, known as Eco-Way for their daily commute for two weeks. The study found an improvement in fuel economy of 6 percent on city streets and 1 percent on highways [26].

Figure 3.4. Eco-driving device.

Real-time normalised indicators as the one specifically developed for this purpose constitute an excellent tool to, in real time while driving, support the driver to achieve a more economic, secure and environment-friendly driving style. This communication device provides immediate feed-back to the driver who can adjust to a more economic and friendly style during the trip itself. It can provide also a post driving summary illustrating the driver's actual costs incurred by driving on a trip-by-trip basis, thus suggesting changes to his/her driving style.

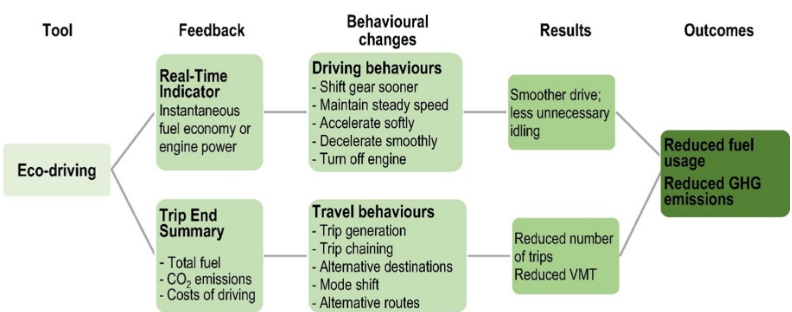


Figure 3.5. Communication of eco-driving results, conceptual framework. Source: Transportation Research [27]

Other measures aimed at improving vehicle and fuel efficiency that are suggested in eco-driving programmes are good maintenance, regular checks

of the car such as tyre-pressure, reduction of unnecessary vehicle weight, and to avoid unnecessary idling. Anti-idling measures will be further discussed in next section, while the benefits of using LRR tyres will be presented in section 3.7.

3.6 ANTI-IDLING REGULATIONS

Anti-idling regulations offer a very effective measure at practically zero cost to reduce vehicle transport emissions from urban areas. As with eco-driving measures, it gives rise to a number of benefits such as improved air quality (both local and global) and improved economy for car owners due to fuel savings and reduced engine wear. An idling vehicle emits significantly more pollutants than when it is driven at a constant speed. Besides, since the emissions from idling vehicles are emitted in inner-city areas, their impacts on human health are of greater magnitude, especially on children, pregnant women and the elderly who are directly exposed. Anti-idling regulations have been in place in many countries and in particular in European countries and the USA. Unfortunately, the level of compliance has been low since drivers are not following the rules as they should, which depends to a large extent on the fact the required monitoring and enforcement mechanisms are not effective. Two likely reasons for the lack of compliance with anti-idling regulations that can be mentioned are: 1) there is a misconception among vehicles drivers regarding anti-idling, grounded on the belief leaving the engine on will consume less fuel than turning it off and on and 2) there is a lack of understanding among car drivers about the negative impacts idling has on both their economy and on the environment. The misconception regarding fuel consumption may have been true for old technology cars but not for today's modern cars equipped with ignition systems that are much more efficient and that require less fuel to switch the engine on. The other reason is the lack of appropriate monitoring and enforcement mechanisms. A likely explanation for the second reason for ignoring the regulation is the lack of knowledge about the negative impacts of idling. An idling car gives rise to a number of negative impacts for the environment besides the ones already known. It dirties the local environment and the engine due to incomplete combustion thus leading to an increased level of pollution and fuel consumption of around 4-5 per cent [28]. In vehicles suited with start-stop systems the engine is (if the system is working properly) automatically turned off when the vehicle is stopped and immediately restarted when the driver presses the accelerator or lifts off the brake/clutch. The system is particularly effective for reducing idling in heavy traffic conditions, when the levels of air pollution are at their highest.

An issue that has come up in conjunction with the development of new and more advanced technologies is that these are not being used optimally and therefore not giving the expected results. Despite the fact most of today's new vehicles (if not all) are equipped with the auto-stop and start technology, this

function can be turned off thus not being used to the fullest. Not very seldom, car drivers are found sitting in idling cars in crowded inner-city areas in many European cities and elsewhere, exposing children, pregnant women and elderly to pollutant emissions such as PM, SOx and NOx, pollutants that as mentioned earlier, may have detrimental impacts on human health. This happens even in cities where anti-idling regulations have been introduced. In this context, there are two important aspects worth consideration; firstly, monitoring and enforcement. Without the required monitoring and enforcement mechanisms in place, compliance will be an issue. Secondly, providing the technology without the necessary information about the benefits of using it adequately will not be enough to get the expected effects. The fact that car drivers are not complying with this law is evidence enough to realise complementary measures as the ones mentioned above, are needed. The effectiveness of new technologies depends very much on the level of understanding of the users about how to use the technology optimally, but also, about the benefits the technology brings if used correctly. In many places, informative campaigns are implemented as a means to raise awareness among drivers of the benefits of this technology. Below examples of anti-idling signs; one with more descriptive information about the negative impacts of idling, the other directly restricting idling.

Figure 3.6. Anti-idling signs in the UK.

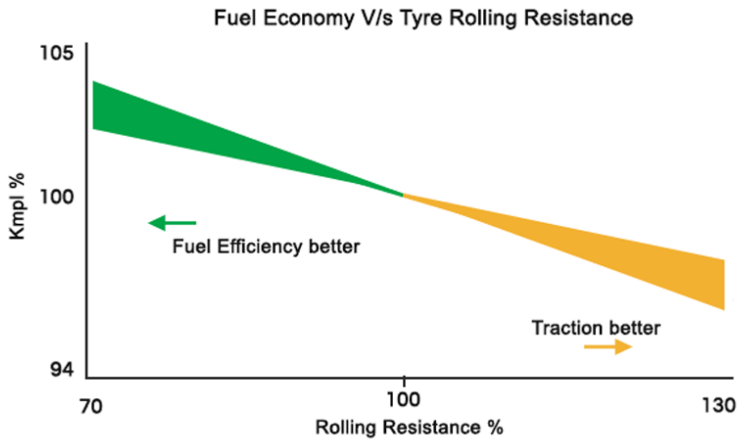
3.7 LOW-ROLLING RESISTANCE TYRES

The type of tyre normally used in vehicles provide a very good grip, which reduces the risk of sliding and also effectively reduces the distance to stop the vehicle when the breaks are applied. This is mainly because the surface area of the tyre in contact with the road is large. The grip can be referred also as

the friction between the tyre surface and the surface of the road. However, for a vehicle to be able to roll, it needs to overcome the frictional force and inertia and for that, the vehicle needs the engine, which in turn needs fuel. Reducing the rolling resistance in vehicles by replacing conventional tyres by low-resistance (LRR) tyres is a way of significantly reducing the power the vehicle needs to travel and thereby, improving fuel efficiency and reducing fuel consumption. The good news is that modern LRR tyres do not compromise safety or performance; they maintain a good grip without increasing breaking distance. A lower rolling resistance can be also achieved to a lesser extent simply by having the right tyre pressure. Reducing the rolling resistance in a vehicle can significantly decrease the fuel expenses for the driver (due to decreased fuel consumption) and hence, the levels of emissions. Rolling resistance stands for around 20-30 per cent of the total vehicle fuel consumption [28] and therefore, any measure aimed at achieving a reduction in rolling resistance is worth consideration. The considerable positive effects LRR tyres have on fuel economy have been also recognised by the EU and it has therefore introduced energy efficiency policies in the EU region regarding the requirement for all new cars, of all models from 2014 to be equipped with low rolling resistance (LRR) tyres. This regulation was followed by a second and more stringent regulation in a second phase in 2017 affecting all new cars [29].

LRR tyres are designed in such a way that the tyres do not absorb the energy used to roll the tyre in the same way conventional tyres do. Studies show a reduction relationship of approximately 10-20 per cent. This essentially means a decrease in rolling resistance by around 10 per cent will end up in a reduction of fuel consumption of between 1 and 2 percent [30]. Another way of reducing the vehicle's rolling resistance is by changing to smaller tyre dimension. This may have a great impact in fuel consumption, but also, the in the level of noise which is beneficial for the driver and passengers. A decrease in the dimension of the tyre by 1 per cent will decrease the aerodynamic resistance by approximately 1.5 per cent [31]

The importance of using LRR tyres is further reinforced by the regulation regarding the requirement for all new cars to be equipped with Tyre Pressure Monitoring Systems (TPMS). Although the existing car fleet in many countries is composed of a significant number of old cars, not being equipped with LRR tyres nor with TPMS, a lower tyre rolling resistance can be achieved simply by maintaining the right tyre pressure. Studies show that a lost in tyre pressure of 1 bar will lead to an increase in rolling resistance of 30 % [25].



Source: Advanced Structures India.

3.8 DISCUSSION AND CONCLUSIONS

There are many noticeable benefits from the use of e-scooters and e-bikes. For public ~~transports~~ commuters it means travel time gains. For the environment, it means reduced levels of pollutant emissions. From the transport efficiency point of view, micro-mobility modes are good options in urban regions with congested and narrow streets, with longer egress and access distance from public transport stops. However, implementing e-scooters or e-bikes as public transport access and egress option can be difficult. As many cities in Europe and elsewhere in the world have seen, those implementing e-scooter and e-bike programs in cities can face issues like problems with vehicle collection, traffic safety, vandalism, and pathway blockage from careless placement (a growing problem for mobility-impaired travellers). More specifically, e-scooters have shown to be unsafe and risky, and many cities have banned their use as shared mobility options.

In developing country contexts like India, and the more specific case of a city like Ahmedabad, these problems can escalate, especially the issues related to vandalism and traffic safety. Modes like the e-scooter can be very difficult and risky to operate in mixed traffic congestion with no bicycle lanes. As these modes also replace the last mile mode which is mostly walking, there are also affordability issues as overall journey price can increase substantially. Therefore, if these e-scooters are not integrated with the public transport ticket costs (or match shared auto-rickshaw prices) they can increase the cost of overall public transport trip and price out a large section of the population.

The problems of collecting the used vehicle with discharged batteries for charging also escalates its global warming impact. A simpler ownership/lease

model for e-scooters can also ease out the need for collection and reduce its GWI impact. The Climate Works EV-100 initiative encourages business and corporates to facilitate a transportation towards EVs (cars). A similar model can be employed for e-scooters, where these are owned by companies or apartment landlords, and leased or loaned to employees or residents for commuting and other travel. Public transport companies can also support such initiatives by allowing PT users to ride on buses or metros with their e-scooters.

Therefore, on the one hand, e-scooters and e-bikes do provide an opportunity to increase the coverage areas of public transport systems, and provide an opportunity for more residents to use the public transport system in congested urban areas. On the other hand, their introduction as first and last-mile options for public transport service has to be planned and designed appropriately. For these to be low cost and viable solution for the developing world, technology for charging will have to improve. Technically, developing countries where labour costs are not very high can also look for cost-effective methods of operating e-scooters, including more efficient collection for charging.

But this will not solve the problem of e-scooters littering the streets. A possible way forward is a cost-effective design of docking stations so that these can be provided in higher numbers, with better access to bikes and e-scooters. Incentives could be provided for docking e-scooters to chargers, reducing the chance of their littering on streets, and also eliminating the need for collection when the battery is discharged.

Achieving the objective of reducing emissions from passenger road transport requires not only the provision of affordable cleaner technologies like e-scooters and e-bikes, but also that other low-cost measures are also implemented concurrently. Only by putting in place a package composed of a series of cost-effective measures, technologies and techniques to reduce emissions (both local and global) will this be possible. Therefore, measures like eco-driving programmes and anti-idling regulations, with the appropriate monitoring and enforcement mechanisms in place, could be an effective way to achieve the desired results. Both eco-driving and anti-idling measure have proven to be effective measures. Eco-driving training programmes have been introduced in many countries, and they demonstrate that significant emissions reductions can be obtained. Similarly, anti-idling regulations have proven to be a remarkably cost-effective measure. Nevertheless, for these measures to be effective, the necessary monitoring and enforcement mechanisms need to be in place. All these technologies require techniques and measures in the form of regulations, and adequate information about how to optimally use the technologies and techniques. Users also need compelling information about the positive effects of the technologies.

REFERENCES

[1] Munshi, T., *Built form, Travel Behaviour and Low Carbon Development in Ahmedabad, India*, in *Faculty of ITC*. 2013, University of Twente: Enschede, the Netherlands.

[2] Zagorskas, J. and M. Burinskienė, *Challenges Caused by Increased Use of E-Powered Personal Mobility Vehicles in European Cities*. Sustainability, 2020. **12**(1): p. 273.

[3] Will, M.-E., Y. Cornet, and T. Munshi, *Assessment of Physical and Ecological Space Consumed by Transport Modes: a Case of Rajkot City, India*. WCTRS, Mumbai, Índia, 2018.

[4] Munshi, T., W. Belal, and M. Dijst, *Public transport provision in Ahmedabad, India: accessibility to work place*, in *Urban Transport X: Urban Transport and the Environment in the 21st Century*, L.C. Wadhwa, Editor. 2004, Wit Press: Southampton. p. 343-353.

[5] Grosshuesch, K., *Solving the First Mile/Last Mile Problem: Electric Scooters and Dockless Bicycles Are Positioned to Provide Relief to Commuters Struggling with a Daily Commute*. Wm. & Mary Envtl. L. & Pol'y Rev., 2019. **44**: p. 847.

[6] Ranieri, L., et al., *A review of last mile logistics innovations in an externalities cost reduction vision*. 2018. **10**(3): p. 782.

[7] Zhu, R., et al., *Understanding spatio-temporal heterogeneity of bike-sharing and scooter-sharing mobility*. Computers, Environment and Urban Systems, 2020. **81**: p. 101483.

[8] Ajao, A., *Electric Scooters and Micro Mobility:Here's Everything You Need to Know*, in *Forbes*. 2019.

[9] Zhu, R., et al., *Understanding heat patterns produced by vehicular flows in urban areas*. Scientific reports, 2017. **7**(1): p. 1-14.

[10] Bigazzi, A. and K. Wong, *Electric bicycle mode substitution for driving, public transport, conventional cycling, and walking*. Transportation Research Part D: Transport and Environment, 2020. **85**.

[11] Galatoulas, N.F., K.N. Genikomsakis, and C.S. Ioakimidis, *Spatio-Temporal Trends of E-Bike Sharing System Deployment: A Review in Europe, North America and Asia*. Sustainability, 2020. **12**(11): p. 4611.

[12] Sachs, C., et al. *Assessing the market of light electric vehicles as a potential application for electric in-wheel drives*. in *2016 6th International Electric Drives Production Conference (EDPC)*. 2016. IEEE.

[13] Gössling, S., *Integrating e-scooters in urban transportation: Problems, policies, and the prospect of system change*. Transportation Research Part D: Transport and Environment, 2020. **79 (2020)**: p. 102230.

[14] Ilkevich, S., *The Sources of Competitive Advantages of Electric Scooter Sharing Services*. Strategic Decisions and Risk Management, 2019. **10**(3): p. 13.

[15] ALA. *Micro Mobility*. 2019 [cited 2020 1st April]; Available from: http://www.ala.org/tools/future/trends/micromobility (Accessed April 1, 2020)

[16] Zarif, R., D. Pankratz, and B. Kelman, *Small is beautiful: Making micromobility work for citizens, cities, and service providers.* Deloitte Insights, 2019.

[17] Hollingsworth, J., B. Copeland, and J.X. Johnson, *Are e-scooters polluters? The environmental impacts of shared dockless electric scooters.* Environmental Research Letters, 2019. **14**(8): p. 084031.

[18] Petrauskienė, K., M. Skvarnavičiūtė, and J. Dvarionienė, *Comparative environmental life cycle assessment of electric and conventional vehicles in Lithuania.* Journal of Cleaner Production, 2020. **246**: p. 119042.

[19] Sophaa, B.M. and S.M. Setiowatia, *Environmental Assessment of Motorcycle using a Life-Cycle Perspective.* 2017.

[20] Kerdlap, P. and S.H. Gheewala, *Electric Motorcycles in Thailand: A Life Cycle Perspective.* Journal of Industrial Ecology, 2016. **20**(6): p. 1399-1411.

[21] Online: https://www.iru.org/system/files/IRU%20Academy%20FS%20ECO%20Driving%20EN.pdf

[22] Online: https://cartreatments.com/gear-shifting-tips-for-car/

[23] Online: www.ecodrive.org/en/home/ecowill_the_project/

[24] Paper: Proc IMechE Part D: J Automobile Engineering 2018, Vol. 232(14) 1865–1882

[25] Online: www.oponeo.co.uk/tyre-article/the-role-of-tyres-in-fuel-economy.

[26] Online: https://eponline.com/articles/2011/02/08/ecodriving-now-receiving-a-lot-of-attention-in-the-united-states.aspx

[27] Kemal Ayyildiz, Federico Cavallaro, Silvio Nocera, Ralf Willenbrock. *Reducing fuel consumption and carbon emissions through eco-drive training*, Transportation Research Part F 46 (2017) 96–110.

[28] Paper: Hamad Sarhan Aldhufairi and Oluremi Ayotunde Olatunbosun. *Developments in tyre design for lower rolling resistance: A state of the art review.* Proc IMechE Part D: J Automobile Engineering 2018, Vol. 232(14) 1865–1882

[29] Cleaner Air for London. Anti-idling facts. Report: MURE Overall Policy Brochure. Available on the Web at: https://www.theclimategroup.org/project/ev100

[30] Sivak, M. (2016). Benefits of Using Tires with Low Rolling Resistance. Working Paper: University of Michigan Transportation Research Institute. (No. UMTRI-2016-1). Available on the Web at http://websites.umich.edu/~umtriswt/PDF/UMTRI-2016-1.pdf


BIKE
ANJO

4. DEMAND-SIDE MANAGEMENT STRATEGIES: NON-ECONOMIC INCENTIVES

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4.1 BEHAVIOURAL CHANGE THROUGH INFORMATION AND AWARENESS RAISING CAMPAIGNS: EXAMPLE

The lack of awareness among politicians and decision makers about the serious, and sometimes irreversible negative impacts that the emissions from the transport sector pose on the environment (local and global), as well as the lack of information about the social, economic and environmental benefits a sustainable transport system may bring about, is one of the main reasons for the inaction towards the implementation of policy measures aimed at achieving more sustainability in the sector. The misconception about the cost of policy measures aimed to achieve this, believing any effective measures may be cost-prohibitive, is another factor to be added. This lack of awareness can be also observed among citizens, which is reflected in individuals' behaviour. It is therefore of paramount importance that information about the negative impacts of unsustainable transportation and of the benefits of sustainable transport, as well as the adequate information about available travel options is conveyed in such a convincing way to politicians and decision makers, but also to all citizens, so the necessary awareness is created which may ultimately lead to an increased political will among politicians and decision makers to address the problem, and to a behavioural change among citizens.

A well-designed information and awareness raising campaign about the benefits of sustainable transport is a very cost-effective way of creating the necessary awareness leading to increased political will and behavioural change, if not in the short term, at least in the long term. Transport authorities at the national and city level as well as municipalities at the local level can organise massive campaigns aimed at influencing and changing transport users' behaviour. In this context, it is very important that all the necessary elements for a successful campaign are taken into consideration, and clearly outlined from the beginning. Important elements to be considered are; objective of the campaign (what is to be achieved), target audience (to whom will the message be directed), message to be conveyed (benefits of sustainable transport), media to be used (what channels i.e., TV, local radio, posters, leaflets, etc.), and type of communication activity (social events, common activities, others). For instance, a campaign with the objective of promoting a modal shift from private motorisation to public transport or non-motorised transport (walking and biking) should be directed to private car owners. This way, both the objective (discouraging the use of private car in favour of public or/and non-

motorised transport) and the target audience (private car owners) have been defined. A well-designed information and awareness raising campaign should also include information regarding alternative modes of transportation, for example public transport (buses, metro, etc.) including the service it provides in terms of frequency (timetable), stops, route, etc. This way, the message being conveyed will provide concrete options on travel choice and enjoy a bigger credibility. A campaign can be designed with an informative focus, and have at the same time an indirect persuasive purpose. For instance, by informing workers, students and other transport users with detailed information regarding best travel options regarding a certain route, and its benefits, which may incentivise citizens to take advantage of the information being provided with respect to available travel options.

The effectiveness of an information and awareness raising campaign will vary depending on the way it has been designed and implemented. In this context, there are strategies that can be applied. In a guidebook on "Planning and Implementation of Campaigns to Promote Bicycle Use in Latin American Countries" [1], four key aspects which a campaign to be effective should focus on are mentioned. These are: 1) affective; 2) rational; 3) movement and; 4) community-social. The first aspect includes strategies directed to people's sensibilities and emotions. This is meant to evoke happiness, the sense of freedom, and all the positive feelings associated with using a sustainable mode of transportation; for example, the bicycle. This should be complemented by persuasive activities, mainly emotional. The affective aspect can be presented in advertisements, through street activities or other activities, which do not necessarily involve citizens. The second aspect relates to the use of rational arguments, technical, statistical and numerical in nature. It includes presenting objective information about the benefits of the suggested transportation mode being suggested and its benefits in terms of, for example, reduced use of road space, zero or decreased pollution when in movement, energy efficiency, shorter travel times, lower cost of use, etc. These arguments should be put forward by citizens who stand for high credibility, through conferences or other information, printed or verbally. The third aspect includes strategies to involve citizens, for example by initiating a travel by foot, bicycle or public transport through the city, for any purpose (preferably with a transport purpose during a work/school day). Sunday bicycle rides and days without the car are also considered, as well as festivals and strategies geared at functional trips, such as trips to work, school, or any other activity that involves people. The fourth aspect involves activities in which teams of people are in charge of promoting sustainable transportation for reasons such as environmental ones. This generates groups of citizens who organise events in their cities to promote, for instance, bicycling. The suggested methodology includes components with a relatively chronological sequence, although some steps could be implemented in parallel. For the suggested methodology it is suggested both government representatives and citizens are involved; having the support from both is key as it helps to create a synergy between

government, citizens and other stakeholders. These four aspects are applicable also to other types of campaigns having the objective of producing behavioural change among transport users. Some examples are campaigns against idling, eco-driving and others, where posters and leaflets can be used. In Chapter 3, section 3.6, examples of posters and leaflets promoting inner-city anti idling, showing the negative impacts it has on human health.

There are many examples showing massive information and dissemination campaigns aimed at raising awareness among relevant stakeholders that have been successfully implemented all over the world, with results beyond expectations. Perhaps some of the most common implemented awareness raising campaigns in this respect, are the ones promoting the use of bicycles. Most of these campaigns have had the objective of discouraging the use of private cars in favour of the bicycle by informing and widely disseminating the health and the environment benefits of biking. An effective campaign aimed at promoting a modal shift from the private car to the bicycle or public transport, will give rise to significant improvements in terms of reduced fuel consumption and thereby reduced fuel expenses for car owners, and most importantly, decreased air pollution. A modal shift to the bicycle will besides have benefits in terms of improved health, thus being a win-win option. Information and awareness raising campaigns may not be something that will, as mentioned earlier, lead to radical changes in the short term, but it will definitely do that in the long term. The bicycle represents a highly efficient mode of transport, and besides being healthy, it decreases the time of travel. Several studies show that the bike is the fastest transportation mode for short distances of up to 5 kilometres, which represents the largest share of travels in dense inner-city traffic. For instance, a comparative study conducted in New York in 2014 between taxi services and bicycle-shared systems, shows that in dense traffic conditions and particularly during peak hours, the bicycle is either the faster or equally fast mode of transportation [2]. Besides the fact bikes can be a faster transportation mode than cars when traveling short distances in inner-city, the urban space taken is significantly less than the one taken by cars. Figure 4.1 shows a comparison between the urban space taken when the same amount of people use three different modes of transportation; the bus, private car and the bicycle. Evidence from many countries shows, achieving an increased share of the bicycle as mode of transportation requires the implementation of a well-designed and massive dissemination campaign, which can influence and convince citizens of the significant benefits of biking and give rise thereby to the desired impacts. In this context, using strong and persuasive arguments such as decreased fuel expenses, improved health,

decreased and much better use of urban space and thereby reduced congestion and air pollution, is crucial.

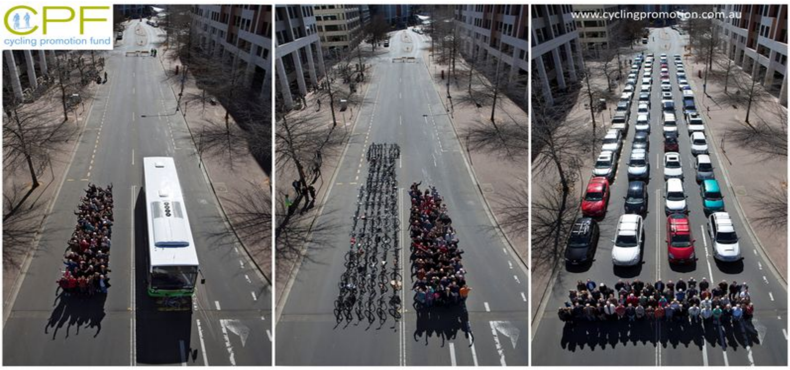

Figure 4.1. Urban space taken by mode of transportation. Source: CPF, Cycling Promotion Fund

Massive dissemination and information campaigns about the benefits of using the bike as mode of transportation have been successfully implemented in a number of cities around the world. Some examples are Bogota, Colombia; Amsterdam, Holland; Lima, Peru and Concepción, Chile, but also in many other cities elsewhere. In the case of Bogotá, NMT policies, an effective awareness raising campaign in favour of the use of the bicycle and political commitment, increased the number of bicycle trips by four [3]. Strategies composed of both individual activities (bicycle rides, bike to work initiatives) and techniques of persuasion for the population (which entails providing information to the community) will be highly effective in changing people's attitude. Below is an example where this type of campaign was successfully implemented.

In December 2010 the city of Concepción, second largest city in southern Chile, implemented a massive dissemination and information campaign about the benefits of the bicycle. The campaign was part of the project "Promoting Sustainable Transport in Latin America and the Caribbean: Concepción, Chile" project, implemented by the United Nations Environment Program (UNEP), and executed by the UNEP DTU Partnership, former UNEP Risø Centre, in collaboration with the Sub Secretariat of Transport (SUBTRANS) and the Inter-ministerial Secretariat of Planning in Transport (SECTRA), both of the Chilean government. This with the objective of encouraging people to use the bike on the newly constructed bicycle lanes, which were meant to be a complementary transportation mode to the newly constructed semi BRT (Bus Rapid Transport) system of Concepción so called BioBio. Before the campaign, these lanes were more or less empty (see Figure 2). The reason for the reluctance to use the bike was mostly cultural in nature; in many conducted interviews, people revealed high precipitation in the city of Concepción as one

of the main reasons for not using the bike. Another reason was the fact that the bike was not considered a valid mode of transportation, a fact that can be associated with the belief that the bike does not signal a high status (it is rather seen as a transport mode for the poor), in comparison to driving a car. The campaign counted on the participation of television personalities and other famous people of the city, and it gave results beyond expectations, with a significant increase of bicycles sales as well as increased ridership. Apart from that, the increased motivation among transport authorities of Concepción and its region, resulted in the construction of 17 additional kilometres in Concepción and of 70 kilometres in the whole region of bicycle lanes between 2007 and 2017, with 24 more kilometres to be constructed.

Figure 4.2. BioBio transport project, Concepción, Chile Source: The authors.

The implementation of the so-called Cycle Rides in the city of Concepción (Figure 4.3), which were part of the promotional campaign, substantially changed the perception about cycling among citizens, and today, the long-term effects of the campaign can be clearly observed. From being a city where the constructed bicycle lanes were nearly empty, the use of the bicycle lanes has increased by around 50% [4]. The city of Concepción is, after investments in its bicycle lanes during the last years, today ranked as one of the cities with the best bicycle lane infrastructure [4]. This is quite likely the long-term result of a massive promotion and dissemination campaign that started several years ago.

Figure 4.3. Cycle Rides in Concepción Chile. Source: Solutiva Consultores

As mentioned earlier, often the lack of information and awareness about the benefits of a more sustainable mode of transportation is what hinders politicians and decisionmakers to be willing to implement measures aimed at achieving the needed improvements, but also, what hinders citizens to change their perception and travel behaviour. For instance, many times simply the lack of information about the services (frequency and stops) public transport like buses can offer, prevents potential riders from using public transport. The reluctance to switch from private car to more sustainable modes applies in a similar way when trying to get people from the private car to the bicycle as when trying to get people from the private car to public transport. However, as the evidence shows, changes can be achieved when well-designed campaigns are implemented.

Other examples of awareness raising campaigns that can be mentioned are the "TravelWise" and "In Town Without My Car" campaigns. These campaigns, which were implemented already in the beginning of the 2000 in the UK included several promotional activities such as Bike Week, Walking to school Week, and used several media channels to raise awareness of the negative impacts originating from certain transport choices, and what could be done to remediate it, including change of attitude and travel behaviour [5].

REFERENCES

[1] Edited by Jorge Rogat. February 2010, UNEP Risoe Centre. "Planning and Implementation of Campaigns to Promote Bicycle Use in Latin American Countries – guide for decision makers"

[2] Ahmadreza Faghih-Imani, Sabreena Anowar, Eric J. Miller, Naveen Eluru. Hail a cab or ride a bike? A travel time comparison of taxi and bicycle-sharing systems in New York City. Transportation Research Part A 101 (2017) 11–21.

[3] Climate Technology Centre and Network. "Promotion of non-motorised transport." Web page. Available at https://www.ctc-n.org/technologies/promotion-non-motorised-transport

[4] Diario Concepción, 25 10 2021.

[5] Cairns S, Sloman L, Newson C, Anable J, Kirkbride A & Goodwin P (2004) *Travel Awareness: Smarter Choices – Changing the Way We Travel.*

БИЛЕТ
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5. DEMAND SIDE MANAGEMENT STRATEGIES: ECONOMIC INCENTIVES

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5.1 INTRODUCTION

Many current policies – from the way we finance transportation infrastructure and design roadways, to parking mandates in zoning codes – are intended to make automobile travel cheap and convenient, often to the detriment of other modes [1]. This results in high levels of vehicle travel, and associated costs. Many jurisdictions are starting to reform automobile-oriented policies in order to increase transportation efficiency and affordability [2]. This chapter describes various ways to do this.

Transportation Demand Management (TDM) refers to various policies and programs that encourage travellers to use the most efficient option for each trip [3]: walking and bicycling for local errands; ridesharing and public transport services when travelling on major travel corridors; telework (telecommunications and delivery services that substitute for physical travel) when feasible; and automobiles when they are truly most efficient overall, considering all impacts (benefits and costs) [4].

TDM can significantly increase transportation system efficiency, that is, it can reduce the money, infrastructure, fuel and land that people require to access services and activities. As a result, it can provide large economic, social and environmental benefits. These include reduced traffic congestion, infrastructure cost savings, consumer savings and affordability (savings to lower-income households), more independent mobility for non-drivers (which helps achieve social equity goals), reduced crash risks, improved public fitness and health, energy conservation, and open space preservation.

TDM can be justified in several ways:

- **To solve specific problems**. Most TDM strategies help solve multiple problems. For example, they can help reduce pollution emissions, traffic congestion and parking problems, and provide more independent mobility for non-drivers. When all impacts are considered TDM strategies are often the most cost-effective solution to these problems.

- **For economic efficiency.** Automobile travel is currently under-priced, since the majority of costs are either fixed or external, resulting in economically excessive motor vehicle travel, that is, vehicle travel with marginal costs that exceed its marginal benefits. TDM strategies can favour higher value trips and more efficient modes, and reduce vehicle travel to more optimal levels.
- **To achieve social equity goals**. Conventional planning creates automobile-dependent transportation systems which poorly serve the mobility needs of people who cannot, should not or prefer not to drive. Many TDM strategies help create a more multi-modal, and therefore more equitable and affordable transport system.

Although most TDM strategies only affect a small portion of total vehicle travel, their impacts tend to become more effective if implemented as an integrated program that includes a combination of coordinated policies and programs. This can create a more efficient, affordable and equitable transportation system. When all impacts are considered, TDM is often the most cost-effective and beneficial way to reduce transportation emissions.

5.2 TYPES OF TDM STRATEGIES

There are various types of TDM strategies. Some improve resource-efficient modes. Others give travellers incentives to use the most efficient option for each trip. Others create more compact communities where travel distances are shorter.

5.2.1 Improve Resource-efficient Modes.

Communities can improve resource-efficient modes with *multi-modal transportation planning* which recognizes the important roles that walking, bicycling, ridesharing and public transport play in an efficient and equitable transportation system.

Conventional planning tends to evaluate transport system performance based primarily on automobile travel conditions, using indicators such as roadway level-of-service and estimates of traffic congestion delay. In addition, most jurisdictions have dedicated roadway funding, plus parking minimums that force property owners to spend money and land on off-street parking; these resources generally cannot be shifted to improving non-auto modes even if such investments are more efficient and beneficial overall. These practices create automobile-dependent, sprawled communities where it is difficult to get around without a car.

Sustainable transportation planning inverts the conventional transport planning hierarchy to favour resource-efficient modes in planning decisions, as illustrated below:

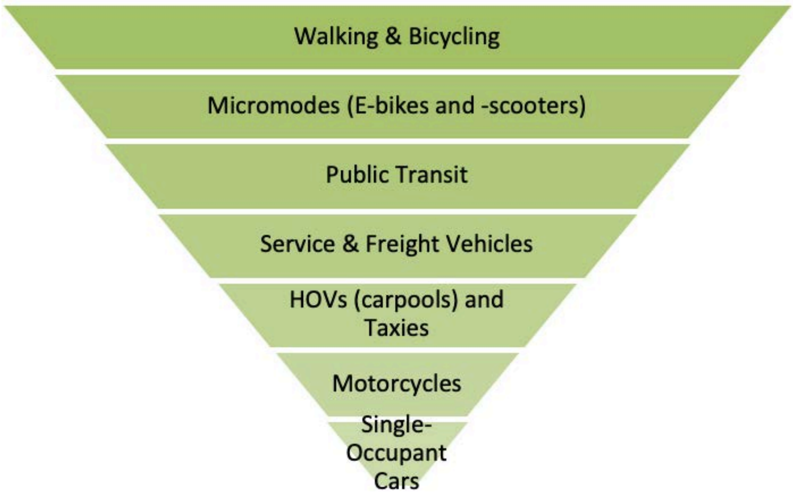

Figure 5.1. Sustainable Transportation Hierarchy. Sustainable transportation inverts the existing planning hierarchy to favour resource-efficient modes over private automobile travel.

5.2.2 Complete Streets and Road Space Reallocation

Multi-modal planning includes *complete streets* policies, which ensure that public streets are designed to accommodate diverse modes and uses [5]. This tends to increase the portion of road rights-of-way dedicated to sidewalks, bike-lanes and bus-lanes, plus crosswalks, traffic calming and traffic speed reduction programs to improve pedestrian and bicycle safety.

Road rights-of-way are most jurisdictions' most valuable assets. Currently, most public roads are designed and managed to favour automobile travel, with most road space allocated to motor vehicle traffic and parking. TDM often reallocates some of this road space to favour resource-efficient modes by widening sidewalks, installing bike- and bus-lanes, and narrowing traffic lanes to reduce traffic speeds. This is particularly appropriate in dense urban areas where road space is scarce and valuable, and there is significant demand for non-auto modes of transport.

For example, bus lanes can be justified on an urban arterial, where, after they are installed, those lanes will carry at least 600 bus passengers, since that is more travellers than a general traffic lane. Such a change also encourages shifts to public transport, by making bus travel faster and more reliable than driving.

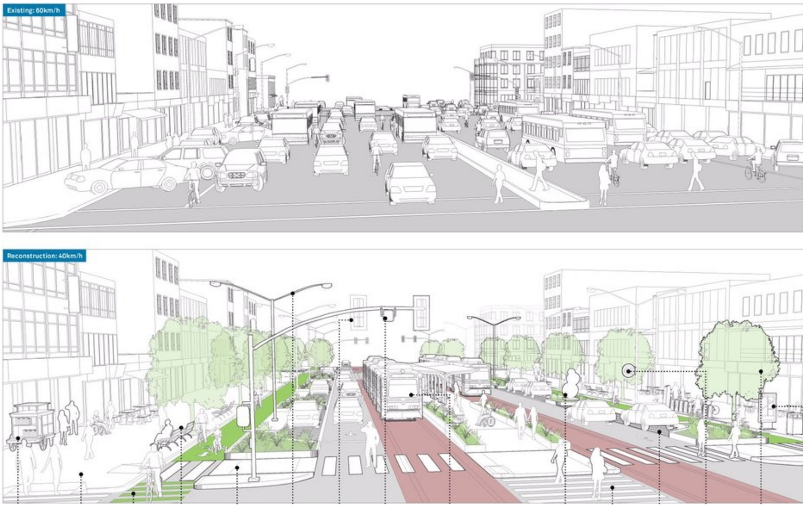

Figure 5.2: Before and After Complete Streets Redesign (NACTO 2017)

5.2.3 Financial Incentives to Choose Efficient Travel Options

For a transportation system to be efficient and fair, vehicle users should pay their share of road and parking facility costs, plus compensation for congestion, crash risk and environmental damages they impose on other people. This gives travellers incentives to use the most efficient option for each trip, for example, to choose routes and modes that reduce congestion, risk and pollution emissions.

Currently, automobile travel is significantly under-priced. Motorists do not generally pay directly for using roads and parking facilities, and are seldom charged for the congestion, crash risk and pollution damages they impose on their communities. There is a rich vocabulary to describe *overpricing*, we say that somebody who is overcharged is *gouged, cheated, or ripped off*. There is no comparable vocabulary to describe under-pricing although it is equally harmful and unfair, since prices that are too low impose costs on other people. Since automobile travel tends to increase with income, such under-pricing tends to be regressive, resulting in poorer households bearing more than their share of costs, while their wealthier neighbours pay less than their fair share.

This under-pricing significantly increases automobile travel and associated costs. For example, roads and parking facilities are never really free; they can either be financed directly through user fees or indirectly through taxes and building rents. When motorists pay directly, they typically drive 20-40% less,

reflecting the low-value vehicle-kilometres that motorists are most willing to forego in order to save money. This indicates that 20-40% of roadway costs, traffic congestion, traffic crashes and pollution emissions are the result of under-priced roads and parking facilities.

Another form of under-pricing results from the large portion of vehicle costs that are fixed expenses that motorists pay regardless of how much they drive. Variable costs – the expenses that motorists consider when making short-term travel decisions – are relatively low. This price structure encourages people to drive even when they have convenient alternatives. For example, because of this price structure, it is often cheaper to drive than to use public transport, because transport fares cost more than fuel costs. A variety of pricing reforms, described below, reward travellers for driving less and relying more on resource-efficient modes.

Motorists often complain when they are charged for using previously unpriced roads and parking facilities, but these facilities are never really free; the choice is between paying for them directly through user fees, or indirectly through higher taxes to pay for roads, and higher rents to pay for off-street parking facilities. Paying directly is always more efficient and fairer, and it gives travellers new opportunities to save money when they reduce their vehicle travel. For example, if residential parking is automatically included in apartment rents, everybody pays including car-free households. If parking is rented separately, households can save thousands of dollars annually if they reduce their vehicle ownership. Similarly, distance-based insurance premiums allow motorists to save hundreds of dollars annually if they commute by bicycle or public transport rather than drive to work, representing the reduced crash risk and insurance claim costs that resulting from the reduced vehicle-kilometres.

Fuel Pricing and Taxes Including Carbon Taxes.

Fuel prices vary widely depending on public policies. Some countries subsidize fuel, while others levy fuel taxes to recover roadway costs, and carbon taxes to encourage energy efficiency. The figure below illustrates the range of fuel prices around the world.

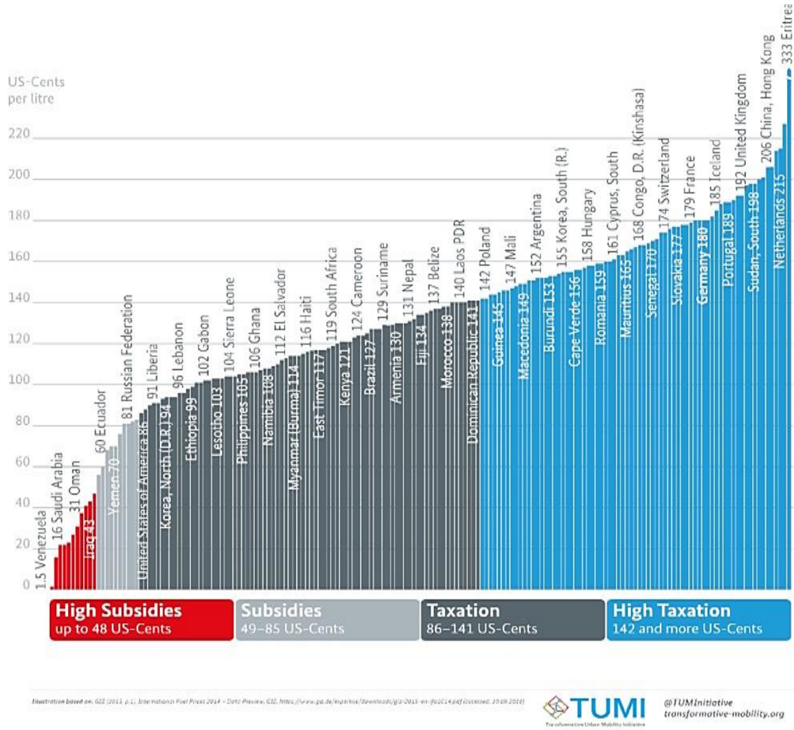

Figure 5.3. International fuel prices. Fuel prices vary widely. Higher fuel prices are an effective TDM strategy and encourage use of more efficient vehicles. [6]

Higher fuel prices are an effective energy conservation strategy. The price elasticity of vehicle fuel is typically about -0.3 in the short run and -0.7 in the long run, meaning that a 10% price increase reduces fuel consumption 3% in a year or two, and 7% in five to ten years. Short-term fuel savings consist of reduced driving and shifts to more fuel-efficient vehicles owned in multi-vehicle households. Over the long-term, higher fuel prices encourage consumers to purchase more fuel-efficient vehicles.

Road tolls and decongestion pricing

Road tolls are fees for driving on a particular roadway, generally used to finance highways and bridges. *Decongestion* (or just *congestion*) pricing refers to road tolls that are higher under congested conditions in order to reduce traffic volumes to optimal levels. Both are effective TDM strategies that can help reduce traffic congestion, accidents and pollution emissions.

Efficient parking pricing

In most jurisdictions, a major portion of parking is subsidized, financed indirectly, which is economically inefficient and unfair, since this forced people who drive less than average to finance the costly parking facilities of those who drive more than average. Efficient parking pricing means that motorists pay directly for using parking facilities, with higher fees at peak demand times and locations, to encourage efficient use of parking resources. Variations include parking cash out (commuters who use non-auto modes receive cash benefits comparable to parking subsidies provided to motorists) and parking unbundling (parking is rented separately from building space, so, for example rather than renting an apartment with a parking space for $2,000 per month, residents pay $1,800 per month for the apartment plus $200 per month for each parking space).

Parking pricing tends to be a particularly effective TDM strategy; shifting from unpriced to efficient parking pricing typically reduces affected vehicle trips by 10-30%.

Distance-based Vehicle Fees

Distance-based (also called *pay-as-you-drive*) pricing converts fixed vehicle taxes, insurance premiums and registration fees into distance-based charges, so motorists save money from marginal reductions in vehicle travel. Generally, the simplest and most effective approach is to prorate existing fees by each vehicle classes' average annual kilometres, so a $400 fee becomes 2₵ per kilometre, and a $1,200 fee becomes 6₵ per kilometre, for a vehicle class that averages 20,000 annual kilometres. These are not new fees, simply a different structure for existing fees. Since road maintenance and crash rates tend to increase with vehicle travel, distance-based pricing tends to increase economic efficiency and fairness, and since per capita vehicle travel tends to increase with income, it tends to be progressive with respect to income.

Vehicle Taxes and Fee Reforms

A number of vehicle taxes and fees can be reformed to reduce total vehicle travel and encourage energy efficiency.

- Tax rates in many countries encourage employers to offer large company cars as an employee benefit, since the additional cost of such vehicles is taxed at a lower rate than if the money were given as cash. This is particularly important because company cars are a major portion of new vehicle purchases and so result in an oversized, less efficient future vehicle fleet. Tax policies can be reformed to limit

the value of company cars, or to favour more efficient and alternative fuel vehicles.

- New vehicle purchase taxes, fees and subsidies can be structured to favour more efficient and alternative fuel vehicles, for example, by charging more for vehicles with larger, fossil fuel engines, or providing subsidies for hybrid and electric vehicles. However, by themselves such policies may *increase* total vehicle travel by reducing the per-kilometre cost of driving, a rebound effect, so such policies should be implemented in conjunction with increased fuel taxes and electric vehicle road user fees.
- As previously mentioned, fixed vehicle purchase taxes and fees can be reduced and converted into distance-based charges, so revenues are collected in a way to rewards marginal vehicle travel reductions.

The table below summarizes optimal transport prices:

Vehicle Costs	**Optimal Prices**	**Current Conditions**
Roadway expenses	Costs are repaid through special fuel taxes, or per-kilometre fees that increase for larger and heavier vehicles.	In many countries, fuel taxes are insufficient to pay full roadway costs.
Road rights-of-way	Motorists pay the equivalent of rents and taxes on land used for highways.	Users generally pay no rent and taxes on road rights-of-way.
Congestion	A decongestion fee charged for driving under congested conditions, to reduce traffic volumes to optimal road capacity.	Only a few cities have decongestion pricing.
Parking	Costs are repaid through user fees, with higher rates during peak periods.	Most parking is unpriced or inefficiently priced.

Accident risk	Vehicle insurance fees should reflect the full costs of crash damages, and be distance-based, so premiums decline if motorists reduce their mileage, and therefore their chance of causing a crash.	Most vehicle insurance premiums provide little or no incentive for motorists to reduce their mileage and therefore crash risk.
Pollution emissions	Additional fuel taxes or special fees should reflect a vehicle's emissions.	Fuel taxes are generally insufficient to reflect both roadway and emission costs.

Table 5.1. Optimal Transportation Prices. Automobile travel imposes various costs. Efficiency and equity require various fees so that motorists bear these costs directly rather than imposing them on all residents regardless of how much they travel by automobile.

5.3 TDM PROGRAMS

A *TDM Program* provides an institutional framework for implementing a set of TDM strategies. Such a program has stated goals, objectives, a budget, staff, and a clear relationship with stakeholders. It may be implemented by a transportation or transport agency, an independent government agency, or through a public/private partnership. Below are typical examples of TDM Programs:

- *Commute Trip Reduction* (CTR, also called Employee Trip Reduction) programs, through which employers encourage their employees to use resource-efficient modes.
- *School transport management programs*, through which schools and local governments encourage students and staff to use resource-efficient modes.
- *Special event transport management programs*, which encourage people who participate in special sport, cultural or civic events to use resource-efficient modes.
- *Transportation Management Associations* (TMAs), which are organizations, often made up of local businesses and transportation agencies, which encourage use of resource-efficient modes in a particular area, such as a commercial district, shopping mall or campus.

TDM Programs ensure that specific strategies are integrated for maximum effectiveness. For example, a typical Commute Trip Reduction program will include information resources, rideshare matching services, parking pricing

and management, bicycle parking facilities, telework and flex-time policies, and other actions that encourage employees to use resource-efficient modes. These programs can reduce vehicle trip generation by a third, and provide parking facility savings that repay program costs [7, 8].

5.3.1 TDM Marketing

TDM marketing includes general advertising of resource-efficient modes, plus individualized marketing to targeted audiences, such as commuters along a travel corridor with a new transport service, or residents of a neighbourhood with improved walking and bicycling facilities. These programs generally encourage people to try new travel options, after which many continue to use these more efficient modes.

5.4 EXAMPLES

5.4.1 Paris, France

The city of Paris has implemented many policies to encourage sustainable transportation. During the last two decades the city has improved public transport services and introduced new mobility options such as the Vélib' bikesharing and Autolib' electric car-sharing. It is reducing city centre parking supply, traffic speeds, vehicle traffic in order to provide more space for pedestrians, bus and bike-lanes, and trees, and reduce noise and air pollution. It has also banned older cars from downtown neighbourhoods during weekdays, reduced car space in parks and squares, and introduced car-free days. Although through traffic is restricted, residents, businesses, visitors and people with disabilities are still allowed to drive on city streets. These policies have proven to be effective at shifting travel from automobiles to more sustainable modes, as illustrated in Figure 5.4.

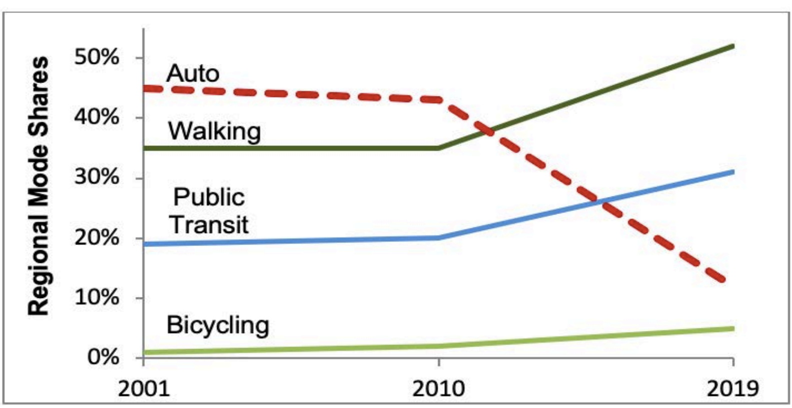

Figure 5.4. Paris mode shares. Source: C40 Cities (2019). [8]

Although the portion of street space devoted to automobile traffic has declined, congestion has not increased significantly, indicating that reductions in road supply have been offset by reductions in vehicle travel. These programs have proven popular with citizens; Mayor Anne Hidalgo easily won re-election in 2020 based on her commitment to continue car traffic reduction programs and improve the city's liveability.

Although the programs have proven effective overall, the travel impacts and benefits are significantly smaller in suburbs. In the city centre, only 15% of trips are by car, compared with 50% in suburbs. Some TDM strategies, such as fuel tax increases, sparked yellow vest ("gilets jaunes") protests led by lower-income motorists in suburban and rural communities. This suggests that additional policies are needed to improve travel options in automobile dependent areas and mitigate the effects of price increases in other ways.

5.4.2 Perth, Australia

Perth, Australia, in cooperation with various state, regional and local organizations, has a strategic transportation plan that established automobile trip reduction targets and identifies an integrated set of specific objectives and actions to achieve them.

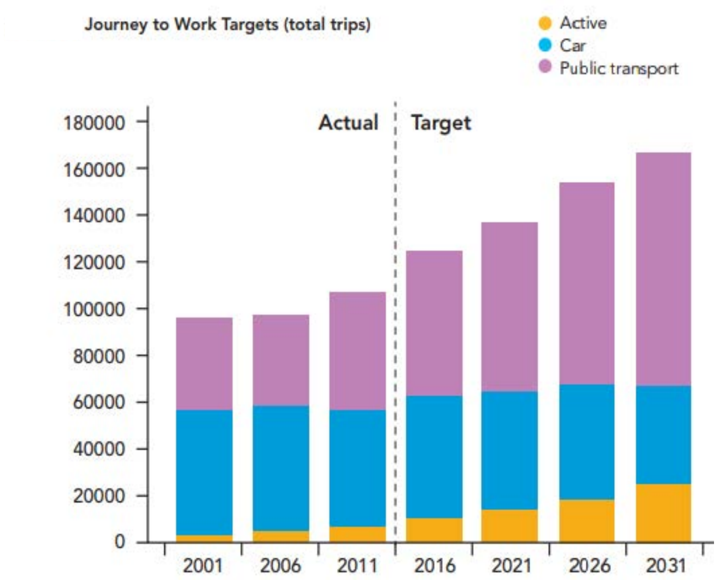

Figure 5.5. Perth Transport Plan Targets and Objectives.

Focus Area	Objectives
1. Integrated planning	1. Lead an integrated approach to transport system planning in the City of Perth. 2. Continue to cater for a more diverse business and residential community in the City of Perth. 3. Seek to achieve significant safety improvements across all modes of transport in the City of Perth. 4. Lead innovative research relating to how the city's transport systems are performing and contributing to Perth's economic, social and environmental wellbeing.
2. A Walkable City	5. Ensure that improving walkability is central to all transport design and management decisions in the City of Perth 6. Lead in the collection, management and use of data to improve our understanding of the City's pedestrian networks. 7. Continue to apply an iterative design approach in testing public realm improvements and design ideas. 8. Continue to promote active transport in the City of Perth through our marketing channels, engagement activities and events program.
3. A Cycling City	9. Continue to develop a connected cycling network. 10. Lead and promote the development of high-quality end-of-trip cycling facilities. 11. Be a leader in the development of innovative cycling infrastructure and support innovation that helps Perth become a more cycle-friendly city.
4. Next Generation Public Transport	12. Influence significant improvements and expansion of the city's passenger rail network. 13. Advocate for improvements in the public transport network's legibility, frequency and connectivity. 14. Support expanded public transport options for crossing and traveling along the Swan River. 15. Support new transport service models and options that benefit the City of Perth community. 16. Reduce negative externalities of buses on City of Perth streets.
5. Progressive Traffic & Parking Management	17. Continue the 'to, not through' approach to designing and managing the traffic network. 18. Continue to lead the car parking industry in achieving sustainable transport outcomes. 19. Support environmental improvements and innovation in vehicle technology within the City of Perth.
6. Innovative Engagement, Knowledge & Data	20. Lead a culture of strong and innovative community engagement in Perth. 21. Improve our knowledge base and evidence that supports decision making. 22. Lead a collaborate approach to last kilometre freight.

Figure 5.6. Perth established targets to accommodate future growth with less driving and increased active and public transport travel. The plan includes an integrated set of TDM programs.

5.4.3 London, England

London's 2018 Transport Strategy is based on detailed analysis of users' travel experience and how to make resource-efficient modes more attractive (TfL 2018). It aspires to increase walking, cycling and public transport to 80% of trips by 2041 through TDM strategies including 'Healthy Streets' pedestrian and bicycling network improvements, bus and rail transport service improvements, parking restrictions, car-free areas, transport-oriented development and the City's road charging scheme.

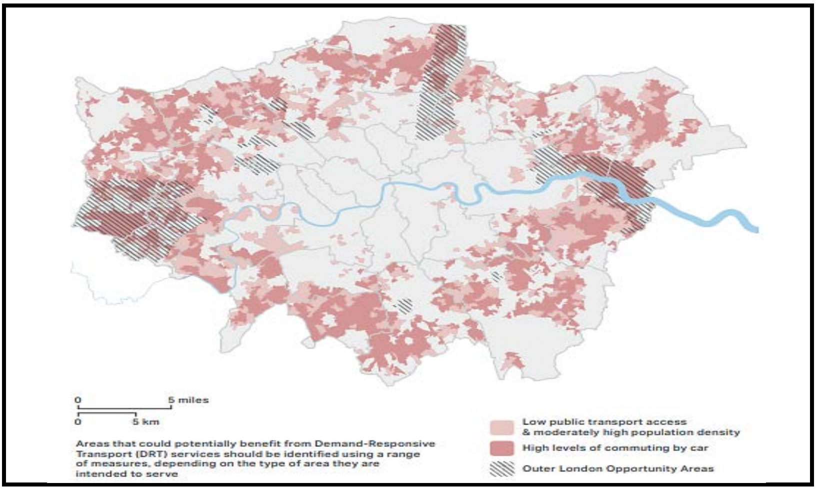

Figure 5.7. Demand response services. London's Transport Strategy is based on detailed analysis of users' travel needs and experience. Although central London has high quality train and bus services, some outlying areas, identified in this map, need demand response. (Source: Transport for London.)

If successful, this Strategy will continue current trends: between 1995 and 2015, London's private vehicle share decreased from 49% to 36% while public transport share increased from 25% to 37% due to previous transportation demand management programs (Rode and Hoffman 2015).

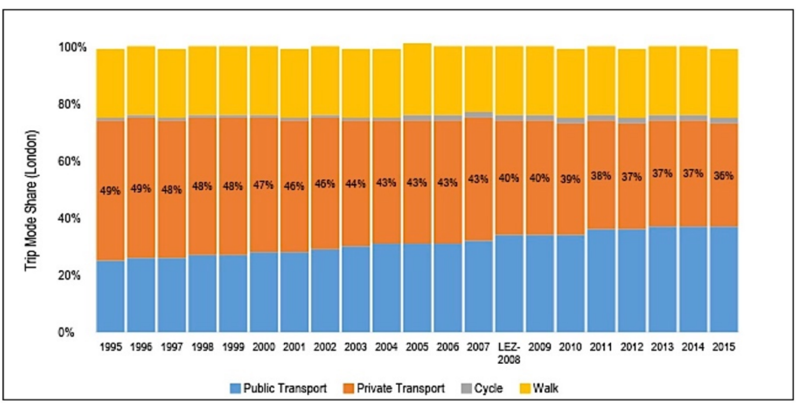

Figure 5.8. During the last two decades London successfully reduced automobile mode share and increased public transport mode share.

5.4.4 German, Austrian and Swiss Cities

The report *Reducing Car Dependence in the Heart of Europe* (Buehler, et al. 2016), finds that the largest cities in Germany, Austria, and Switzerland – Munich,

Berlin, Hamburg, Vienna, and Zurich – have significantly reduced automobile travel over the past 25 years, despite high motorisation rates, through an integrated program of policies that favour walking, bicycling and public transport over automobile travel in roadway design, pricing and land use policies. Each city is unique. The German cities have done the most to promote cycling, Zurich and Vienna offer more public transport service at lower fares. All five cities have implemented similar policies to promote walking, foster compact development, and discourage car use. Of the car-restrictive policies, parking management has been by far the most important. The five case study cities demonstrate that it is possible to reduce car dependence even in affluent societies with high levels of car ownership and high expectations for quality of travel.

5.4.5 Puget Sound Commute Trip Reduction Program

Washington State has targets to reduce per capita Vehicle Miles Travelled (VMT) 30% by 2035 and 50% by 2050. In addition, in 1991 Washington State established commute trip reduction (CTR) policies and programs that apply in large urban areas.[i] These include various state projects to improve walking, bicycling, and public transport travel; partnerships with local and regional transportation agencies to encourage non-auto travel; and requirements for larger employers to develop commute trip reduction plans.

These policies and programs have significantly reduced vehicle traffic in the Seattle region. From 2010 to 2018, total regional VMT increased 6%, much lower than the 12% increase in population and the 22% increase in employment during that period, transport boardings increased 20%, and single-occupant automobile mode shares declined from 74.4% to 72% during that period, as illustrated below.

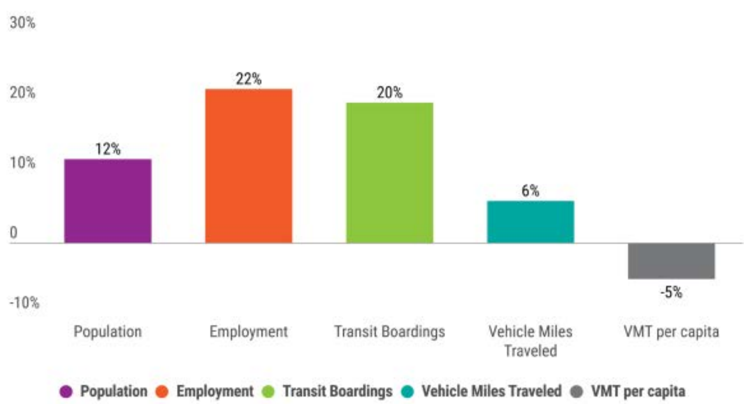

Figure 5.9. Population, Employment, Transport Boardings and VMT in Central Puget Sound, 2010-2018

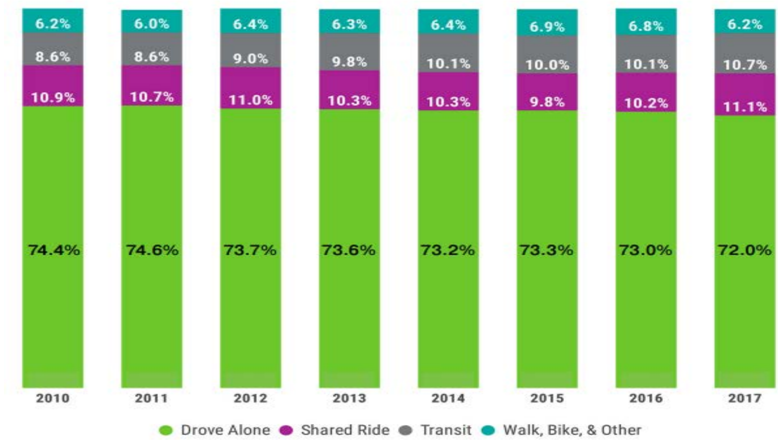

Figure 5.10. Mode Shares to Work, Central Puget Sound Region, 2010-2017

Even larger changes occurred in central cities. For example, the share of commute trips to downtown Seattle declined from 35% in 2010 to 26% in 2019. Similarly, in the nearby suburb of Bellevue, single-occupant commuting declined 76% in 1996 to 61% in 2018, and from 68% to 51% during that period.

This program's success at reducing VMT and shifting travel to other modes can be attributed to the comprehensive nature of their policies and programs which guide diverse stakeholders to support efficient transportation. Because Puget Sound cities are growing rapidly and geographically constrained, the region is limited in its ability to expand highways or urban fringe development. This forced policymakers and practitioners to consider new solutions, including TDM and Smart Growth strategies that create more compact and multimodal communities where residents' need for access can be achieved with less vehicle travel [9,10].

5.4.6 Gothenburg

Gothenburg is Sweden's second largest city with approximately 580,000 residents in the urban area. It has a large automobile manufacturing industry and its transportation planning was previously automobile-oriented, but during the last decade has implemented an integrated transportation demand management program that includes active and public transport improvements, parking policy reforms and congestion pricing (Gothenburg 2014). This shows significant leadership for a small size city.

The Strategy focuses on three areas: *Travel* – to create an easily accessible regional centre where it is easy to reach key places and functions irrespective of the mode of transport. *Urban space* – create attractive city environments where people want to live, work, shop, study and meet. *Transport of goods* – support Gothenburg's position as a major logistics centre where new and existing industries can develop without encroaching on quality of life, sustainability and accessibility. About 100,000 people currently travel into Gothenburg and about 45,000 people travel out of the city each day. During the next two decades the number of jobs is expected to rise by 80,000 in the city and 50,000 in the surrounding region. The City is committed to accommodating this growth through increases in public transport rather than driving.

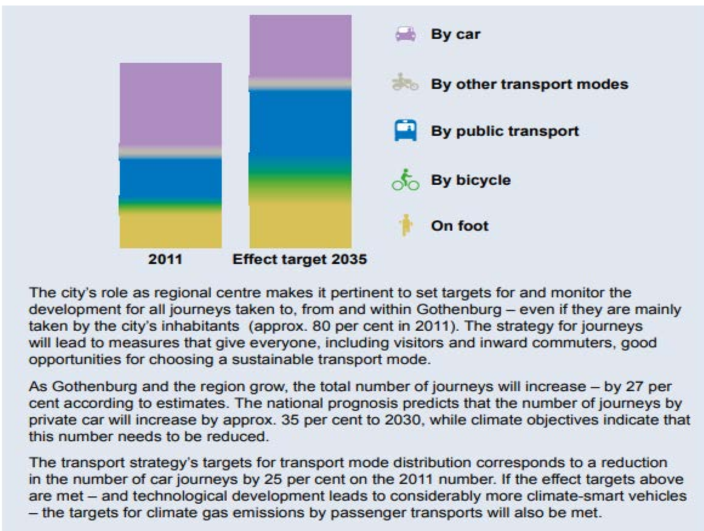

Figure 5.11. Travel Growth and Mode Share. Gothenburg's Transport Strategy includes targets to accommodate future growth in commuting trips in resource-efficient modes. This will be accomplished by implementing various TDM strategies including active and public transport improvements, more efficient parking management, more compact development, plus a congestion tax implemented since 2013 which discourages peak-period driving and helps fund public transport improvements. Support for this tax increased since it was first implemented, indicating the congestion pricing and other "radical" TDM strategies may become politically acceptable once residents experience their impacts and benefits.

5.5 EVALUATING TDM

New methods are often needed to evaluate TDM programs. Conventional transport models are often unable to predict the travel impacts and full

benefits of a TDM policy or program. For example, many TDM strategies are intended to improve the convenience, comfort and social acceptability of non-auto travel; most conventional models are designed to measure the effects of time and money costs, and are unable to measure such qualitative impacts. Similarly, few models can account for the synergistic effects of integrated TDM programs.

Household Vehicle Travel by Location[ii]

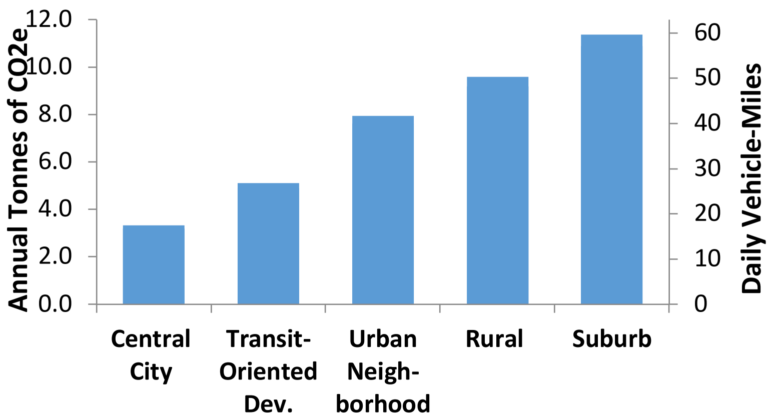

Figure 5.12. Household vehicle travel by location. Motor vehicle travel is much lower (20-60%) in compact, transport-oriented than in sprawled, auto-dependent areas.

Below are some typical travel impacts:

- Residents of walkable, bikeable and transport-oriented communities tend to own fewer vehicles, drive less and rely more on walking, bicycling and public transport than they would if located in automobile-dependent areas. Figure 5.12 above illustrates the differences in average annual vehicle travel by residents in various locations in California.
- Efficient parking pricing, with cost recovery pricing and rates that are higher during peak periods, tend to reduce affected vehicle travel by 10-30%.
- Commute trip reduction programs typically reduce affected travel by 5-15% if they only include information and promotion, or 10-30% if they also include significant financial incentives such as cost-recovery parking fees or public transport subsidies.
- Efficient road pricing, with fees that are higher during urban-peak conditions, can significantly reduce congestion problems but

generally provides only modest emission reductions since only a small portion of total vehicle travel occurs under urban-peak conditions.

- TDM marketing programs, which encourage people to try resource-efficient modes, can help reduce vehicle travel, particularly if implemented in conjunction with improvements to non-auto modes.
- Because commercial and freight vehicles are energy intensive, freight transport management can provide large energy savings and emission reductions.

Because it increases transportation system efficiency and reduces total vehicle traffic, TDM tends to provide more total benefits, and therefore tends to be more cost-effective overall, than other transportation system improvements, such as roadway expansions or shifts to more efficient and alternative fuel vehicles, as illustrated in the following matrix.

Planning Objective	Roadway Expansions	More Efficient and Alt. Fuel Vehicles	Win-Win Solutions
Motor Vehicle Travel	*Increased*	*Increased*	*Reduced*
User convenience and comfort	✓		✓
Congestion reduction	✓		✓
Road & parking cost savings			✓
Consumer savings			✓
Reduced traffic accidents			✓
Better mobility options			✓
Energy conservation		✓	✓
Pollution reduction		✓	✓
Physical fitness and health			✓
Land use objectives			✓

Table 5.2. Transportation Demand Management Benefits. (✓ = Achieve objectives.) Roadway expansion and more fuel-efficient vehicles provide few benefits, and by increasing total vehicle travel they exacerbate other problems such as congestion, accidents and sprawl. TDM increases system efficiency and reduces total vehicle travel, which helps achieve many planning objectives. [11]

5.6 CONCLUSION

Transportation Demand Management (TDM) includes various policies and programs that result in more resource-efficient travel behaviour. Although most TDM strategies only affect a small portion of total vehicle travel, their impacts are synergistic; they are more effective if implemented together.

Examples and case studies indicate that integrated TDM programs can often reduce affected by travel by 10-30%, and more if implemented with complementary land use development reforms that create more compact and multi-modal communities. Achieving significant impacts and benefits requires comprehensive TDM programs.

By increasing transportation system efficiency, TDM strategies can provide multiple economic, social and environmental benefits, and so are often the most cost-effective transportation improvement, considering all impacts. However, TDM implementation often faces many obstacles, so a variety of institutional and planning reforms are often required for TDM to be implemented to the degree justified.

REFERENCES

[1] Document: Gregory H. Shill. "Should Law Subsidize Driving?" University 0f Iowa Legal Studies Research Paper No. 2019-03, *New York University Law Review*, (http://dx.doi.org/10.2139/ssrn.3345366), 2020.

[2] SSTI. *Modernizing Mitigation: A Demand-Centered Approach*. State Smart Transportation Initiative and the Mayors Innovation Project, 2018; at https://bit.ly/2TCxtBD.

[3] Document: FHWA. *Integrating Demand Management Into The Transportation Planning Process: A Desk Reference*, Office of Operations, U.S. Federal Highway Administration: https://ops.fhwa.dot.gov/publications/fhwahop12035/index.htm.

[4] Website: VTPI, *Online TDM Encyclopedia*, Victoria Transport Policy Institute; at www.vtpi.org/tdm.

[5] NACTO. *Global Urban Street Design Guide*. National Association of City Transportation Officials, 2016; at http://nacto.org/2016/10/13/nacto-global-designing-cities-initiative-release-global-street-design-guide.

[6] Report: TUMI, *International Fuel Prices*. Transformative Urban Mobility Initiative (www.transformative-mobility.org), 2019; at www.transformative-mobility.org/publications/international-fuel-prices.

[7] Mike Spack and Jonah Finkelstein (2014),*Travel Demand Management an Analysis of the Effectiveness of TDM Plans in Reducing Traffic and Parking in the Minneapolis-St. Paul Metropolitan Area*, Spack Consulting (www.spackconsulting.com); at https://bit.ly/3lXRjY4.

[8] C40 Cities (2019), *Why Green and Healthy Transport Modes Deliver Vast Rewards for Cities*, C40 Cities Knowledge Hub (www.c40knowledgehub.org); at https://bit.ly/3p3Qxef.

[9] WSDOT (2021), *Commute Trip Reduction - Rules, Policy, and Guidance*, Washington State Department of Transportation (https://wsdot.wa.gov): at https://wsdot.wa.gov/transport/ctr/rules-policy.

[10] PSRC (2019), *Vehicle Miles Travelled*, Puget Sound Regional Council (www.psrc.org); at www.psrc.org/sites/default/files/trend-vmt-201911.pdf.

[11] Report: Salon, D., *Quantifying the Effect of Local Government Actions on VMT*, UC Davis Institute of Transportation Studies, 2014; at https://bit.ly/2NHsmkS.


SCHMIZZA
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NE Cherry Dr
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ONE WAY
ORENCO STATION
HUB 9
LEASING OFFICE
This way!
TRIMET
En route to your new job...
TREK

6. RE-THINKING THE TRANSPORT AND LAND USE CONNECTION

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6.1 INTRODUCTION

One of the most important components of cost-effective, low-emissions transport planning is the surrounding land use. It is the use of the land, after all – residential, employment, commercial civic or mixed – that generates the users of the transport system, and it is the location and density of those potential users that largely determines the efficiency of the system.

For this reason, it is important to think of transport and land use as a single integrated system, containing an optimum mix of transport modes supported by an optimum framework of land uses. With more integrated transportation and land use planning, a community can become much more accessible, inclusive and resource efficient. Residents of walkable urban neighbourhoods drive less than half as much as they would living in an automobile-dependent area, and as a result spend far less money on transportation, are far more likely to achieve physical activity targets, and produce far less air pollution. Examples from around the world, including both developed and developing counties, indicates that well-designed neighbourhoods significantly improve affordability, public fitness and health, and residents' economic opportunities, as well as reducing public infrastructure costs."

Then the question arises, what are those optimums for the land use and transport system? And the next question is, how are those optimums to be achieved? Those are the topics we will examine in this chapter, for both new-build and retrofit scenarios. Of course, the tools and approaches needed will vary in these two scenarios.

In each case, we will consider three key aspects of land use: the ***distribution and mix of uses***, the ***connectivity of street patterns,*** and the ***patterns of density***. We will first consider how the understanding of these three aspects has changed over recent decades, and in particular, the emerging understanding of public space as a critical framework of land use. We will then consider the challenge of implementation, especially in existing urban fabric, and some of the unique implementation tools and strategies that have been shown to be effective.

6.2 MOVING FROM SEGREGATED-USE TO MIXED-USE MODELS

One of the major reasons that existing transport emissions per capita are high in many countries is that the model used to plan land use and transport has been based on the segregation of functions, including both land use and transport functions. It was believed by late 19th and early 20th century planners that this arrangement was a more rational response to the many ills of the industrialising cities of that era.

In that era, many cities suffered from high levels of disease, poor sanitation, pollution, and overcrowding. In many cases the pollution came from the industrial activities of the day, which often involved combustion of coal and other fossil fuels. A natural impulse (but one with fateful consequences as we will see) was to segregate the workplace from the home, and from other kinds of land uses. These separated functions would then be connected with linear modes of transport, including rail and, later, passenger cars.

One of the most influential models of that era came from the English planner Ebenezer Howard, whose "garden city" model featured an elaborate scheme of segregated land uses.[1] His famous diagram (below) separated the city into a series of satellite cities, and further into wards and districts, each with a restricted land use. These uses included industry, commerce, residential, civic, and myriad other segregated functions including "homes for inebriates," "insane asylum," "homes for waifs," and so on (Figure 1).

This model reflected the preferred method to resolve conflicts between urban uses: namely, to segregate them by function. If an industry was emitting toxic gases, the solution was to spatially segregate it from residences and other uses that might be harmed. If the "home for inebriates" was not considered a desirable neighbour, it was to be spatially isolated. All the functions of the city would be separated out and given a unique location. There would be "a place for everything, and everything in its place."

This approach had a significant drawback, however. Since functions would no longer be within close adjacency to one another, travel distances on average would have to increase, often greatly. The increased physical separation generally came with lower density of people and activities over larger areas, contributing to what we now refer to as "urban sprawl" low-density, fragmented urban development.

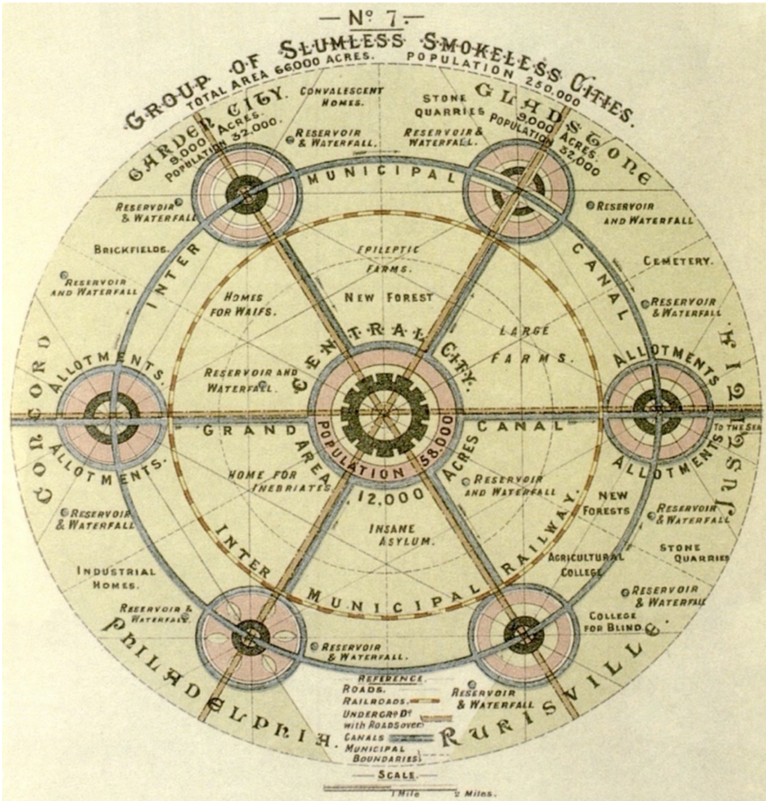

Figure 6.1. Ebenezer Howard's "Garden City" would separate out the various uses of the city, and thereby, it was hoped, end the conflicts between them [1].

6.3 LAND USE AND ITS STREET PATTERNS

In practice, this segregated land use pattern significantly increased the distances that people must travel each day, which required higher speed travel. This in turn justified a hierarchical street pattern consisting of a linear main "arterial," branching "collectors," and finally branching "local streets." For this reason, it is sometimes referred to as a "dendritic" or tree-like street pattern. This pattern was common for rural roads throughout history, and it was indeed an efficient way of connecting major urban centres to their hinterlands. However, it was a much less efficient way of connecting smaller nearby centres *within* an urban area, as can be seen from Figure 6.2.

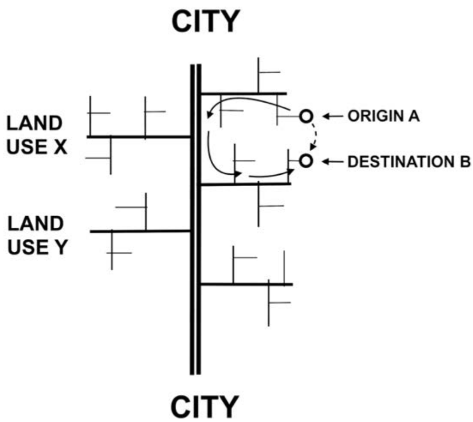

Figure 6.2. Although a tree-like or "dendritic" street pattern is efficient for direct travel between two cities or other major destinations, in fact it requires longer travel distances for many other shorter trips, as demonstrated in this diagram. A direct path between Origin A and Destination B would be quite short (dotted arrow), but the actual path required by the street pattern is much longer (solid arrows). This is true for many of the ordinary origins and destinations within the urban fabric.

An alternative to the hierarchical or dendritic street pattern is a more integrated "web-network" or grid pattern, in which local travel is possible with more direct routes. The simplest version of this web-network is the street grid. In this structure, any point of destination lies within a relatively straight path from any point of origin, making local trips more efficient (Figure 6.3). In addition, multiple paths are available, allowing for dispersal of traffic onto narrower, slower streets.

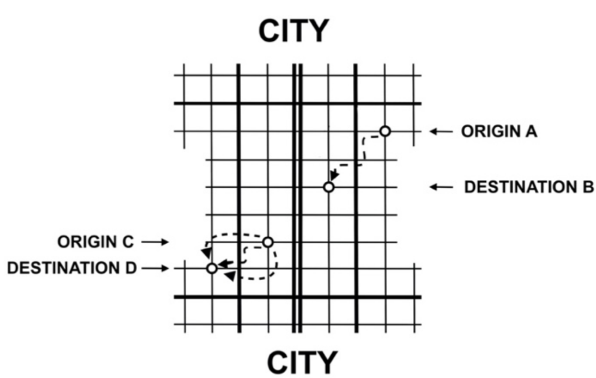

Figure 6.3. In a simple grid pattern, a relatively direct path exists between any origin (such as Origin A) and any destination (such as Destination B). Moreover, there are usually

multiple paths available, allowing dispersal of traffic onto narrower, slower streets (such as those between Origin C and Destination D).

Why is it important to make local trips more efficient? This is because there is also an optimum distribution of trip types for urban residents. This optimum distribution on average includes only a few longer trips, many shorter trips, and a medium number of trip lengths in between. This kind of distribution pattern is sometimes referred to as a "power law" or "lognormal" distribution.

While the "dendritic" pattern may indeed be optimum for the longest trips, it is highly inefficient for shorter trips, which are typically the most frequent (Figure 6.4). These are the routine trips around the neighbourhood, e.g. for groceries, school and so on. The longer trips are typically less frequent, and occur across a city or a region – often for special shopping trips or cultural activities.

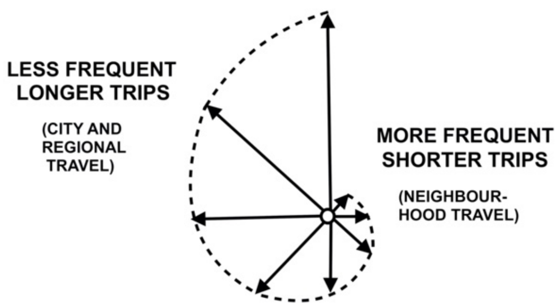

Figure 6.4. The optimum distribution of trips by residents retains most trips within the neighbourhood, with only a few trips across long distances, and a middle range of medium-length trips (i.e. a "lognormal distribution").

That means that the dendritic pattern is *not* the most optimum distribution overall. While major arterial streets are still needed to connect the largest nodes of a region, the surrounding fabric is optimally inter-connected into a web-network or grid-like pattern. (This pattern need not be a literal grid, as can be seen in Figures 6.5 and 6.7 below.)

6.4 COMBINING MIX OF LAND USES WITH MULTIPLE MODES

A second implication is that the optimum distribution of the uses themselves – the origins and destinations – is also a power law or lognormal distribution. That is, most people should be able to access most routine needs provided by a compact mix of land uses within their local neighbourhoods, thus "capturing trips" within a short range, and leaving longer trips for less routine destinations.

A related implication is that a more optimum land use mix also tends to make possible a more optimum transport mix. Since walking and biking are slower and more appropriate for shorter distances, they are also more appropriate for routine daily destinations – but only if those destinations are nearby, and easily accessed through a web-networked street pattern.

The converse is that a more dendritic street pattern, combined with a more functionally segregated pattern of use, is far more likely to require longer trips by vehicle, typically by automobile. This is of course a severe handicap for the poor, the elderly, the infirm, children, and the mothers who must drive them. It can also add a major expense to the household, and to the region and its infrastructure – that is, it can be the opposite of a cost-effective, low-emissions transport system. (This is true even if the cars are electrified, since their production as well as the infrastructure and land area they require will typically generate significant financial and environmental impacts, including emissions, and the electricity itself may be generated from high-emissions fuels like coal.)

One can readily understand this problem by considering the difference between the two urban forms in Figure 6.5 (below). The top part of the drawing shows the dominant pattern of conventional 20th century development, where uses are segregated and the street pattern is dendritic. Because of their length, most trips must be by car, or secondarily, a public transport system, which is likely to be inconvenient, inefficient, expensive, or a combination. Passengers will have to walk longer distances to access the transport stations, often across fast-moving and dangerous streets.

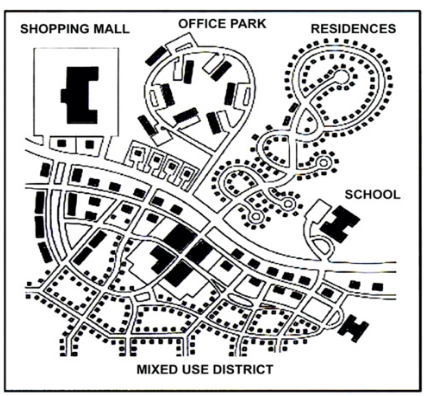

Figure 6.5. In the conventional "sprawl" development shown at top, uses are segregated and streets are dendritic (tree-like) patterns, also referred to as branching hierarchies. In the mixed-use district shown at bottom, uses are mixed and streets are in a web-network or loose grid. Average trips are shorter at bottom, and walking, biking and transport are much more feasible. Drawing courtesy DPZ CoDesign.

In the bottom section of Figure 6.5, uses are mixed, and the web-network of streets means that walking and biking are convenient, especially for shorter local trips, as well as trips by car or public transport. Access to public transport stops is also likely to be shorter and via slower, safer streets.

This pattern of functional segregation can occur at the regional scale and also at the local neighbourhood scale – and both are problematic. Figure 6.6 shows a functional classification "superblock system," typical of what is seen in many USA cities (as in the example shown of Phoenix, AZ). Here the streets are broken down into arterials, collectors and local streets, with local streets and collectors branching into the superblocks. The arterials run at the perimeters of the superblocks, at the scale of ½ to 1 mile (800 to 1600 metres).

Figure 6.6. A "superblock" system with functional classification of streets, and functional segregation of uses. Image at left courtesy of Federal Highway Administration (USA); image at right courtesy of Google Maps.

Note that the street system within the superblock is "dendritic," containing many loops and dead ends. The result is that there is poor internal connectivity for pedestrians or bicycles. The superblock also applies functional segregation to the land uses of commercial (at edges only), residential (in middle only) and civic (at centre only).

By contrast, a more continuous grid system with a mix of uses more easily supports multi-modal travel. Figure 6.7 demonstrates a simple grid pattern surrounded by arterials. The grid may be regular, as seen in Manhattan for example, or more irregular, as seen in many older cities. (This figure will be discussed again in the next chapter.)

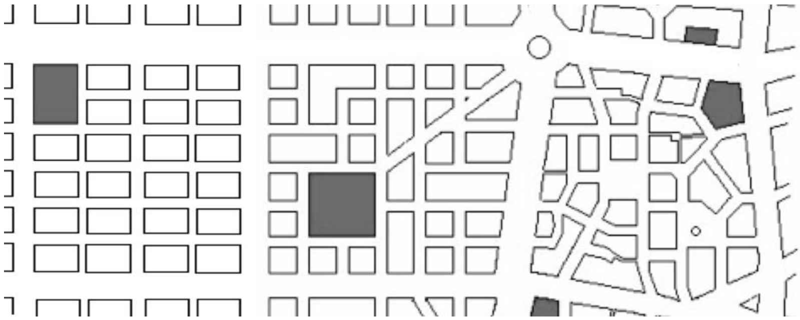

Figure 6.7. A simple grid system supports multi-modal transport as well as a more fine-grained mix of uses. It may be quite regular, as shown at left, or more irregular and "picturesque," as shown at right. (Parks and squares are shown in dark grey.)

6.5 OPTIMUM PATTERNS OF DENSITY

In addition to mix of uses and interconnected street patterns, another critical aspect of land use is the density of people and activities. While higher densities are generally more supportive of cost-effective, lower-emissions, multi-modal transport, it does not follow that all densities everywhere should be at the same high level. Nor is it the case that the density of a region should be uniformly high in the centre and uniformly low in the periphery – a "monocentric" model.

In most cities through history, densities have tended to form naturally into "polycentric" patterns, that is, around primary, secondary and tertiary clusters. This pattern, referred to as "density rings" by the architect Christopher Alexander, has a number of advantages, including advantages for more efficient transport [2]. These density rings are associated with "urban villages" where most commonly needed services and activities can be easily accessed without required automobile travel within about 15 minutes.

If our goal is to retain most vehicular (auto and transport) trips within each neighbourhood, with fewer trips required across longer distances, then we can see a problem with the monocentric model. The higher-density areas are typically the locations of regular daily destinations, provided by commercial, civic and office uses. If those higher-density uses can only be found in the core, then all the residents who do not live in the core – typically the majority of the city region – will be forced to make more and longer trips between their homes and the core. But if these higher density areas are distributed within a polycentric system, then it is easier to "capture trips" to routine destinations within local sub-areas.

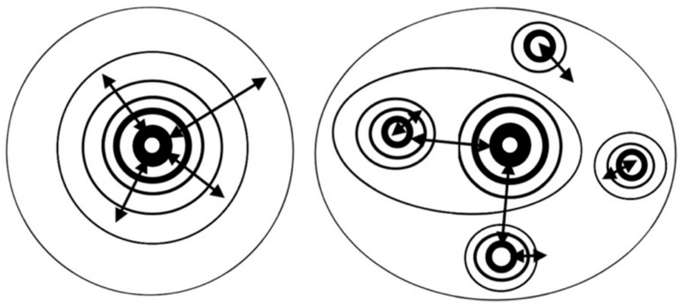

Figure 6.8. A "monocentric" pattern of density (left) can be less efficient than a "polycentric" pattern (right), where clusters of local density are dispersed throughout the city region. These neighbourhood centres offer residents local access to most of their routine daily needs and activities, without having to travel longer distances in and out of a single city core.

6.6 CHANGING PROFESSIONAL MODELS OF TRANSPORT AND LAND USE: A "NEW URBAN AGENDA"

Beginning with Ebenezer Howard at the turn of the 20th century, urban and transport planners began to adopt the model of segregated land uses and transport functions on a widespread basis. Functions were even more radically segregated under the 1933 Charter of Athens, developed by the Congrès Internationaux d'Architecture Moderne (CIAM) and published by the architect Le Corbusier [3].

This model of urban development has undeniable appeal, even today. It offers rapid, apparently efficient urban development offering large economies of scale and standardisation. However, it requires increasingly unsustainable injections of resources, with increasingly unsustainable levels of emissions, resource depletion, ecological degradation, and other "externality costs." There are other impacts on human health, social interaction, and equity, particularly when a neighbourhood is dependent on the automobile for transport. As noted previously, this is highly inequitable for those who cannot drive, including the poor, the elderly, the infirm, children, and the mothers who must drive them. The more diversified, more optimum mix of land uses and transport modes that is characteristic of older cities actually performs better in many ways, including the long-term cost-effective and lower-emissions performance of their transport systems [4].

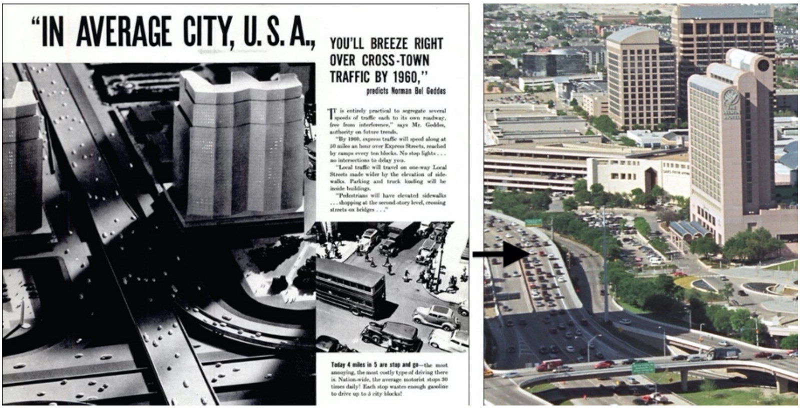

Figure 6.9. An advertisement in 1937 shows a very clear model of segregation by land use and by transport function, replacing the mixed street in the inset with a much more large-scale, single-use superblock system. This model came to dominate late 20th Century development, as could be seen in the example of Dallas, Texas USA (above right) and many other cities across the world – with fateful consequences for emissions and other challenges.

That is one reason why the New Urban Agenda, the outcome document of the Habitat III conference in 2016, explicitly embraces the more diversified models of land use and transport, including mixed use, polycentrism, walkability, compactness, and other key aspects [5].

The New Urban Agenda is not the only model of mixed-use, mixed-mode urban systems, but it is clearly a landmark in the reform of earlier models, since it has been adopted by acclamation by all 193 countries of the United Nations, and thereby enshrined in international policy. Of course, there is a long road ahead to implementation – but the significance of the agreement is undeniable. The New Urban Agenda is also a repudiation of the Athens Charter, as several of its key proponents – including Joan Clos, the Secretary-General of Habitat III who oversaw its creation – have pointed out [6].

6.7 THE CONNECTIVE FRAMEWORK OF PUBLIC SPACE

One key feature of the New Urban Agenda is its explicit language about the importance of public space. For example, its paragraph 67 sets the goal of "well-connected and well-distributed networks of open, multipurpose, safe, inclusive, accessible, green and quality public spaces," while paragraph 37 sets the goal of "safe, inclusive, accessible, green and quality public spaces, including streets, sidewalks and cycling lanes" that are "multifunctional areas for social interaction and inclusion, human health and well-being, economic exchange and cultural expression".

We can readily understand the importance of the public realm for the land use and transport system – the streetscapes, pathways, squares, parks, and other elements that people must use to be able to walk or bike, and to access nearby transport stops. These spaces must not only provide functional and attractive routes for walking, they must also serve as a connective framework between people and their private spaces, and an arena for human interaction.

Recent research has shown that these public spaces are very important in providing the "propinquity and serendipity" that are key to generating social interaction and "knowledge spillovers," which seem to be essential to healthy economic growth and opportunity for all [7]. This was an insight famously expressed by the urbanist Jane Jacobs, who described the "lowly sidewalk (pavement) contacts" as "the small change from which a city's wealth of public life may grow" – and it now appears that other more literal forms of wealth also grow form this "small change" [8].

Clearly the 20th century model formulated by CIAM also does work to generate wealth, particularly from the burst of resource consumption and technological development associated with its construction. But the long-term negative impacts of this model are increasingly evident, and they are the ones identified in the New Urban Agenda: increasing resource consumption and depletion, emissions, ecological degradation, urban fragmentation, isolation, inequity, and deprivation for those who are too poor, elderly, young, infirm, or otherwise unable to own and operate private vehicles – or to access convenient and functional public transport.

In this sense, the economic boost from the 20th century model of urban development is a bit like a drug high from crack cocaine: intense in the short term, destructive in the long term, and ultimately unsustainable.

We can see now too that the nature of public space is at the heart of the issue. If our urban systems are entirely mechanised, with individuals increasingly encapsulated in homes and offices connected only by vehicles (often private ones), then there is little role for public space, or the connectivity, interaction, propinquity and serendipity that it affords. If there is poor-quality public space between origins and destinations, including transport stops, then that confers an inequitable advantage (with associated costs and emissions too) to those wealthy enough to own private vehicles. The increasingly high energy and resources required to fuel this scheme mean it is fundamentally unsustainable.

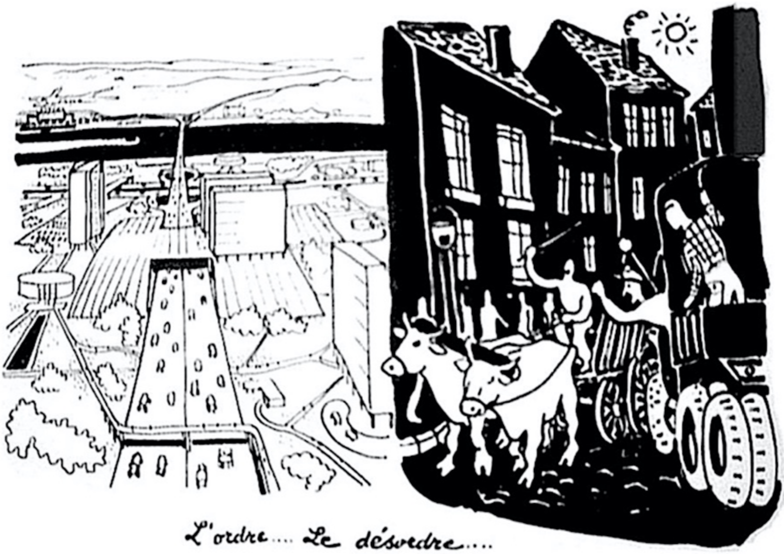

Figure 6.10. A drawing by Adolf Bayer in 1948 shows the allure of functionally segregated streets connecting superblocks with typically isolated, monofunctional buildings. In place of the messy, crowded, diseased city, we would have a city of pristine order. However, public space would no longer be a place of compact mixing, diversity, or connectivity between private spaces. Pedestrians would be dispersed onto long, mostly empty (possibly dangerous) pathways. The benefits of social, cultural, and economic interaction would have to be provided with artificial mechanisms requiring high, ultimately unsustainable, levels of energy and materials.

6.8 INTEGRATING THE LAND USE AND TRANSPORT SYSTEM: THE NEW-BUILD SCENARIO

The next question to ask is how to implement the reforms called for in the New Urban Agenda and other landmark documents, and also needed for low-emissions, cost-effective transport planning: the provision of walkable public space networks, mix of uses, sufficient compactness at critical nodes (including transport nodes), well-connected street patterns, and other land use characteristics as discussed in this chapter.

The challenges for achieving these characteristics is clearly more straightforward in a new-build scenario, where urbanisation has not yet occurred – for example, in an urban extension, a large infill site, or a new "greenfield" settlement area. (It should be noted that the New Urban Agenda and other documents prioritise infills and urban extensions over new settlements, because existing development and infrastructure typically offers much greater efficiency and long-term benefits; at the same time, these

existing areas also pose additional barriers to implementation, as we will discuss.)

Transport-Oriented Development (TOD)

One of the most influential new models of urban development is the TOD or transport-oriented development (referred to as "transport-oriented development" in the USA). In this model, a "density ring" of compact, mixed use, interconnected development is clustered around one or more higher-speed transport stops, typically rail transport. This model gained popularity when, in 1989, the American architect Peter Calthorpe proposed what he termed a "pedestrian pocket" [9]. As can be seen in Figure 11, the model combined a density ring, a connected street grid, and a proposed mix of residential, commercial and civic uses, all within a single compact zone.

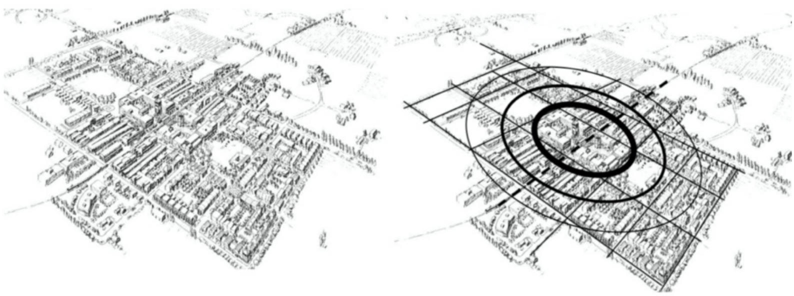

Figure 6.11. Peter Calthorpe's "pedestrian pocket" concept, combining a density ring centred on a high-speed transport stop with a grid of walkable, multi-modal and mixed-use streets. Source: Peter Calthorpe.

One of the best-known examples of this model is a TOD project in the Portland, Oregon (USA) region on which Calthorpe worked, known as Orenco Station. This project included some 2,400 homes and 25,000 square metres of commercial adjacent to several major industrial sites, in a mixed-use format. Although the neighbourhood included a major light rail stop, it also featured two bus lines, a shuttle bus operated by an adjoining high-tech company, and extensive facilities for walking, biking, car share, scooter, and other multi-modal travel options. All of these mixed uses and modes were integrated into a supportive walkable street grid.

Evidence shows that the neighbourhood has indeed achieved a low-emissions, cost-effective transport system. Research by the sociologist Bruce Podobnik showed that the rates of automobile use for commuting are about as low as those of the famously walkable and mixed-mode central Portland, while walking rates are even higher, and far higher than in the surrounding suburbs [10].

Figure 6.12. The TOD or "pedestrian pocket" of Orenco Station, built in the late 1990s in the Portland, Oregon region of the USA. The neighbourhood features density rings, a walkable grid of streets, and a diverse mix of uses. To the left is a more conventional subdivision built several decades earlier.

Research by Ewing et al. also showed that demand for parking spaces by passenger cars has proven to be substantially below the predictions of standard engineering manuals (less than half of the value in the Institute for Transportation Engineers' *Parking Generation Manual).* Also, vehicle trip generation rates are about half what is predicted in the ITE *Trip Generation Manual*, indicating a substantial "trip capture" rate. The automobile mode share was found to be 31 percent of all trips, with the remainder being mostly transport and walk trips [11]. This is low by USA standards. Furthermore, the distances of those trips are also significantly shorter on average, since the community is surrounded by employment centres and other routine destinations.

This research is in line with other research. For example, researcher Deborah Salon [12] used detailed travel survey data to analyse how demographic and geographic factors affect travel activity (how and how much people travel),

and developed models for predicting how various land use development changes will affect travel. Her research is summarised in Table 1 below:

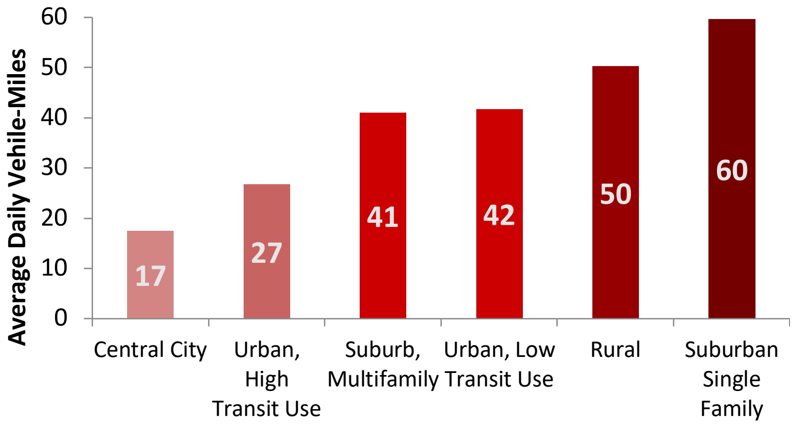

Table 6.1: Household vehicle travel by location. Motor vehicle travel is much lower (20-60%) in compact, transport-oriented than in sprawled, auto-dependent areas. Source: Deborah Salon [12].

The implementation of the Orenco Station plan faced considerable barriers, as many retrofit projects do when they seek to transition to a more mixed, compact, inter-connected model. These barriers had to be overcome through a number of innovative tools and strategies.

First, ***the segregated zoning was replaced by a single mixed-use zoning code***, prescribing not the use of buildings but their form as they would shape and define streetscapes and other public spaces. Second, ***the City committed to working through variances*** and other non-standard features in street design and public improvements, with the private development team. Third, ***the private development team committed to experimenting with innovative design approaches*** to achieve the public and private goals of the project. Fourth, ***a number of jurisdictions provided new funding mechanisms to assist with the economic feasibility of the project***, particularly in the early phases. These included ***grants, deferred charges, offsets,*** and other tools.

Large-scale Regional Planning

In the case of Orenco Station, the project was not an isolated effort, but part of a much larger regional planning reform within the Portland region and the State of Oregon. Prior to Orenco Station, the Portland region adopted its "2040 Growth Concept," which included a polycentric regional plan of TOD greenfield developments as well as urban infill sites [13].

This "centres and corridors" plan provided a web-network of more compact density rings across the region, each with a mix of uses and an inter-connected street grid, connected to other centres along "corridors" (or main street arterials). Many of these centres were existing towns or neighbourhoods, while others were new sites in targeted locations, e.g. along light rail corridors.

The Metro regional planning authority recognised that the framework plan was not enough by itself, but needed implementation tools and strategies. In 2009, a panel was convened to develop a "toolkit," an "action plan," and an ongoing collaborative platform to develop additional innovative resources to unlock development potential. The tools included new financial and regulatory approaches, some of which are discussed below [14].

Another large-scale regional land use planning tool is the "Planning for Rapid Urbanisation Toolkit" published by The Prince's Foundation, The Commonwealth Association of Planners, the Commonwealth Association of Architects, and the Commonwealth Local Government Forum. The toolkit offers processes for visioning, mapping, area targeting, framework structure, financial and process tools, and neighbourhood structure, with a focus on rapidly urbanising parts of the world [15].

Following are several of the critical aspects of land use transformation for new-build conditions.

Changing the Street Grid

Instead of the "dendritic" or branching hierarchical street pattern, grids are laid out in tightly connecting spaces, with intersection spaces roughly 90 metres (300 feet) to 180 metres (600 feet) in spacing, and connections between all intersections (offering pathways for pedestrian and non-motorised vehicles at least, if not motorised vehicles).

Streets are designed explicitly to be multi-modal, with a priority for walking and non-motorised vehicle pathways. The size of streets also follows a "power law" or "lognormal" distribution. Most streets are narrow and low-speed, while very few are very high-speed (but with provisions for continuing the multi-modal grid uninterrupted). A medium number of streets is at an intermediate size. (For more on the specific layout patterns, see Chapter 7.)

Getting Compactness

It is difficult to mandate compactness, but certainly possible to allow it. In the case of residential density, this can be done through regulatory reforms, easing restrictions on housing types, divided units, multi-family buildings, and accessory dwellings. In the case of commercial, it can be done with codes that allow more intense land use, combined with provisions to mitigate the

potential impact. For example, requirements for parking spaces per unit of floor area can be combined with strategies to "capture trips" and other "transportation demand management" strategies. Codes that regulate building forms can provide pathways to increase building volume while reducing impact on adjoining properties, for example through required "step-backs" at higher levels.

Compactness can also be incentivised with a number of financial and regulatory tools, including grants, tax structures and credits, "feebates' (reduced fees based on greater density), and contractual agreements between the public and private sectors (so-called "Public-Private Partnerships"). In some cases, the increased revenue to the public sector from greater compactness – for example, producing a higher income from taxes – can be used to help to finance the public improvements of a project, in exchange for increases in the number of units per area.

Finally, the public sector can mandate minimum densities. However, if the market is not ready to support that minimum level, the result may simply be a failed project. The conditions must be present, and must be nurtured with incentives as well as restrictions.

In conditions where the market does not appear ready to accept a more compact development pattern, carefully developed pilot projects can increase the appeal of this neighbourhood type (as in the case of Orenco Station discussed above).

Getting a Mix of Uses

Once again, it is difficult (if not impossible) to mandate a mix of uses, but certainly possible to allow and even encourage it. Zoning codes can be reformed to become more liberal with regard to use, and more restrictive only on the public edge and streetscape structure. Incentives can be provided through the kinds of financial and regulatory tools discussed previously, including grants, tax structures and credits, "feebates' (reduced fees based on greater density), and contractual agreements between the public and private sectors (so-called "Public-Private Partnerships") as well as value capture and "tax-increment finance."

As before, carefully developed pilot projects can increase the appeal of the format, and increase the confidence of the private sector that the risk-reward profile is acceptable. In the case of Orenco Station, the first phases were careful not to build too much around the station area, where risk was higher. The latter phases, following the success of the first phases, saw very strong growth in this area, and much stronger investor appeal in the model.

6.9 INTEGRATING THE LAND USE AND TRANSPORT SYSTEM: THE RETROFIT SCENARIO

Retrofit projects – those that seek to transform an existing urban area into a more mixed-use, multi-modal, compact area – clearly pose different, often greater barriers than new-build projects. First, their ownership patterns often make changes to street patterns or land uses difficult. Second, existing residents may be unwilling to see changes that might affect their homes or businesses. Third, construction in existing built-up areas can be much more costly, because of the need to accommodate existing operations. Fourth, land costs in existing urbanised areas are often higher than at unbuilt sites. They may also include demolition, remediation and other costs.

On the other hand, there are significant long-term economies to be had in retrofitted urban areas. In a sense, retrofit by itself is a cost-effective strategy, in comparison to new-build. The existing buildings and infrastructure represent a high existing capital investment that can be leveraged to produce greater return on incremental investment. Transport systems can take advantage of the existing network of destinations and users, and supplement them with infill or enhancements of buildings and infrastructure. Historic structures can provide cultural value as well as enhanced quality of life without the investment that would be required to produce the same level of quality. Finally, embodied energy and materials in existing buildings and infrastructure represent a very large "carbon investment" (and an investment in other important resources) that need not be duplicated in all-new structures.

To complete this retrofit work, however, a distinct set of tools and strategies is needed. We discuss a few of them below. A number of these strategies are further described in other publications, including the book *Retrofitting Suburbia* [16], and the chapter "Growing Sustainable Suburbs: An Incremental Strategy for Reconstructing Modern Sprawl," in the book *New Urbanism and Beyond* [17].

Changing the Street Grid

As noted, it is often difficult to acquire the property for additional rights of way to add connectivity to existing street grids. In late 20th century suburban environments, with their many "dendritic" street patterns, this can be a significant problem. However, several strategies are available:

- ***Parking Lots to Streets.*** In some cases, large parking lots afford space for lanes to convert to future streets. Owners may be willing to see the conversion, if they benefit from new street frontage. On other cases, they may be willing to sell easements for future conversion (see below).

- ***"Future-proofing" easements.*** In some cases, owners may be willing to set up tracts of land for future rights of way, in exchange for a fee. The owners are given a period of years before the actual construction will occur – perhaps beyond the period when they might expect to own the property.
- ***New pedestrian and/or bike paths.*** In some cases where vehicular connectivity cannot be improved, it is possible to create pedestrian or bike connections along easements and other unbuildable tracts.

In addition to new street connections, existing streets can be improved significantly with widened pavements, narrowed vehicle lanes, introduced features that slow vehicle speeds, and other retrofit strategies. Sometimes these can be implemented more easily with initial temporary changes that can be evaluated and then made permanent.

Getting Compactness

Among the tools for increasing the compactness of land use:

- ***Zoning code reforms that allow infill on existing lots,*** with appropriate controls on impacts to the surrounding neighbourhood.
- ***Provisions for accessory dwellings,*** including subdivided residences, basement units, apartments added to garages, and other forms of infill.
- ***Liberalization of restrictions on commercial use of residential property,*** including allowing live-work formats and conversion to of buildings to mixed use.
- ***Incentives for renovation and addition to existing buildings,*** including streamlined regulations, tax incentives, grants and other financial mechanisms.
- ***Changes to reduce or eliminate parking minimum requirements,*** so that property owners can decide how much parking to supply based on user demand, and car-free households are no longer required to pay for costly parking spaces they do not need.
- ***Tools to "unlock" marginal sites that could support additional infill,*** including parking lots, excess rights of way, derelict structures, and other under-utilised sites. These should include diagnostic tools to identify and assess sites, financial and taxation tools to incentivise their redevelopment, and regulatory tools to streamline entitlement and construction.

Getting a Mix of Uses

The tools and strategies needed to increase mixed-use retrofit development are similar to those needed to increase compactness, but they may also include incentives for larger-scale developments:

- ***Incentives to re-develop under-utilised large-format or "big-box" sites and shopping malls.*** Many of these sites have failed in recent decades, and are available for
- ***Incentives to assemble smaller parcels into more developable sizes.*** These also include taxation strategies to incentivise assembly for development and disincentivise land banking, finance mechanisms (including land value capture and tax-increment finance strategies), and direct grant and purchase programmes.
- ***Strategies to assemble parcels over a longer time horizon.*** Often it is not possible to assemble sites immediately, because property leases and other instruments run over different periods (for example, lease provisions for parking fields). But an incremental programme of assembly as leases and other agreements expire can make larger properties possible.
- ***Regulatory streamlining to make mixed use easier to create.*** This can include simplified codes, assistance offices, "plug and play" models, and pre-approved types that can be permitted more easily.

6.10 GETTING PUBLIC SUPPORT

One of the biggest mistakes made by those seeking to change land use is to fail to work with the residents and other stakeholders who will be most affected by the changes. As a result, the process can become unnecessarily adversarial, litigious, and even more costly and burdensome to achieve. This is clearly not the path to a cost-effective transport system. There are many cautionary examples of this problem.

Furthermore, this adversarial approach is largely unnecessary. When land use and transport are optimised, the result is a direct benefit to the residents themselves of a more convenient, cost-effective, liveable neighbourhood. However, it is natural that stakeholders will be suspicious of a development process that could potentially go awry, producing more congestion, ugly new buildings, and other undesirable impacts. Bad examples erode trust and create a more adversarial climate, while good examples build trust and "win-win" outcomes.

Many good examples do exist (including Orenco Station, mentioned previously) where a new model of mixed-use, compact, connected development becomes popular, and gains the support of stakeholders. But the development participants must be willing to work in good faith *with* the stakeholders, and earn their trust and willingness to collaborate. At the same time, citizen-stakeholders have a responsibility to work toward the win-win possibilities, and share in the civic and educational process. (The specific topic of public involvement is beyond the scope of this chapter, but there are many

good references that can be found in Chapter 9, "Resources and Further Reading.")

We might refer to this kind of win-win collaborative approach as "QUIMBY" – or "Quality In My Back Yard" – as opposed to "NIMBY," "Not In My Back Yard." When residents and stakeholders have meaningful roles and responsibilities as citizens taking part in the process, the dynamic can become much more constructive.

The result is often a more compact urban development that actually responds to consumer demands, as well as providing broader economic, social and environmental benefits. Surveys consistently indicate that most residents prefer living in walkable urban neighbourhoods over automobile-dependent, urban fringe areas, provided that they are convenient, affordable and safe [18].

In some cases, the optimum approach is to work with residents and stakeholders to develop "plug and play" models of development, giving them greater certainty over the kind of development being created. At the same time, the development team also has greater certainty over the entitlement and development process, translating into lower risk and lower cost.

By targeting under-utilised sites in more distributed, polycentric locations, developers can further reduce the cost of the final developments, and assist with achieving goals of affordability and equity.

6.11 CONCLUSION

In structuring the land use and transport system, there are critical roles to be played by public sector institutions (local governments, agencies, etc.) and private sector ones (for-profit developers, non-profit professional organisations, etc.). Urban development that is successful – that provides equitable opportunity, safety, sustainability, and quality of life, must also successfully integrate the roles of the public and private sectors.

It is not possible for the public sector to command markets into being, or to command successful economic activity into existence. On the other hand, "letting the market decide" is folly, because markets can fail, and economic activities are limited by the "bounded rationality" of their actors. "Laissez-faire" development can lead to short-termism, high externality costs, and catastrophic long-term impacts. Moreover, the public sector has a key role in identifying and achieving the public goods that are part of any successful urban development, especially the public spaces and public infrastructure on which everyone depends for healthy, safe, equitable, sustainable development. At the same time, the private sector (including for-profit and non-profit

private institutions) also has unique expertise in responding to market conditions, and engaging the technical and production systems successfully.

The challenge of urban development, then, is not that of a "command and control" problem, or at least not in crucial respects, but that of a complex adaptive system that must be managed. We could say that in this sense, urban development is "a challenge more like gardening than carpentry." As in gardening, it is not enough to specify the elements, but one must water, fertilize, use good seeds, prune, and also build trellises and planter boxes. In urban development too, it is not enough to merely specify, or to command. One must provide incentives, suitable models, regulatory controls, and a minimum framework of infrastructure.

REFERENCES

[1] Howard, E. (1902). *Garden cities of tomorrow.* London: Faber.

[2] Alexander, C., Ishikawa, S., Silverstein, M., Jacobson, M., Fiksdahl-King, I., & Angel, S. (1977). *A pattern language: Towns, buildings, construction.* New York: Oxford University Press.

[3] Le Corbusier (1943). *La Charte d'Athènes.* Paris: Éditions Minuit.

[4] Schneider, R.J., Handy, S.L. and Shafizadeh, K. (2014), "Trip Generation for Smart Growth Projects," *ACCESS 45*, pp. 10-15; at http://tinyurl.com/oye8aqj. Also see the *Smart Growth Trip-Generation Adjustment Tool* hosted by the University of California at Davis, accessed at http://ultrans.its.ucdavis.edu/projects/smart-growth-trip-generation.

[5] United Nations (2017). *Resolution adopted by the General Assembly on 23 December 2016: 71/256, "New Urban Agenda."* New York: United Nations (25 January 2017.

[6] Sennett R., Burdett, R., Sassen, S., and Clos, J. (2018). *The Quito Papers and the New Urban Agenda.* London: Routledge.

[7] Roche, M. P. (2019). Taking Innovation to the Streets: Microgeography, Physical Structure and Innovation. *Review of Economics and Statistics, 1*-47.

[8] Jacobs J. (1961). *The Death and Life of Great American Cities.* New York: Random House.

[9] Calthorpe, P. (1989). *The Pedestrian Pocket.* In *The Pedestrian Pocket Book,* D. Kelbaugh, Ed. (350-356).

[10] Podobnik, B. (2011). Assessing the social and environmental achievements of New Urbanism: Evidence from Portland, Oregon. *Journal of Urbanism: International Research on Placemaking and Urban Sustainability, 4*(2), 105-126.

[11] Ewing, R., Tian, G., Park, K., Sabouri, S., Stinger, P., & Proffitt, D. (2019). Comparative case studies: Trip and parking generation at Orenco Station TOD, Portland Region and Station Park TAD, Salt Lake City Region. *Cities, 87*, 48-59.

[12] Salon, D. (2014), *Quantifying the Effect of Local Government Actions on VMT,* UC Davis Institute of Transportation Studies (https://its.ucdavis.edu), and California Air Resources Board, available on the Web at https://bit.ly/2NHsmkS.

[13] Metro (2014). Metro (Oregon) 2040 Growth Concept. Website. Accessed at https://www.oregonmetro.gov/2040-growth-concept.

[14] Institute for Portland Metropolitan Studies (2009). Achieving Sustainable, Compact Development in the Portland Metropolitan Area: New Tools and Approaches for Developing Centers and Corridors. Policy Report. Accessed at https://www.oregonmetro.gov/centers-and-corridors-report

[15] The Prince's Foundation (2020). *Planning for Rapid Urbanisation: A Toolkit for Mayors and Urban Practitioners.* London: The Prince's Foundation. Accessed at

https://issuu.com/comarchitect.org/docs/a_toolkit_for_mayors_and_urban_prac

[16] Dunham-Jones, E., & Williamson, J. (2008). *Retrofitting Suburbia: Urban Design Solutions for Redesigning Suburbs.* New York: John Wiley & Sons.

[17] Steil, L., Salingaros, N. and Mehaffy, M. (2008). Growing sustainable suburbs: An incremental strategy for reconstructing modern sprawl. In T. Haas, ed., *New Urbanism and Beyond : Designing Cities for the Future*. New York: Rizzoli.

[18] National Association of Realtors (2017), *National Community Preference Survey* (Web publication). Accessed at www.nar.realtor/reports/nar-2017-community-preference-survey.


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7. COST-EFFECTIVE TRANSPORT PLANNING: ALLOCATION AND SPACING

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7.1 INTRODUCTION

One of the most important lessons of recent research on cost-effective transport research is the impact of transport *networks* as interactive systems, as opposed to collections of isolated point-to-point movements utilizing a range of modes. These interactive, dynamic systems include not only individual modes and their interactions, but also the interactions *between* modes, some of which are much more cost-effective than others. If we seek mode shifts away from relatively costly modes (such as private automobiles) to more cost-effective ones (such as walking and cycling), we must understand the dynamic nature of transport behaviour and use, including the optimal physical configuration of the systems.

Put simply, it does little good to provide, say, a transport line, if it is too far away for most users to walk to the transport stop. It also does little good to provide, say, a central arterial for automobile use, if drivers experience massive congestion because traffic is over-concentrated in one location. It is important, in other words, to provide a diffuse but coordinated network of transport pathways, including pedestrian paths, urban streets, mobility corridors, rural roads, rail lines, and other elements.

In this chapter, we will look at optimum spacing and alignment for these transport elements. We will consider two very different transport planning scenarios: the *greenfield scenario,* where new land is being developed for the first time, often as part of urban extensions; and the *retrofit scenario*, where existing urban areas are modified to accommodate new or upgraded transport systems. Often the greenfield development is occurring in rapidly urbanizing parts of the world including the Global South, whereas the retrofit scenario is required in more mature urban areas, especially Europe and large parts of North America. Each of these scenarios poses its own distinct requirements and challenges: the greenfield scenario often generates significant environmental impacts and barriers, whereas the retrofit scenario often poses higher cost burdens as well as disruptions of existing transport systems.

In turn, for each scenario we will examine several basic elements of transport planning, including transport systems, street pattern configurations, and street space allocations. This will necessarily be a brief overview analysis. Each of

these topics is already covered by extensive literature to which we will refer, and here our interest is in an overview understanding of how these elements can be integrated into a more cost-effective approach to policy and practice.

7.2 TRANSPORT PLANNING FOR INTEGRATED FRAMEWORKS

Broadly speaking, we need to plan for four categories of transport mode:

1. ***Non-motorised modes,*** including walking and cycling;
2. ***Private motorised vehicles,*** including automobiles and motorbikes;
3. ***Shared motorised vehicles,*** including taxis, transport network companies, car-share services, and most recently, motorised rental e-scooters;
4. ***Public motorised vehicles,*** including rail, trams, gondolas, funiculars, streetcars and buses.

It is important to understand and plan for all of these modes as elements of an integrated network, with all working in complementary ways – for example, the walking mode must bridge the critical gap between most modes of public and shared transport and the places of passenger origin or destination. At the same time, it is important to recognise that each of these modes can generate conflicts with other modes – for example, motorised scooters have been reported to disrupt pedestrian travel in a number of cities. Therefore, it is critical to allocate sufficient space for each mode, and to distribute pathways, stations and platforms optimally. Following is a summary of best practice guidance.

Non-Motorised Modes

Walking and cycling, the most common non-motorised modes, are often the least expensive to plan and build. However, travel distances can be limited, and challenges can be posed by topography, climate, land use patterns, and perhaps most important, habits of behaviour. These habits in turn are reinforced by unsafe or unattractive facilities, and by unsuitable land use patterns, creating a "vicious cycle" of decline in walking and bicycling mode travel in many parts of the world.

But the corollary is that carefully planned provisions for walking and cycling, integrated with other modes, can produce remarkably cost-effective results. Evidence shows that the immediate and secondary economic benefits can be significant in even challenging locales, for example where terrain (as in San Francisco) or climate (as in Copenhagen) would seem to pose formidable barriers.[1]

In addition, as discussed in the introduction, non-motorised modes are important sub-components of other modes – for example, users of public

transport and other public motorised vehicles will most often access stops by walking or bicycling. Users of car-share services and other shared motorised vehicles also typically walk or sometimes bicycle to or from the vehicle stations. Even private motorised vehicles are often accessed on the street or in car parks that are accessed by walking.

For all these reasons, non-motorised modes are properly thought of as the "platform" for all other modes. It follows that their planning should be thought of as part of the fundamental framework of cost-effective transport planning – not as an afterthought.

Non-Motorised Modes in Greenfield Scenarios

Existing undeveloped and urbanizing areas offer an important but limited opportunity to plan a coordinated multi-modal framework with non-motorised modes at its core. Once an area is urbanized, it is much more difficult and expensive to retrofit integrated multi-modal systems.

While the types and spacing of different transport modes will vary depending upon population density, geography and other factors, there is one constant for all systems: the mobility of the human pedestrian. Every cohesive multi-modal system requires that users can access elements of the system, usually by walking. The scale at which a human being typically moves in turn generates the optimal scale of spacing for pathways, station nodes and destinations. Best practice generally seeks to avoid required pedestrian travel that is greater than about five minutes duration, which translates into about 400 metres or ¼ mile of distance.

Indeed, the scale of spacing for principal through streets in has been found to be remarkably consistent through history, and in the range of about 400 metres or ¼ mile spacing [2]. This spacing generally allows individuals across the urban region to access the services on these streets – including transport systems – with typically no more than a 400 metre or ¼ mile walk from any adjacent destination. (It should be noted, however, that the surrounding urban fabric also needs to be well-connected, walkable and free of barriers; a fragmented urban form would violate the five-minute goal.)

Using this roughly 400 metre framework as a guide, best practice calls for a grid of principal through streets at this typical spacing in both directions. Larger arterial streets and "mobility corridors" with grade-separated or other higher-speed lanes can be integrated into this grid system, as shown in Figure 1. Users of non-motorised modes can then access bus stops, tram platforms and rail stations within an overall hierarchy of street sizes.

It is important to note that this is only a rough guide, and the streets themselves need not be laid out in a rigid grid pattern – so long as they are

roughly spaced in this pattern so as to allow safe and convenient pedestrian and bicycle access.

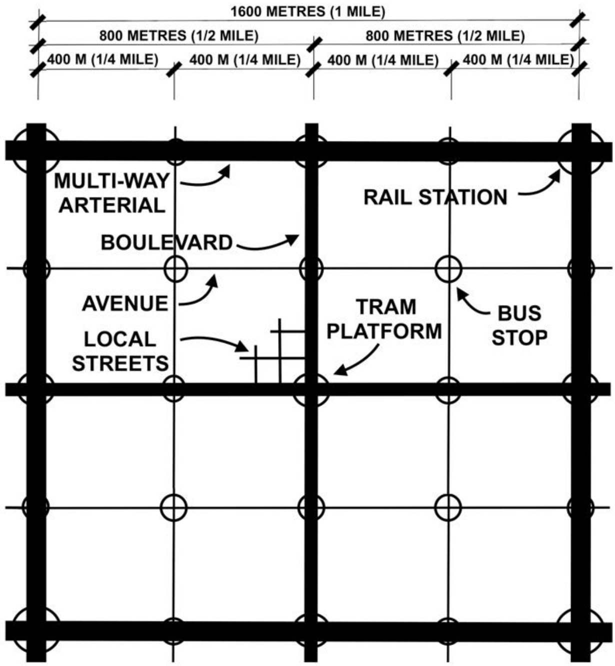

Figure 7.1: An optimum grid framework of 400 metres or ¼ mile, incorporating a hierarchy of street sizes and transport access points (e.g. bus, tram and rail). Source: The author.

Within the roughly 400 metre diameter areas between the principal through streets – regions that are sometimes referred to as "pedestrian sanctuaries" [3] – a permeable network of pedestrian pathways must also be created at a smaller scale. The simplest way to ensure that such a network exists is to regulate maximum block size. The specifications can include maximum length on the long side of the block as well as maximum length on the short side of the block, or alternatively, a maximum perimeter size. This size can be increased by allowing a pedestrian mid-block passage.

Best practice suggests that the ideal pedestrian network should be no larger than about 100 metres for any segment (or about 330 feet) [4]. This specification can be met with a block size of roughly 70 metres (230 feet) on the short side, by 180 metres (590 feet) on the long side, when a mid-block pedestrian pathway is included (Figure 7.2). Such a block configuration is

ideally oriented with the longest side leading toward transport stops, neighbourhood centres, or other frequent pedestrian destinations.

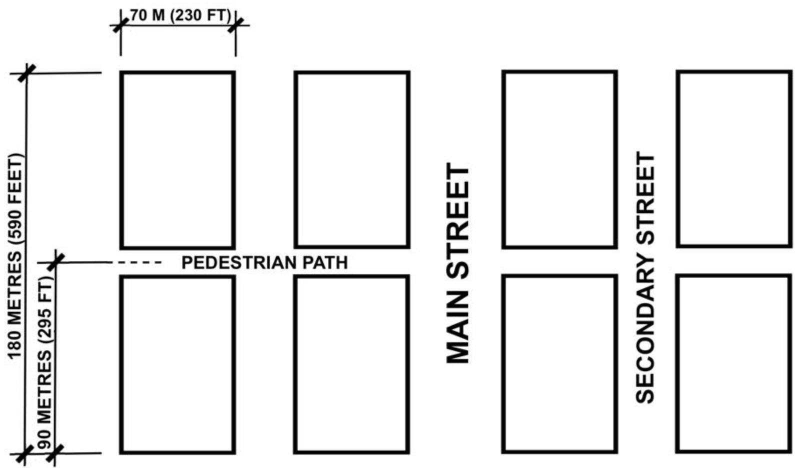

Figure 7.2. A typical best-practice configuration of blocks showing maximum block size when combining a mid-block pedestrian path. Source: The author.

It is important to emphasize that the block arrangement need not be rigid, but can be deflected and irregular, so long as the pedestrian network maintains the maximum distance between intersections. The lower portion of Figure 7.4 (on page 110) shows a more irregular block structure that maintains the same maximum block size and maximum path length. (See also Figure 6.7 on page 84.)

Non-Motorised Modes in Existing Retrofit Scenarios

In existing urbanized areas, non-motorised modes can be enhanced with improvements to walking and cycling paths, including **widening**, **adding missing links and connections,** and **adding greenery and other visual enhancements**. Also important is to create **"paths and goals"** by inserting appealing destinations at a minimum periodic spacing, including pocket parks, refreshment vending stations, viewpoints, and other attractions. Evidence suggests once again that a minimum spacing is approximately 400 metres, or ¼ mile.

As noted previously, the network of walkable streets must be spaced closely enough that any single pedestrian can access the system safely and conveniently at both the start and the end of trips. Existing street networks should therefore be assessed for their fragmented or deficient areas, where distances significantly exceed 400m. Wherever possible, additional paths should be created to improve the connectivity of these areas – for example,

by converting unused railroad right of way (e.g. "rails to trails") or, if possible, by building new street segments.

In some existing urban areas, larger tracts of land are sometimes available for infill redevelopment – for example, former industrial uses, military facilities, and other vacated or under-utilized sites. Their redevelopment offers the opportunity to provide much greater pedestrian walkability, as well as a more limited ability to improve surrounding walkability. Figure 7.4 (below) shows an urban "greyfield" redevelopment that achieves much greater walkability than the surrounding urban fabric, while maximizing the limited opportunities to connect to the larger area. Note that the small block pattern is not rigid, and features deflections and irregularities that help to create pedestrian interest.

Figure 7.3. Orenco Station, a large-scale retrofit TOD project in the Portland, Oregon (USA) region, a large-scale infill redevelopment of a former failed or "zombie" subdivision. Note the rectangular blocks (thicker lines) with pedestrian cut-throughs (thinner lines). Note also the very different block and street structure from the older neighbourhood to the left, which has a highly fragmented and unwalkable form. Such retrofits can contribute at least partially to improving the pedestrian connectivity in their surrounding urban fabric. Source: Google Maps.

Private Motorised Vehicles

Cars, trucks, and other private motorised vehicles are highly mobile, and in general they do not require fixed stations – although they do of course require car parks, loading docks or on-street parking near their destinations. Their flexibility and relatively low upfront cost are key reasons that so many parts of the world have embraced them as dominant modes in planning.

Unfortunately, private motorised vehicles also generate significant externality costs for citizens and for governments, including health impacts from air pollution, runoff water pollution, depletion of resources, long-term infrastructure operating and maintenance costs, and many other significant

costs. There is also evidence of significant social and health costs from automobile-dependent cities and towns, including negative health impacts from a more sedentary lifestyle, and from the consumption patterns associated with the "choice architecture" of automobile-oriented neighbourhoods [5].

Less obvious, planning around private automobiles consumes large amounts of valuable urban space, both in the streets and in the spaces required for parking. In fact, as Litman (2011) has shown, the amount of space automobiles require for parking "greatly exceeds the space they require for roads, and is many times greater than the total space required by other travel modes" [6].

Planning around automobiles also produces a feedback cycle of traffic congestion. The more destinations are pushed apart to accommodate automobile transport and parking facilities, the farther automobiles must drive, putting more cars on the road, degrading non-motorised modes, and further fuelling the spiral of traffic congestion.

For these reasons, many cities around the world have implemented aggressive measures to discourage private automobile use – for example by implementing congestion charges – and to encourage alternative modes of travel that are healthier with lower impacts. Once again, the challenge of retrofitting existing areas is formidable, particularly when it comes to changing land use to provide a denser and more diverse network of destinations.

Nonetheless, private motorised vehicles are likely to play a continuing role in most cities, along with shared motorised vehicles (whose spatial requirements are similar). Therefore, in both greenfield and retrofit scenarios, attention must be devoted to providing for these vehicles while minimizing their negative impacts.

Private Motorised Vehicles in Greenfield Scenarios

The same factors that shape the optimum layout of non-motorised vehicles for undeveloped and urbanizing areas also apply to private motorised vehicles, and indeed other motorised vehicles as well. Indeed, the optimum configuration for all modes manifests a kind of balance across scales, giving primacy to the pedestrian and bicyclist at the smaller scales, and primacy to motorised vehicles at larger scales, while allowing pedestrians, bicyclists and motorised vehicles to access all areas.

A hypothetical layout of streets is shown below in Figure 7.5, once again demonstrating a hierarchy: at larger scales (e.g. above 1600 metres), fast-moving "mobility corridors" (typically grade-separated); at medium scales (e.g. 800 metres), multi-way boulevards; at smaller scales (e.g. 400 metres), through

avenues, and finally, at smaller than 400 metres, the "pedestrian sanctuaries" that provide slow-moving "shared space" lanes.

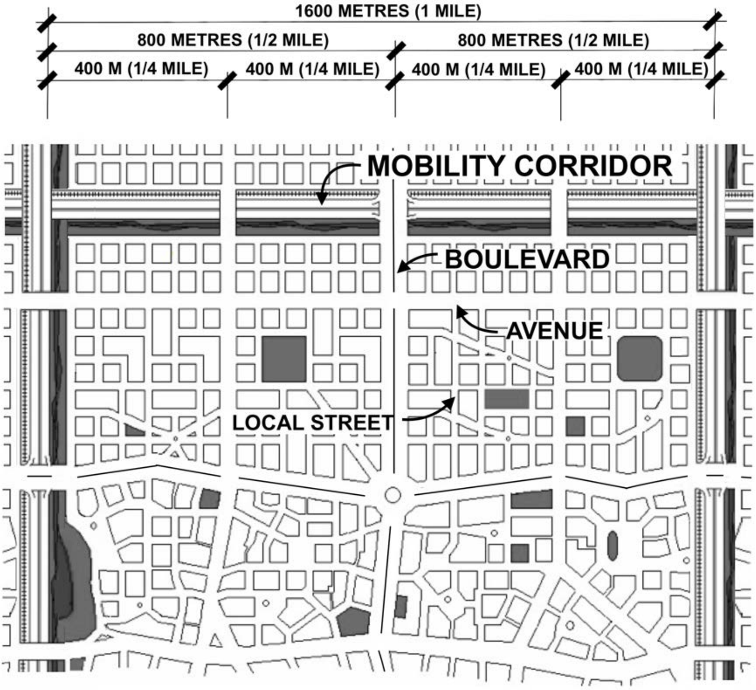

Figure 7.4. A hypothetical street grid showing the 400m spacing of principal through streets, with the slowest streets at the smallest scale, and faster streets spaced at larger scales. Note that the grid need not be rectilinear as shown at the top of the plan. It can be highly deflected and irregular (as shown at the lower part of the plan), so long as the general spacing follows the 400m scale. Source: The author.

Private Motorised Vehicles in Existing Retrofit Scenarios

As discussed previously, in spite of their low upfront cost and flexibility, private motorised vehicles typically generate significant externality costs. For this reason, many cities and towns have begun extensive retrofit programmes to restrict their use, or to reduce their impacts. Following are several of the strategies that have been implemented.

Street retrofits can reduce motorised vehicle lane widths, and widen (or add) pedestrian and bicycle pathways. These projects can produce important long-term benefits, including reduced maintenance of paving areas, improved water runoff quality, and perhaps most significantly, reduced incidence of injuries and deaths from collisions.

Added on-street parking reduces the negative walkability impacts of large car parks, as well as allowing the narrowing of motorised vehicle travel lanes. Parked cars and motorbikes also provide protection for pedestrians, as well as tending to slow traffic as vehicles enter and exit their on-street parking stalls.

Added street segments, though often difficult to accomplish, can have important benefits for dispersing traffic and improving walkability and safety. These projects can vary in scale from short (and more feasible) connections between residential areas, to large-scale insertions like the famous 19th Century multi-way boulevards of Haussmann in Paris. Some street segments can be added in a mid-block configuration to produce quiet shared-space lanes, affording additional well-distributed spaces for parking (as in the example is shown in Figure 7.6). These mid-block lanes can also provide additional walking and biking connections.

Figure 7.5. Catfiddle Street in Charleston, USA, an example of an added midblock street segment (shown at left in white) creating a beautiful shared lane that also accommodates additional parking for cars (shown at right). Drawing by Bevan and Liberatos, photo and project by Urban Ergonomics.

In addition to these physical retrofits, many cities and towns have introduced congestion fees, tolls, and other economic incentives and disincentives, as discussed in more detail in Chapters 4 and 5.

Shared Motorised Vehicles

Taxis, transportation network companies (TNCs), car sharing services, and **e-scooters,** can all contribute to a more flexible, more cost-effective transport system. They can do this by reducing demand for parking, by lowering the number of vehicles required, and by shifting some trips to smaller vehicles, including e-scooters.

At the same time, shared motorised vehicles also pose significant challenges. Taxis and TNCs have similar impacts as private motorised vehicles on congestion, and in some cases may even increase congestion. In particular,

evidence shows that the requirement for "deadheading" or making additional out-of-service trips to pick up users can generate additional vehicle kilometres travelled.[7] It is therefore important to plan for the accommodation of these vehicles in both greenfield and retrofit scenarios, maximising their benefits and minimising their negative impacts.

Shared Motorised Vehicles in Greenfield Scenarios

The street and block structure shown in 2.1.1 and 2.2.1 are also applicable for shared motorised vehicles. It may be useful to plan for **taxi ranks, car share locations,** and **TNC pickup locations** (for example, regularly spaces short-term parking spaces). In addition, many cities have planned and built electric charging facilities for car share vehicles.

A particular challenge is posed by electric scooters or so-called **"e-scooters."** When allowed on pedestrian paths and in other public spaces, they pose particular dangers to pedestrians. However, when allowed in traffic lanes, they pose particular dangers to the e-scooter users themselves. Therefore, for all but the slowest streets, it is generally considered best practice to provide for e-scooters in dedicated lanes, usually combined with bicycle lanes, and adjacent to pedestrian paths (not to vehicle lanes or to parking spaces, due to the danger of opening car doors). This optimum spacing is further discussed in Section 3.

Several technologies are in development at this writing that may merit "future-proofing" considerations for greenfield sites. One of those is **shared autonomous vehicles,** which may reduce the demand for parking, offer greater safety for pedestrians, reduce congestion, and provide other benefits. Even more promising, group rideshare vehicles could become autonomous, in effect serving as on-demand shuttle buses. At least in theory, shared autonomous vehicles do not require extensive new infrastructure and lend themselves to retrofits.

However, many questions remain for autonomous vehicles of all types, and at least until the technology is further developed, there are limited implications for new greenfield developments.

Shared Motorised Vehicles in Existing Retrofit Scenarios

A similar set of requirements exists for existing retrofit conditions – for example, identifying suitable locations for **car share locations** and **TNC pickup locations**. Often existing on-street parking stall locations can be dedicated to their use, or adjacent off-street parking and pickup areas. When streets are retrofitted with additional on-street parking (as discussed in Section 2.2.2) this is an excellent opportunity to dedicate some spaces to car-share use (and possibly electric vehicle charging) as well as TNC pickup zones.

Once again, **e-scooters** pose a particular challenge, especially when space is not available for dedicated lanes, and when dangerous traffic conditions encourage them to travel along pedestrian paths. Some cities have actually prohibited e-scooters, at least in some areas. Another retrofit challenge is to find suitable places to park e-scooters, and there are many reports of e-scooters left blocking pedestrian paths or in other inappropriate locations.

Public Motorised Vehicles

Buses, streetcars and trams, gondolas, funiculars and **railway lines**, all offer different advantages and disadvantages. **Railway lines**, including light rail, tend to be the most expensive but also the fastest, and are therefore more suited to longer regional trips and station spacing of typically 1600 metres (1 mile) or more.

Buses (including privately operated buses and shuttles serving the public) are generally the least expensive but also tend to be slower, making them especially suitable for shorter distances, with designated stops generally in the range of 400 metres or ¼ mile. Because buses typically run within traffic, they also contribute to traffic congestion and suffer delays when traffic is heaviest. **Bus Rapid Transport** can be faster, but also requires dedicated lanes and increased width, adding to cost.

In between the cost of bus and rail are the various fixed-rail **tram and streetcar** systems. These also generally operate within traffic, and suffer similar limitations as buses. However, because they are fixed-rail, stops tend to be more permanent, and users tend to have higher confidence in their long-term availability. At the same time, in most cases they are significantly more expensive than bus systems.

Lastly are **gondolas, funiculars** and other special application systems. These are generally point-to-point systems that traverse otherwise inaccessible paths, for example over steep terrain. They can be expensive, but cost-effective in relation to other systems over the same terrain – or in fact they may be the only systems that are feasible.

Public Motorised Vehicles in Greenfield Scenarios

Figure 7.1 shows a greenfield spacing scheme in which **buses, streetcar/trams** and **rail** are all integrated at different spacing. It is important to note that buses and streetcar/trams run within traffic and are limited by traffic flow, unlike rail systems, which can operate on separate lines and/or below grade. However, a dispersed grid pattern helps to alleviate the potential for congestion "choke points" and keep all modes of traffic moving smoothly. Of course, the capacity of vehicles needs to be adequate for the expected

population density and projected travel patterns. This calculation is not difficult to make based upon an analysis of market demand, population growth and other foreseeable factors.

As noted previously, **bus rapid transport** requires separate travel lanes, and as with rail, generally must be planned at the outset with dedicated station platforms and pathways.

Gondolas and funiculars should also be planned at the outset, even if their construction will be in the future.

As with other systems, all public motorised vehicle systems should be "future-proofed" to evolve as conditions change. For example, in the early years of a greenfield development, rail systems might not be cost-effective or otherwise feasible. By providing an alignment where a system could go in later years, enormous future cost and disruption could be avoided.

Public Motorised Vehicles in Existing Retrofit Scenarios

The retrofit of existing urban areas to accommodate **buses, streetcar/trams** and **rail** poses additional challenges, but they are familiar ones for many cities. Indeed, the history of urbanization from the late 19th Century offers many lessons for the challenges of retrofit, including tunnelling, widening and bridging.

Buses are the easiest to plan in retrofit scenarios, since they can be accommodated in existing lanes and with flexible stop locations (ideally in "pullout" spaces, so that they do not block traffic). They also impact the flow of existing traffic – although if they can capture trips that would otherwise occur by car, their negative impact on traffic flow can be reduced, or even become positive.

Streetcars/trams and **bus rapid transport** generally produce significant disruption from the construction of track and construction of platforms, but this can be minimized with careful phasing. Their initial construction and operating cost is generally more than bus systems, but less than rail systems.

Below-ground rail systems, funiculars and **gondolas** are the least disruptive to construct, but are also generally very expensive systems. **Above-ground rail systems** are generally less expensive but more disruptive in retrofit scenarios.

7.3 PATH, STREET AND ROAD SPACE ALLOCATIONS

While it is important to allocate significant street (i.e. urban) and road (i.e. rural) space for all modes, it is also critical to understand that demand for different transport modes is highly elastic, and often highly unpredictable. Vehicular traffic on streets is not akin to a liquid flowing within a pipe; because drivers are agents who exercise choice, there is no simple formula for determining traffic flow at a given point.

Indeed, one of the most important mistakes of the last century of transport planning was to assume that if automobile travel in particular was restricted by congestion, the remedy was always to widen streets and roads. Usually the accepted methodology has been simply to make traffic counts, and then, when the volume warrants, make “improvements” to the street to accommodate traffic. Less common has been to practice what Jane Jacobs called “attrition of automobiles” [8, 9].

However, this methodology has failed to account for the phenomenon of “induced demand,” the tendency to encourage more trips by automobile when it becomes more convenient. Because travel demand is elastic, it is important to maintain a balance in the system, by offering a range of viable alternative travel modes, and by calibrating incentives and disincentives to reflect long-term costs, including so-called “externality costs” (air pollution, health impacts, etc., as discussed previously). This does not mean eliminating private automobile trips, but making them less frequent and more efficient.

Moreover, it is important to be aware of the potential to generate extra and/or longer trips, simply by creating land use patterns that require or encourage extra travel – as we will discuss further in Section 4.

In allocating area for each kind of path, street and road, we must consider the width of each lane or pathway, the number of each, the curbside allocation [10], and the spacing of each component in each direction within the network. In the case of “multi-way boulevards” (discussed further below), the so-called “slip lanes” will be narrower than the main travel lanes. In addition, for certain kinds of streets known as “queueing streets,” there may be only one lane that is used for both directions of travel, as vehicles will pull to the side or pass in succession.

Below is a table of typical allocations for different kinds of paths, streets and roads, following guidance from the National Association of City Transportation Officials in the USA. These sizes work with the grid scheme indicated in Figure 7.1.

Item	Allocated Space		
	Width per Lane (Stall)	**Number of Lanes**	**Spacing**
Pavement (sidewalk) - Commercial Area	3.5-6.0 Metres (12-20 Feet)	1 per Street Side	Every 70-90 Metres (230-300 Feet)
Pavement (sidewalk) - Residential and Other Areas	1.5-3.5 Metres (5-12 Feet)	1 per Street Side	Every 70-90 Metres (230-300 Feet)
Bicycle Lane	1.0 Metre (3 Feet)	2 per Street	90-180 Metres (300-600 Feet)
Parking Stall	2.2-2.5 Metres (7-8 Feet)	n/a	n/a
Shared Space Lane	2.7-3.0 Metres (9-10 Feet)	1-2	90-180 Metres (300-600 Feet)
Local Street	2.7-3.0 Metres (9-10 Feet)	2 per Street (One if Queueing Street)	90-180 Metres (300-600 Feet)
Avenue	3.0-3.6 Metres (10-12 Feet)	2-4 per Street	Approx. 400 Metres (1300')
Multi-Way Boulevard	3.0-3.6 Metres (10-12 Feet; Slip Lanes Narrower)	4-8 per Street (Including Slip Lanes)	800-1600 Metres (2600-5200 Feet)
Mobility Corridor	3.6 Metres (12 Feet)	2-8	1600-3200 Metres (1-2 Mi.)
Rural Highway	3.6 Metres (12 Feet)	2-8	n/a

Table 7.1: Path street and road allocations.[11]

7.4 CONCLUSION: TOWARD OPTIMAL TRANSPORT NETWORKS

We must recognise that the optimal interconnected, multi-modal network described in this chapter is an approximate ideal, and furthermore, is often impossible to fully achieve. Yet there are many encouraging examples of projects that have shown the benefits of progress toward that ideal. Even in retrofit conditions, significant improvements can be made through infill and other strategies.

We saw an example in Figure 7.4, the transport-oriented development (TOD) of Orenco Station, in the Portland, Oregon (USA) region. That project's urban design was modelled in large part on the successful urban fabric of the central part of Portland (Figure 7.7). That city offers an intriguing example of

an optimally well-connected transport framework, including some retrofit elements that have been added in recent decades. Its walkable small-block structure is remarkably continuous, even extending into vibrant industrial areas, hospitals, universities, and other typically large-block or "campus" users.

Figure 7.5. The remarkably continuous street grid and multi-modal transport system of Portland, Oregon USA. Principal through streets are largely consistent with an optimal 400m (1/4 mile) spacing framework, extending even over the river, freeways and other potential barriers. In some cases, smaller street grid extensions also extend over freeway obstacles, forming a continuous walkable fabric (inset). Some areas, like the Laurelhurst neighbourhood, also show irregular or deflected grid patterns without interrupting the overall 400m grid spacing. Source: Google Maps.

Portland is just one example of best practices in cost-effective transport networks for both existing retrofitted areas and new greenfield extensions. The city and its region have demonstrated that a combination of incremental retrofits and greenfield extensions can indeed achieve a more successful, multi-modal, cost-effective transport network.

However, we must also consider another major element of the equation: the surrounding land use. Clearly the distribution of origins and destinations affects the length of trips, and the cost-effective operation of different modes. Furthermore, the character of land use can have important psychological impacts on transport behaviour, for example, willingness to walk [12] and willingness to use public transport [13. 14]. Unfortunately, we have made serious mistakes in land use planning, which now demand their own reforms and cost-effective solutions.

REFERENCES

[1] Litman, T. A. (2017). *Economic Value of Walkability*. Canada: Victoria Transport Policy Institute.

[2] Mehaffy, M., Porta, S., Rofe, Y., & Salingaros, N. (2010). Urban nuclei and the geometry of streets: The 'emergent neighborhoods' model. *Urban Design International, 15*(1), 22-46.

[3] Appleyard, D. (1980). Livable streets: Protected neighborhoods?. *The ANNALS of the American Academy of Political and Social Science, 451*(1), 106-117.

[4] Speck, J. (2018). Walkable city rules: 101 steps to making better places. Island Press.

[5] Mehaffy, M. W. (2018). Neighborhood "Choice Architecture": A New Strategy for Lower-Emissions Urban Planning?. *Urban Planning, 3*(2), 113-127.

[6] Litman, T. (2011). "Why and How to Reduce the Amount of Land Paved for Roads and Parking Facilities," Environmental Practice, Vol. 13, No. 1, March, pp. 38-46; at http://journals.cambridge.org/action/displayJournal?jid=ENP. Also see, Pavement Busters Guide, Victoria Transport Policy Institute (www.vtpi.org); at www.vtpi.org/pavbust.pdf.

[7] Erhardt, G. D., Roy, S., Cooper, D., Sana, B., Chen, M., & Castiglione, J. (2019). Do transportation network companies decrease or increase congestion?. *Science Advances, 5*(5), eaau2670.

[8] Jacobs, J. (1961). The Death and Life of Great American Cities. P. 338-371. New York: Random House.

[9] Litman, T. (2017). "Determining Optimal Urban Expansion, Population and Vehicle Density, and Housing Types for Rapidly Growing Cities," Transportation Research Procedia, for the 2015 World Conference on Transport Research; at www.vtpi.org/WCTR_OC.pdf

[10] Roe, M. and Toocheck, C. (2017), Curb Appeal: Curbside Management Strategies for Improving Transport Reliability, National Association of City Transportation Officials; at https://nacto.org/tsdg/curb-appeal-whitepaper.

[11] National Association of City Transportation Officials. (2013). *Urban Street Design Guide*. Washington D.C.: Island Press.

[12] Ewing, R., & Handy, S. (2009). Measuring the unmeasurable: Urban design qualities related to walkability. *Journal of Urban Design, 14*(1), 65-84.

[13] Yoh, A., Iseki, H., Smart, M., & Taylor, B. D. (2011). Hate to wait: Effects of wait time on public transport travelers' perceptions. *Transportation Research Record, 2216*(1), 116-124.

[14] Guo, Z., & Ferreira Jr, J. (2008). Pedestrian environments, transport path choice, and transfer penalties: understanding land-use impacts on transport travel. *Environment and Planning B: Planning and Design, 35*(3), 461-479.


ALPHA

8. FINANCING AND BUSINESS MODELS

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8.1 INTRODUCTION

The long-term trajectory of mobility is skewed toward more shared, electrified, and automated modes of transportation rather than away from them [1]. There is a significant movement underway from traditional transportation modes to new mobility services and business models that support them.

Organizations that want to be at the forefront employ design thinking, strategy, and a willingness to adapt their business models. Customers in this digital age are searching for organizations that have disrupted the status quo by reinventing their business models and providing value for them.

Moreover, in order to achieve sustainable and profitable solutions, a clear and innovative business model should be defined. Traditionally, a business model describes the rationale of how an organization creates, delivers, and captures value, in economic, social, cultural or other contexts. However, business models are commonly focused on value creation through economic benefits, often ignoring environmental and social concerns.

In this regard, and focusing on sustainability, affordability and innovation, this chapter will introduce different business models for the road transport sector (i.e. car sharing) and further analysis will follow using the Business Model Canvas for Sustainability (BMCS).

Furthermore, strong attention will be on the affordability and limitations of these business models concerning a sustainable transport landscape.

Additionally, this chapter will also analyse the low-cost infrastructure investment needed in the road transport sector and the different financial tools and risk-sharing mechanisms that can facilitate the decrease of the relative risk-return profile of sustainable transport infrastructure projects.

8.2 THE ROLE OF BUSINESS MODELS

Our vehicles, how we travel around, and our lifestyle, are shaped and changed by new technologies and business models.

Nowadays, we can easily access shared cars, bikes, and scooters using smartphone apps. In that way, our view is that travel is not a long-term commitment to a single mode of transport, but rather, a short-term flexible service.

Electric bikes, scooters, and modular automated shuttles, for example, may make transportation more accessible by reducing the "last mile" between our homes and workplaces. At the same time, vehicle sharing can increase revenues by having cars available 24 hours a day and utilizing the road more efficiently [2]. Consequently, the long mobility trend bends in the direction of more shared, electric, and automated transportation, not the other way around.

With the COVID-19 crisis, operating in the black is nearly challenging without some assistance and the development of efficient business models [1]. Simultaneously, consumer behaviour and mobility patterns are evolving. The COVID-19 pandemic is accelerating these changes, which are promoted by digital solutions and the use of shared and collaborative mobility services [3].

All these facts are accelerating the need for more sustainable and efficient business models.

Several studies show that businesses that reinvent their business models have a better chance of succeeding [4, 5, 6, 7]. Not only is the importance of Business Model Innovation (BMI) addressed in academic literature, but it is also a highly debated subject within the mobility sector.

Because mobility innovations are challenging traditional business models (BMs), the creation of new BMs will be critical to the mobility sector's growth [8, 9, 10]

To thrive in today's competitive climate, transportation companies must create a sustainable business plan. "A business model articulates the reasoning, the data, and other facts that support a customer value proposition and sustainable revenue and expense structure for the company that delivers that value. It's about the value the company can provide to consumers, how it will structure to do so, and how it will regain a percentage of that value" (p.179) [11]. Well-defined business models allow organisations to identify what customers want and need and how organisations may best meet and pay for those demand [12].

8.3 SUSTAINABLE BUSINESS MODELS FOR THE PASSENGER ROAD TRANSPORT SECTOR

Businesses nowadays are pressured to operate more sustainably and consider the economic, environmental, and social logic behind their business practices to create value for their stakeholders. This fact is also valid in the transportation sector due to this industry's multiple negative environmental impacts, and those from road transportation in particular.

Business models have traditionally focused on generating value through economic benefits while disregarding environmental and social problems. However, within business model innovation, the idea of sustainability, which encompasses all three pillars (social, environmental, and economic), is gaining popularity and is now a major emphasis in academic research [13].

Although academics have focused more on how business models promote sustainable urban mobility through innovation, they have given less attention to what makes a business model sustainable and innovative in the context of urban mobility. According to the study made by de Souza et al. [13], the following features play an essential role towards the sustainability of an urban mobility business model: (1) promoting the use of clean energy, (2) maximizing the use of transportation resources and capabilities, (3) promoting sustainable mode substitution; providing service orientation and functionality, (4) formulating initiatives that address the needs of a wide range of stakeholders in transportation systems, (5) limiting demands, (6) extending benefits to society and the environment in a systemic perspective and (7) building mobility solutions that can be scaled up.

However, it is also relevant to consider how BMIs can foster the affordability barrier to access the transport sector and promote its transformation. The Sustainable and Smart Mobility Strategy launched by the European Commission in 2020 stated that mobility must be accessible and affordable to all, so that rural and distant areas remain connected, and that the sector delivers favourable social conditions and appealing employment opportunities [3].

This section introduces the new business model canvas for sustainability (BMCS) developed by (Cardeal et al., 2020). BMCS focuses on integrating the three pillars of sustainability in one business model canvas [14].

Thus, the BMCS preserves the point of the original Osterwalder and Pigneur (2010) canvas, the "sense-making," still focused on the value of a product, process, or organizational innovation, while integrating the three pillars of sustainability as we see in Figure 8.1. [15].

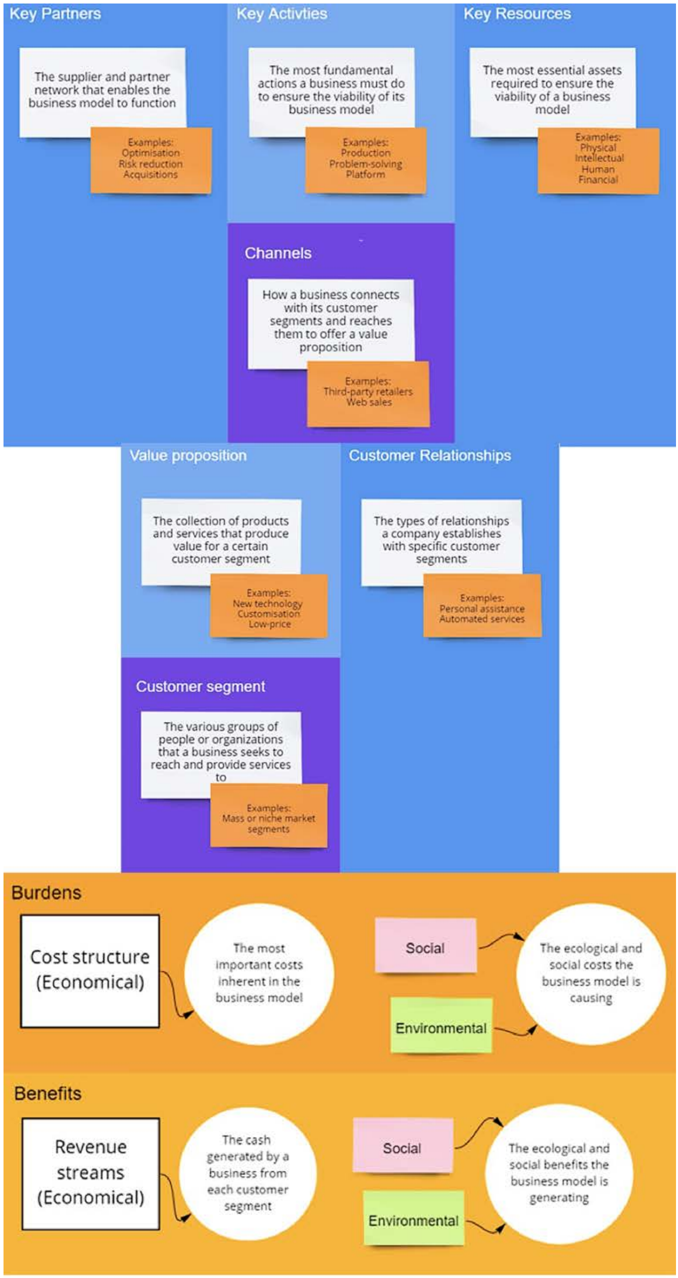

Figure 8.1. Business model canvas for sustainability. Source: adapted by the author using information from (Osterwalder & Pigneur, 2010; Sarasini & Langeland, 2017) and designed using Miro (an online whiteboard & visual collaboration platform) [15, 16].

BMCS will analyse the selected business models depicted in sections 8.3.1 to 8.3.3 to determine their potential as sustainable and low-cost alternatives. However, due to the limits of this study, this section will mainly focus on the burdens and benefits while considering the three pillars of sustainability previously discussed.

The following business models have been selected to propose an alternative to fight the increasing pressure on passenger transport networks in both urban and suburban regions, and they can be integrated as part of digital solutions. For instance, a move towards shared and collaborative mobility services (shared cars, bikes, ride-hailing, and other types of micro-mobility) coincides in many cities, allowing for a reduction in everyday traffic [3].

8.3.1 Shared mobility (Car-sharing and Ride-sharing)

Car and ride-sharing are increasingly seen as a way to transportion to a more sustainable transportation system. They are linked to better urban management, increased energy efficiency, among other benefits. Car-sharing, while driven by new mobile technology and applications, is focused on changes in travel behaviour as a practice, new markets, and business model innovation [16].

Car-sharing

Currently, the business viability of car-sharing conglomerates such as Car2Go primarily consists of city-dense metropolitan areas. Cities naturally have the densest concentrations of workplaces and residential regions, with the best access to public transportation. The possibilities of combining multiple forms of transportation are also most significant here. However, this does not rule out vehicle sharing as a feasible option in suburban and rural regions.

Car-sharing is especially appealing to persons who don't use vehicles on a regular basis by providing access to mobility services instead of owning the car. Car-sharing also improves resource utilization by redistributing, sharing, and utilising excess capacity [16].

Mobility services, such as car-sharing, are presently viewed as a critical area for innovation. This fact is due in part to digitalization and the use of information and communications technology (ICT) technologies in the transportation sector [17, 18]. It is also owing to the emergence of new business models that leverage the value comprised in collaborative consumption, multi- and multimodal travel, and big data analytics [19, 20, 21].

There are three main types of car-sharing business models. Business to Consumer (B2C) and business-to-business (B2B) car-sharing describe the

supply of services to private companies and private individuals, respectively. A corporation operates a fleet of cars and promotes car-sharing among members. The workforce receives fleet access through their company while using B2B car-sharing, also known as corporate car-sharing or employer-based car-sharing [22]. Peer-to-peer (P2P) car-sharing is when existing car owners allow their vehicles to be used by others. There are different car-sharing schemes such as station-based (roundtrip) and free-floating (point-to-point) [16].

The B2B and B2C business models act as **integrators** and handle the value proposition delivery for their customers. Car-sharing businesses utilize a fleet of shared vehicles owned and operated by the company. P2P car-sharing, on the other hand, involves individuals who function as orchestrators, who develop platforms for individuals to share their assets (vehicles). Multi-sided platforms facilitate car and ride-sharing. Some car-sharing organizations also operate as licensors, allowing other organizations to set up their car-sharing services. In B2B segments, businesses serve as both integrators (where they own vehicles) and as licensers (Sarasini & Langeland, 2017).

In this chapter we will focus on integrators and orchestrators, whose business models are summarised in Table 8.1 (next page).

<table>
<tr><th></th><th colspan="2">Integrator</th><th>Orchestrator</th></tr>
<tr><td>Key partnerships</td><td colspan="2">The network of suppliers and partners that make the business model work.</td><td>Direct contact with individuals.</td></tr>
<tr><td>Key activities</td><td colspan="2">Customer support and marketing.</td><td>Customer research and co-creation.</td></tr>
<tr><td>Key resources</td><td colspan="2">Mix of internal combustion engine (ICE) and electric vehicle technologies.</td><td>Physical: Existing vehicle stock.</td></tr>
<tr><td>Value propositions</td><td colspan="2">Station-based or Free floating.</td><td>Rental from peers' homes.</td></tr>
<tr><td>Customer relationships</td><td colspan="2">Looser ties based on digital surveys and feedback.</td><td>Close ties based on continuous interaction.</td></tr>
<tr><td>Channels</td><td colspan="2">• Smartphone apps;
• Website</td><td>• Smartphone apps;
• Website;
• Social media;
• SMS</td></tr>
<tr><td>Customer segments</td><td colspan="2">B2C/ B2B</td><td>P2P</td></tr>
<tr><td rowspan="2">Benefits</td><td>Revenue Streams</td><td>• Monthly subscription payments;
• Hourly fees;
• Kilometre fees</td><td>Provisional fees</td></tr>
<tr><td>Eco-Social Benefits</td><td colspan="2">• Car-sharing improves the use of resources by redistributing, sharing, and utilising excess capacity;
• Car-sharing increases economic output by enabling job seekers who cannot afford a car to utilize one if they need one for job hunting and employment purposes. Additionally, car-sharing can serve specific market segments. For instance, small firms could use car-sharing as a more efficient and flexible alternative to owning automobiles that are only used on an as-needed basis if there is no local conventional vehicle rental service;
• Social inclusion.</td></tr>
<tr><td rowspan="2">Burdens</td><td>Cost structure</td><td>• Vehicle fleet maintenance and operations;
• Parking fees;
• Congestion charges;
• Employees</td><td>• Employees</td></tr>
<tr><td>Eco-Social costs</td><td colspan="2">• The social costs of car-sharing are moderate;
• Car-sharing allows drivers to pay as they go, incurring small fixed expenses but significantly greater variable costs.</td></tr>
</table>

Table 8.1. BMCS for the car-sharing business model. Source: compiled by author using data from Sarasini & Langeland, 2017, Litman, 2000, Roblek et al., 2021, and Deloitte (2017) [16, 23, 24, 25].

Observing Table 8.1, car-sharing could be considered as a merit good that produces external benefits. However, these benefits may not be fully recognized, and relevant stakeholders have also to provide the means for customers to realize the potential of car sharing and promote its positive environmental effects.

Considering the cost structure portrayed in Table 8.1, several measures to make car sharing most cost efficient are discussed by several authors in the literature.

To begin with the integrators business model, the availability (and cost) of parking is a significant impediment to the expansion of these business models. In this regard, Cohen & Kietzmann (2014) suggest, in most B2C car-sharing schemes and some street furniture bike-sharing programs, cities give service providers free or discounted parking. This situation is because many local governments realize the value of these shared mobility options in complementing their comprehensive transport services [8].

Furthermore, Sarasini & Langeland (2017) explain different options to reduce free-floating service costs. As an illustration, one operator in the Nordics has devised a novel pricing plan that rewards users who relocate their vehicles. The operator saves money by not having to hire staff to redistribute vehicles after use [16].

Additionally, some integrators provide lower usage prices as part of a monthly subscription, while others do not charge a monthly fee, allowing members to register without obligation. This allows customers to pay for services on a pay-as-you-go basis, allowing for easy and flexible access to those who prefer to experience them before adoption. Through BMI, integrators frequently test various price packages with varying degrees of coverage to improve the value given.

Moreover, some integrators offer electric vehicles (EV) at a lower cost than ICE vehicles, but this is due to relationships with municipalities ready to support environmental journeys. This subject could be further explored to align the implementation of EV car-sharing programs with municipality's sustainable plans or at a higher level like the European Strategy for low-emission mobility). In this regard, (Arbeláez Vélez & Plepys, 2021) established that B2C and P2P car sharing could reduce transportation emissions if it encourages individuals to change their travel behaviours, such as switching to low-emission options and reducing vehicle ownership [26].

According to Sarasini & Langeland (2017), integrators also advocated for policymakers to prioritise developing EV charging stations. Like parking, integrators must install charging stations on a scenario basis; therefore, many

have teamed with specialized suppliers who operate as intermediaries between landowners, utility companies, and vehicle sharing integrators [16].

Integrators' experiments also aim to reduce the differences between customer segments. Instead of focusing exclusively on business or consumer segments, several integrators have tested or are testing new services that allow commuters to access a shared vehicle for private usage at night and on weekends. The same car might be used by others for business trips and is kept at their workplace during work hours. In this context, one integrator offers different rates for different user categories and hours.

These improvements in the business model can connect commuters' homes to workplaces, which often relate to towns, cities, and suburbs. However, in some countries like Finland, the tax system does not distinguish between different forms of vehicle usage within the same contract.

Like integrators, orchestrators are constantly testing new business models. Some orchestrators focus on adding new value propositions by expanding their initial offerings. As an illustration, in the case of P2P car-sharing orchestrators, they might begin offering P2P ride-sharing or vehicle leasing in addition to their services. Similarly, other orchestrators focus on scaling their business models by entering new partnerships with municipalities and businesses (among other actors). By better-utilizing vehicles owned or leased by them (or others), these businesses aim to cut their own or others transportation costs and environmental impacts.

To conclude, as described above, there are different measures that could decrease the current cost structures of car-sharing business models while benefiting from its positive environmental impacts. However, in order to foster the switch from car ownership to car sharing, there are still several factors to be considered. According to Deloitte (2017), the following success elements are important for free-floating providers: (1) location, dense population to attract enough clients per car, (2) time-based pricing, (3) cooperation with local authorities to grant parking spaces/permits, and (4) convenience, wide availability of (small) vehicles across city areas. Additionally, stationary providers must examine the following success factors: (1) location, considering urban, suburban, and rural areas proximity (2) a wide range of stations, including central hubs (e.g. train stations), (3) distance-based price or hourly rates and (4) fleet versatility. Moreover, for P2P car-sharing, the following aspects must be taken into account: (1) advance user-friendly technology and (2) a broad and diverse network ensuring an optimum match for all customers [27].

Ride-sharing/ Ride-hailing

In cities across the world and motivated by internet and mobile technologies, P2P ride-sharing has developed as an important mobility choice. For P2P ridesharing, social networks and mobile geolocation technology can be utilized to provide real-time ridesharing (e.g., Lyft and Uber) [28].

Key partnerships		• The drivers (the supply side of Uber) can join or leave, as they like. It is essential to have a sufficient number of them to give the consumer proposition (timely pick-up at low cost); • Investors; • Technological partners
Key activities		Commuters can use rideshare apps while at home to identify the nearest pickup spot. Transit vehicles only stop in prefixed locations. Rideshare apps offer dynamic stations while remaining within the radius of operation. It also provides the freedom to move when public transportation is not operating.
Key resources		• Network effect; • Data and Analytics; • Skilled staff; • Apps, Architecture; • Venture capital; • Brand
Value propositions		• For the Driver: Income generation; Flexible Work Hours; ease of joining; low idle times; • For the Rider: Fast pick up; lower cost; convenience; easy transaction; rating/ feedback; • Cheaper and faster than taxis and social networking
Customer relationships		Close ties based on continuous interaction.
Channels		Private vehicles and drivers; Smartphones applications with location-based service
Customer segments		P2P
Benefits	Revenue Streams	The primary source of revenue production is provided by 20% of the fare charged to the customer, with the remaining 80 percent going to the driver as compensation.
	Eco-Social Benefits	• Reduce the environmental impact of local transportation by lowering car use and fossil fuel consumption; • Resources and supply chains that are underutilized. The vehicles used are personal vehicles owned by individuals who wish to share their vehicles; • Interaction with peers and with customers
Burdens	Cost structure	• The main costs involve: sales, marketing & promotion cost; • Aside from that, there are various more costs to consider, for instance: (1) infrastructure cost, (2) research and development, (3) platform maintenance, (4) legal and settlement costs, (5) insurance costs.
	Eco-Social costs	Srnicek (2017) describes the new sharing economy phenomena as "a sort of platform capitalism" that illustrates Uber's so-called social costs. Uber's international operations, many of which are banned, include: (1) violation of the labor legislation (primarily because employees do not recognize drivers' status, irrespective of the amount of job they are carrying out), and (2) infringement of legislation setting the safety of the road/workplace.

Table 8.2. BMCS for the ride-sharing business model. Source: compiled by author using data from Cohen & Kietzmann (2014), Satti, (2019), Sarasini & Langeland (2017), Asirin & Azhari (2018), Roblek et al. (2021), and AppsRhino (2020) [8, 16, 24, 29, 30, 31].

Ride-sharing has a long and widespread history. Non-profit and governmental organizations have offered support for older business models such as traditional carpooling and flexible carpooling schemes. Emerging business models such as P2P ride-sharing have garnered significant market share in a

short period. However, their lack of collaboration with local governments has challenged the long-term success of these models [8].

Table 8.2 (above) describes the results after analysing the ride-sharing business model through the BMCS. It provides an overview to understand its sustainability impacts and the possibilities better to make it more cost-effective.

P2P ridesharing platforms such as Uber and Lyft do not have to employ drivers or buy vehicles, so they can use social networking to grow and scale up their businesses. However, private ridesharing providers have chosen to avoid involvement with local governments. Thus, legal action and other threats from local governments and taxi operators have made their business models vulnerable [8].

To ensure long-term success, Cohen & Kietzmann (2014) suggested that shared mobility service providers should work with local governments [8]. This also means maximizing public and environmental goals to achieve active city support. Incentives to use these P2P networks, such as incorporating ridesharing data into transportation apps, could reduce expenses for riders. This situation would move P2P ridesharing business models for sustainability (BMfS) towards merit models, reduce agency conflicts, and improve social license to operate [32].

Until Uber and Lyft came along, Zipcar was the world's most successful shared mobility firm. Before being acquired by Avis, Zipcar was a for-profit corporation with elements of merit goods. In this regard, it received free parking places from local governments to promote the service and keep costs low for users. In Washington, D.C., Zipcar had free use of 86 curbside parking spaces until 2011.

It is possible to optimize access and environmental effect by viewing shared transportation as a merit good while at the same time reducing the typical agency conflicts usually found in strictly private business models [8].

Therefore, it can be concluded that to reduce the costs (both economic and social) from ride sharing business models, merit good BMfS could play an important role. For doing so, the promotion of public-private partnerships (PPP) is crucial. More details about PPP will follow in the section 8.4.

Mobility as a Service (MaaS)

Mobility as a service (MaaS) is connected to the combination or integration in one single intermodal mobility offer of several forms of travel (e.g., public transport, taxis, bicycle pools). MaaS is evolving in numerous initiatives across Europe, in certain parts of the United States, and Australia as a replacement

for private car ownership by allowing consumers to acquire monthly mobility subscriptions through smartphone apps [16].

MaaS intends to create a linked and cooperative transport market while reducing inconvenience for users. This situation will only happen if a new player, a MaaS provider, enters the transport sector. MaaS providers should be able to eliminate travel-related pain points (Kamargianni & Matyas, 2017).

The MaaS provider connects transport operators and users. MaaS uses data that each transport operator supplies (through secure Application programming interface - APIs), buys capacity from the operators, and then resells it to users. Only one interface is required for the search and transport mode selection. The MaaS operator can use real-time data about the network to find the best options for each journey (supply-side) and customer preferences (demand side) [9].

Various business models with diverse methods exist when the MaaS operator is either a private or a public entity.

MaaS operators strive to enhance their services by integrating other services relating to transport into its standard range of offerings. These extra services can include city bikes, taxis, and other services, including mobile ticketing, payment, multimodal planning, and (re)routing by the mobile service provider (MSP).

Contrary to other business models of MaaS operators, PPP MaaS operators include local logistics service providers (LSPs) and transport service providers (TSPs) and MSPs within MaaS service [33]. The following Table 8.3 portrays the results of MaaS business model analysed through the BMCS.

Key partnerships		The MaaS provider's ecosystem is made up of several actors, including: (1) Transport operators (mobility service providers are also included in this category, i.e. parking space providers), (2) data providers, (3) technology and platform providers (technical back-end providers), (4) ICT infrastructure, (5) insurance companies, (6) regulatory organisations and (7) universities and research institutions.
Key activities		• Development and delivery of MaaS services, such as booking, journey planning, ticketing, and payment; • Customer service to support and help MaaS clients; • The MaaS operator must collect, analyze, and interpret consumer data as well as supplied feedback, and ensure that the appropriate actions are taken to improve the services provided; • Managing relationships with other key partners
Key resources		• Physical resources: Software platform (ticketing services, real-time travel times); • Human resources: Product design and pricing specialist, partnership management, IT personnel, marketing team, and CRM team; • Financial resources; • Information Resources
Value propositions		• A seamless and integrated interface for planning, payment, and ticketing (e.g., price competitiveness, cost reduction, convenience with less time); • Improved end-to-end client experience through multi-modal transportation options; • The MaaS model delivers value to clients by providing them with hassle-free, cost-effective, and personalized mobility.
Customer relationships		In terms of customer relationships, the personal assistance approach could be used in the MaaS business model. Customers would contact a real customer representative for support, primarily through email or call centers. Furthermore, through the MaaS website and application, some automated services may be built where users could help themselves on a self-service basis. Another interface that might be used to improve client connections is user communities.
Channels		• App-based channel; • Website channel; • Third party platforms (utility, energy banks, etc.)
Customer segments		MaaS providers could deliver B2C, B2B, or both services. For example, MaaS operators could provide services to individuals and corporate services to businesses for their employees' business trips.
Benefits	Revenue Streams	• The major source of revenue for the MaaS operator is the provision and sale of MaaS services; • Subscription fee (with basic and premium options) from customers; • Pay-as-you-go; • Fee for additional services (premium services)
	Eco-Social Benefits	• Several economic benefits result from the integration of services, including cost savings, greater economic activity, and enabling new one-way (or point-to-point) alternatives that were previously unavailable; • Modal shift; • Reduced car ownership; • More mobility options; • Better air quality; • Improved transport quality; • Efficient energy use
Burdens	Cost structure	The original development of the MaaS scheme includes the investment cost and the operating and maintenance costs of the system: • The investment costs include those related to the design and development of the platform, the smartphone application, and the creation of the brand; • Operational costs include system operation and maintenance. They are further subdivided into fixed and variable costs: o Fixed costs are costs that do not vary with the number of customers served and include amortization of the investment cost, marketing and advertising costs, maintenance costs for the website, mobile application, and information system, legal-related costs, and data security and privacy costs; o Variable costs for MaaS include providing the service, customer service and support fees, personnel costs, and insurance costs.
	Eco-Social costs	MaaS is likely to generate or encourage some modes of transportation (such as Uber or peer-to-peer car-sharing) that existing regulatory systems are inadequately to handle. This is a drawback of MaaS for governments and cities that view regulation as essential to achieving objectives such as public safety or environmental protection.

Table 8.2. BMCS for the MaaS business model. Source: compiled by author using data from Kamargianni & Matyas (2017), Polydoropoulou et al. (2020), Kao et al. (2019), S. Shaheen & Chan (2015), The International Association of Public Transport (2019), and CIVITAS PROSPERITY (2020) [9, 34, 35, 36, 37, 38]

As shown in Table 8.3, MaaS business models produce several eco-social benefits; however, the cost structure implies the integration and coordination of the different actors involved. But as a novel concept, further research and synergies still need to be done.

Eckhardt et al. (2017) suggest that that in and between cities and suburban areas, the model of the public transport operator is likely to succeed more, given these areas are already relatively well covered by public transport. The PPP model might potentially deliver substantial savings in the public sector, making it more sustainable, particularly in rural areas (where total traffic volumes are small, but journey distance is rather lengthy) [33].

Future market adoption of MaaS will be hindered without creating prototype business models to provide high-value bundled mobility services, as well as helping the MaaS operator and its partners gain revenue.

To illustrate a successful example of how MaaS adoption could bring innovative and cost-efficient changes is led by the company Skipr. A strategy Skipr (a MaaS app that helps initiate and implement a new mobility policy in companies) pursued in Brussels offers MaaS solutions to employers instead of individuals. Skipr CEO Mathieu de Lophem announced a recent €7 million ($8.3 million) fundraising by addressing MaaS companies directly, stating, "Our B2B solution has been producing income from day one".

In 2016, more than 10% of Belgium's 5.7 million cars were registered as corporate cars in 2016. The government has started giving "mobility budgets" for firms that pay their employees a salary to commute via transport or e-scooters. Encountered in Germany and France, company cars suggest a greater market for B2B MaaS solutions [39].

With increasingly integrated services enabling more particular, targeted use of a more appropriate vehicle to shared ownership, the MaaS potential can only grow this role. However, physical infrastructure enabling car-sharing and data integration is needed. Furthermore, cities should put out visions for boosting car-sharing competitiveness vs. individual car ownership (Bloomberg, 2020).

The revenue allocation is a major concern within MaaS. As being a new concept, MaaS faces challenges of deployment and market acceptance. All of this is accompanied by integration costs, coordination, governance, and uncertainty about users' willingness to pay (WTP) for services.

Transforming cities' current mobility into MaaS will need addressing numerous elements, including operational and technical requirements, and most crucially, financial viability.

Maas' future model is unclear but relies on a series of technological, social, mobility, and regulatory changes and developments [34].

8.3.2 Micro-mobility

Congestion in metropolitan areas is taking public spaces with car parks, large roadways, and multi-tiered bridges. Most developed cities have commuter-oriented micro-mobility. This business idea saves customers money while also providing service providers with a cost-effective source of revenue.

The micro-mobility industry provides micro-mobility services. The industry is characterized to sell to consumers (B2C), but may also supply to groups (B2G) or other businesses (B2B). The vehicles produced by the industry mostly comprise scooters, bicycles, and cars. They are electric vehicles. These firms obtain the majority of their raw materials from technology firms and vehicle manufacturers. In some cases, the automobiles are supplied by original equipment manufacturers (OEM). Additionally, the Shared-Micro-Mobility-Industry focuses on offering mobility services that the users share [40].

Shared micro-mobility is an innovative transportation approach that enables users to have short-term access to a transportation mode (bicycle, scooter, or other low-speed mode) on an as-needed basis. Shared micro-mobility includes (mostly) station-based bike-sharing (bicycles can be taken up and dropped off at any station or kiosk) and dockless bike-sharing and scooter-sharing (a bicycle or scooter picked up and returned to any location).

There are several scooter-sharing systems (both standing electric and moped-style scooters) across the globe [41]. For the purpose of this study, the analysis will be done for e-scooter sharing and bike sharing business models.

Scooter sharing (e-scooter)

Scooter-sharing has evolved significantly. According to Kao et al. (2019), the market is still growing, and new players are entering the market [35].

Many key elements influence players' business models. First, city authorities' approaches vary significantly. In many cities, just a few scooter firms are allowed to operate. Second, investors have been flooding the industry with funding.

Local governments must give clear advice and restrictions to respond to this situation, particularly for disruptive innovations like free-floating scooter-sharing. These guidelines would help mobility firms create sustainable business models and commercialize the services faster [35].

The following Table 8.4 introduces the analysis of e-scooters business model using the BMCS approach.

Key partnerships		• Scooter producer; • Operator for picking up and charging scooters; • City authorities; • Insurance (AXA); • Investors.
Key activities		• Scooter & App maintenance; • Communication with authorities; • Customer experience optimization
Key resources		• Electrical scooters; • GPS tracker system and the App; • Human resources: sales and marketing team, mechanics; • Depot for maintenance; • Financial resources
Value propositions		• Improved end-to-end short-distance transport experience with a shared electric scooter; • More cost effective than owning a scooter.
Customer relationships		Automated and self-services, as well as personalized support in some scenarios.
Channels		• App based channel; • Website based channel; • Physical scooter presents in cities
Customer segments		• Commuters in cities; • Users of public transports who travel their 'last-mile'.
Benefits	Revenue Streams	• Fixed fee per scooter trip; • An additional fee for each minute spent on the scooter.
	Eco-Social Benefits	• Better community cohesion; • Less traffic congestion (for short trips); • Lower emissions, thereby contributing to better air quality; • Because e-scooters are smaller than other modes of transportation and easier to ride on sidewalks than bicycles, women may feel safer riding them than men may. Women may also be more distance-sensitive than men, making it easier to stand on an e-scooter than a bicycle.
Burdens	Cost structure	• Scooters acquisition, maintenance, collection and charging; • Maintenance of the app
	Eco-Social costs	• A major source of greenhouse gas emissions from shared e-scooter use is materials, manufacturing, and automotive use for the collection of e-scooter for charging; • In addition, recycling is essential since electric scooters consist of rare elements that are possibly polluting. The batteries (and the cell itself), which makes them responsible for a large amount of pollution from which it cannot be escaped, have to be taken care of, at least until the battery recycling industry is better developed; • While some cities have been slow to adopt micro-mobility, micro-mobility players must tread carefully. Customers abandoning damaged or outdated scooters on the street are difficulties, as are safety concerns.

Table 8.3. BMCS for the shared micro-mobility (e-scooter) business model. Source: compiled by author using data from Kao et al. (2019), Boglietti et al. (2021), Fong et al. (2019), and Hollingsworth et al. (2019) [35, 42, 43, 44].

The results of Table 8.4 display great eco-social benefits and costs. Therefore, according to the literature and the current market trends, in order to optimize the use of e-scooters and promote its cost-efficiency, e-scooters business models should consider the following to thrive: (1) utilize e-scooters for the last mile, lengthen their lifespan, and ride them in a more careful manner to prolong their life, (2) enhance the charging infrastructure (to avoid recharging them with conventional cars) and (3) not to be used to substitute trips that are already low-carbon, such as public transportation, walking, or cycling.

There are different factors that can portray successful e-scooter business models. For instance, Bird (micro-mobility company based in California) CEO Travis Vander Zanden states that unit economics have improved significantly in the last four years. Upgrades to scooter durability and pricing increases for clients have boosted Bird's and likely other micro-mobility platforms' contribution margins. Despite these favourable changes, the industry will need to reduce operational costs and gain market share to be profitable [45].

On the other hand, the economics of shared micro-mobility favor industry players. Micro-mobility assets (like electric bikes) are easier to scale than car-based sharing systems. For example, an electric scooter now costs under $400, against thousands for a car. An e-scooter may break even in less than four months, according to an industry leader's outside-in business case [46].

The year 2019 saw a 62% increase in overall rides, driven by a 130% rise in e-scooter journeys. However, COVID-19 slowed the trend, first reducing rides by 60-70%. The first COVID-19 shock has since reversed and is on track to fully recover by 2021–22.

The high demand and adoption of micro-mobility is estimated to have a market potential of $500 billion by 2030. Untapped markets like this have fuelled an industry rush of investment, with the battle for market share still ongoing [45].

Bikesharing

Bikesharing is one of the fastest rising modes of transportation in many cities. Bikesharing users can rent bikes for one-way or round-trip travel using one of three bike-sharing models: (1) station-based bike-sharing, where users access bicycles via unattended stations offering one-way service, (2) dockless, where users may access (unlock) a bicycle and park it at any location within a predefined geographic region, and (3) hybrid bikesharing systems, offering both physical station-based and dockless bike-sharing. These systems currently work with both traditional (non-motorized) and electric (e-bike) bikes. There are also closed campus and peer-to-peer bike-sharing [47].

In most bike-sharing systems around the world, anyone can borrow a bike for a nominal fee, and a credit or debit card is required to use this system.

The following Table 8.5 describes the results after applying the BMCS to the bike sharing business model.

Key partnerships		• Municipalities; • Public transport; • IT technology providers; • Component/material providers
Key activities		• Development and production; • Platform and fleet maintenance; • Rental terminal maintenance; • Marketing
Key resources		• Production facilities and materials; • Platform; • Terminals; • (e-)Bicycle fleet; • IT and customer support employees
Value propositions		• (e-)Bike-sharing service; • Bike-sharing solution; • Advertising space (on bicycles and mobile apps)
Customer relationships		• Automated & self-service; • Tailored business customer service; • Active online communities
Channels		• Website/platform Apps (iOS, Android, Microsoft); • Terminals Bicycles; • Social media profiles
Customer segments		• Universities; • Companies; • Municipalities; • Individual bike riders The industry usually sells their service directly to customers (B2C), but may also sell some products to groups (B2G) or to other businesses (B2B) (Aasebø, 2019).
Benefits	Revenue Streams	• Subscription fees; • Usage fee (time-based); • Sponsorship; • Advertising
	Eco-Social Benefits	Bike-sharing programs must be used in big numbers in order to provide the greatest possible benefits. Bike-sharing program provide the following eco-social benefits: • They provide cities with flexible mobility, decrease congestion, and serve as a "first/last-mile" connection to boost public transportation; • A recent study revealed that the health advantages of the 12 major Bike-sharing systems bike-sharing systems (BSS) in Europe outweigh the hazards of increased air pollution and road traffic deaths. If all bicycle sharing journeys in these cities replaced car trips, 73 deaths per year could be averted; • Nonetheless, the environmental advantages of bicycle sharing appear to be related to increased cycling rather than reduced resource usage. BSS members own more private bicycles than non-members, according to research.
Burdens	Cost structure	• Marketing; • Platform maintenance and customer relations; • Bike fleet and terminal maintenance.
	Eco-Social costs	• Bicycle maintenance and management.

Table 8.4. BMCS for the shared micro-mobility (e-scooter) business model. Source: compiled by author using data from Kao et al. (2019), Boglietti et al. (2021), Fong et al. (2019), and Hollingsworth et al. (2019) [40, 48, 49, 50, 51, 52, 53].

In order to maximize profits and reduce costs, different innovative ideas must be explored in the industry of bike-sharing.

As stated at the beginning of this sub-section, there are different modes of bike-sharing, where hybrid bike-sharing offers a different approach maximizing flexibility and minimizes chaos. In this regard, Urban Sharing (a Norwegian software platform for micro-mobility) has incorporated custom hardware designs to develop a better solution for bike-sharing. Its proprietary hybrid lock supports both physical and virtual bike-sharing stations. The technique works by locking the bike "to itself" during a break in the borrowing period or returning it to a physical dock. This paradigm provides user flexibility while keeping an ordered and optimized urban functioning.

The hybrid lock also enables "virtual" stations constructed utilizing geofencing technologies. During peak hours, visitors can park and lock their bikes next to the dock. Requests for bike borrowing are intelligently allocated based on the previous usage to balance wear and tear across the fleet. If the station has any "overflow" bikes, they will be allocated first to maintain the well-organized streets. The bike´s technology, not the dock, reduces installation and maintenance expenses for physical stations, as no power connection to the docks is required. A hybrid system is also a cost-effective approach to develop and construct bike share programs, as virtual stations may be tested at almost no cost. Thus, usage trends may be analysed before permanent stations are built.

The geofenced region of virtual stations can be easily increased or decreased based on demand. Virtual stations are a quick and economical approach to expand and adjust the system based on the unique needs of the city and its population [54].

Technological advancements are clearly changing the way people use and own vehicles, affecting all transportation networks. The concept of geofencing—a virtual barrier around a predetermined region or building —could provide a compromise between traditional station-based and free-floating BSSs, enabling the benefits while relieving the issues associated with these systems. Having designated sites to pick up and drop off vehicles could assist overcome some docked BSS restrictions (i.e., insufficient racks or station faults), while keeping some of the parking flexibility given by free-floating BSSs [53].

Cities must encourage shared micro-mobility proactively if they are to realize the market potential and mileage commercialization benefits. Therefore, they could help the micro-mobility business model to ease traffic issues. Encouraging the use of micro-mobility for short journeys could be one option. Cities might also develop intermodal hubs for micro-mobility and public transportation to become more suitable. Nevertheless, micro-mobility players need to go carefully as certain cities today are reluctant to use the

service, including safety restrictions; and the low entry barriers allowing competitors to steal a player´s customer base by investing a bit more [46].

8.3.3 Remarks and Recommendations

After exploring the different business models depicted from sections 8.2.1 to 8.2.4, it can be concluded that they provide several eco-social benefits and some challenging cost structures. Therefore, to exploit these sustainability benefits and reduce costs, BMI has to take place. Both public and private stakeholders have the chance to explore new synergies that could open room for new disruptive business models. These innovations, of course, will depend on the different countries' context, the investment opportunities, and the WTP of potential customers.

Nevertheless, the COVID-19 issue highlights the fact that the "old mobility normal" was already destroying local economies through congestion, overspending on roads and parking, and drivers injuring and killing too many people through collisions and air pollution. Our mobility system was previously faulty and is currently in disrepair [1].

Many people avoided taking public transportation during the epidemic for fear of getting COVID sickness. As a result of national authorities limiting the use of public transportation, some of these passengers have switched to driving, yet cycling is rising in popularity in many locations. As cycling has grown, cities have responded by improving infrastructure, albeit in some cases just temporarily.

The current pandemic has also influenced the concept of smart cities as a sustainable city model in 2020, affecting urban mobility. Cities started accelerating pedestrian and cyclist projects and preparing new vehicle or bike-sharing schemes with private partners. COVID -19 epidemic in 2020 forced car-sharing businesses to close. For instance, companies focus on innovative mobile solutions that provide users more cost-flexible ways (like the launch of "pay-as-you-go") and increasing payment via apps. The effects of a pandemic may be seen in the rise of micro-mobility solutions (sharing scooters, bicycles, and scooters) [24].

According to UNECE (2021), there are different enablers factors that could trigger the public support for a green and sustainable transport [55]:

- Boost public authorities' efforts to identify public concerns about the future of sustainable mobility.
- Local authorities, transport operators, the community, and the private sector must form a solid collaboration.

- Information programs demonstrating how better public transportation, active commuting, and suitable spatial planning can alleviate those concerns
- An ongoing educational and communication campaign similar to the anti-smoking campaign.

Applying BMCS allows having a bigger picture of different sustainable transport business models and identify potential strengths and obstacles. It could serve as a basis for decision-making processes and a foundation for investment plans opportunities. However, further research would be beneficial to compare both the burdens and benefits of the BMCS quantitatively.

8.4 ACCESS TO FINANCIAL INSTRUMENTS TO PROMOTE SUSTAINABLE TRANSPORT

8.4.1. Introduction to financial instruments

(Duțescu, 2019) defines financial instruments following the International Accounting Standards 32 (IAS 32). In this regard, a financial instrument is defined as a contract that produces both a financial asset for one business and a financial obligation or equity instrument for another business. The term "financial assets" refers to "cash, contractual rights to receive cash or another financial asset, or equity instruments" given by other businesses. On the other hand, financial liabilities are contractual commitments to transfer cash or other financial assets or "to interchange financial instruments with another business under potentially unfavourable terms." Equity instruments are contracts that represent a residual interest in a business's net assets [56].

A government, public institution, or any private organization may employ various tools to finance its expenditure. Commonly, financing instruments are categorized as either debt or equity [57]. Within these two broad categories, the investing or borrowing entity may define a wide range of rights, privileges, and constraints.

For this section, the classification of the financial instrument will follow a broader categorization suggested by the European Investment Bank (2018). Thus, financial instruments can be classified as follows [58]:

- **Equity instruments**, such as private equity and venture capital, constitute ownership interests entitled to dividend payments when they are declared but have no explicit right to a return on capital, according to Alexopoulos and Wyrowski (2017) [57]. Equity instruments are employed throughout a company's life cycle, with venture/growth capital being more prevalent in the early stages and private equity in the later stages.

The most fundamental type of equity instrument is the common stock. Due to the unlimited potential for dividends, appreciation in the value of their common stock, and realization of liquidation profits, holders of common stock have the most significant opportunity to participate in a company's performance. On the other hand, common stockholders have the most important risk of loss due to their general subordination to all other creditors and preferred stockholders.

- **Debt instruments,** comprising senior debt, project financing, and asset-backed debt, are described by Alexopoulos and Wyrowski (2017) as a fixed obligation to repay a given sum at a specified future period plus interest. They are used to finance businesses in their late growth and profitability periods, when they have proven business models, a solid balance sheet, recurring revenues, and stable, steady cash flows to fund interest and principal repayments [57].

Additionally, debt instruments also include notes, bonds, and debentures, typically entitled to payments paid first before preferred or common stockholders. The following are some of the benefits of issuing debt instruments: (1) predictable payments to investors, (2) no loss of management's interest in company growth and voting power, and (3) investors assume a lower risk of loss in their investment. Some of the disadvantages include (1) potential operational limits, and (2) restrictions on the use of working capital due to debt servicing commitments.

- **Hybrid instruments,** which include venture debt, mezzanine, and quasi-equity, are those that combine the features of debt and equity, such as mezzanine financing, venture debt, shareholder loans, and preferred equity. Hybrid instruments are typically utilized during a company's growth phase to access funding and ensure expansion without compromising the founders' and current owners' shareholding.

- **Public and risk mitigation instruments,** such as grants, public loans and guarantees, and public-private partnerships (PPPs), intend to assist businesses in growing and obtaining financing – that are generally offered by national and EU-level public bodies. They supplement private market instruments and enable companies to invest in research and development (R&D) and expansion.

These four types of financial instruments are shown in Figure 8.2, and categorised by their level of risk.

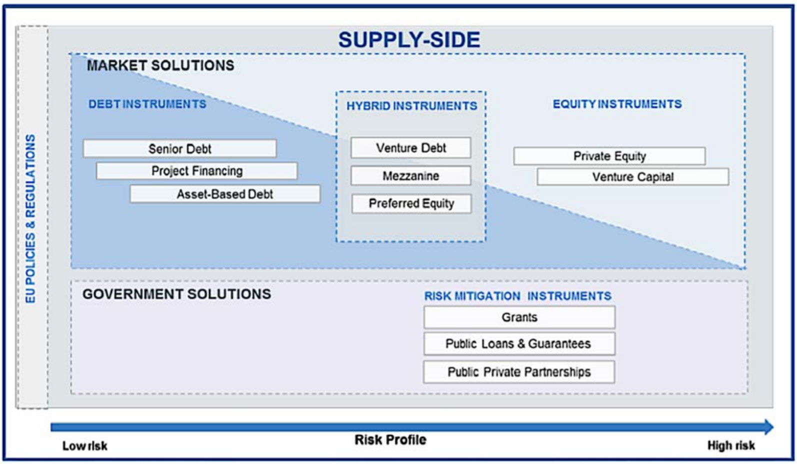

Figure 8.2. Financing instruments overview. (European Investment Bank, 2018).

There are several factors to consider when determining which type of financial instrument to finance transportation infrastructure and services. The planner should think about the many sorts of instruments that may be employed and the relative benefits and drawbacks of each. Besides, it is critical to examine both short- and long-term objectives when developing funding strategies for transportation infrastructure and services. In this regard, it is crucial to develop innovative financing mechanisms to unlock the potential of the different business models within the transport sector. Section 8.4.3. will introduce specific tools available in the market and comment on the adequacy of each of these tools.

8.4.2. Need for investment and financing

The global COVID-19 epidemic in 2020 produced one of the most significant economic downturns in a generation, and the mobility industry was one of the hardest hit. The crisis has imposed a new revenue and profit imperative on automotive OEMs, suppliers, and other mobility players: design a sustainable business model that matches the reality of the future normal [59].

According to Ang and Marchal (2013), today's transportation infrastructure investment presents a once-in-a-lifetime chance to meet rising transportation demand and development goals while avoiding "edging" emissions-intensive development paths. Involving the private sector will be a critical component of attempts to close the infrastructure investment gap, especially given the current limitations on public finances [60].

The rise in global transportation demand, as well as the challenge of reducing greenhouse gases (GHG) emissions in the transportation sector, will necessitate:

- Increasing investment in upgraded or new transportation infrastructure to achieve development goals and rising travel needs, particularly in emerging markets, and

- Transitioning investment away from carbon-intensive road transport and toward sustainable forms of transportation.

Concerning investor categories, it is not the automobile industry investing in shared-mobility startups. Since 2010, around $100 billion has been spent on businesses that provide shared mobility. About 72% of all declared investment since 2010 has come from venture capital and private equity firms, implying a bet on the future rather than on proven and sustainable business models.

In 2019, the global consumer spending on shared mobility was roughly $130 billion to $140 billion. E-hailing accounted for the most significant, between $120 and $130 billion, or more than 90% of the total market. When car-sharing and P2P car sharing are combined, they account for less than 10% of this market, which indicates e-hailing's greater convenience (the customer is driven, may spend the time in the vehicle on other activities, and is not required to find a parking place) [59]. For reference, e-hailing is defined by Jais & Marzuki (2020) as a method of requesting a vehicle that is dependent on network connectivity and the usage of a particular digital application through the Internet [61].

In this context, a more accessible financing environment would benefit the following three emerging sectors: (1) urban green mobility solutions and services; (2) low carbon, highly energy-efficient road vehicles; (3) automated, linked road transport [58].

By mobilizing co-investment from other public and private sector sources, financial instruments might provide a significant new financing channel for strategic investments [62].

Using alternate forms of finance for public transportation, such as green bonds, PPPs, and enabling local businesses to invest in public transport, as mentioned by Americo et al. (2021), will allow them to reap the benefits of increased usage. Finally, governments now allocating some of the greatest public funds in history must incorporate public transportation in their COVID financial recovery plans, prioritise it, and ensure that funding is available. They must also maintain and even step up planned investments in public transportation infrastructures and services due to the numerous

positive multiplier factors that will assist in the achievement of several Sustainable Development Goals (SDGs) [63].

8.4.3. Financing instruments and risk mitigation instruments suggested

As urbanization and car ownership show rising levels, there is a crucial need for a stable and robust financing framework of urban mobility [64]. In this sense, Nyikos (2015) argues that access to funding is a major element of the establishment, survival, performance, and growth of small and mid-size enterprises (SMEs) [62].

Finally, section 8.4.3. will discuss various financial strategies and risk-sharing arrangements that can improve the relative risk-reward profile of sustainable transportation infrastructure and service projects, some of them already described in section 8.2. The financial instruments and risk-sharing mechanisms aim to support the implementation of both private and public projects and can be summarized as follows:

- Public-private partnerships (PPPs).
- Loans;
- Grants;
- Loan guarantees; and
- Green bonds

Growing attention has been given to the issue of financial inclusion and easy access to funds in emerging and developing nations. Increasing concern among policymakers is that the benefits of financial intermediation and markets are not being distributed extensively throughout the population and across economic sectors, with possible negative implications on growth, income distribution, and poverty levels, among others. Additionally, they may be concerned about the adverse effects of macroeconomic stability associated with the concentration of financial system assets in a small number of individuals, enterprises, or sectors [65].

Public Private Partnerships

PPPs have grown in prominence among governments since the 1980s as a means of efficiently executing large-scale transportation infrastructure projects [66].

PPPs are procurement methods that help for private sector participation and risk sharing, as Ang & Marchal (2013) have stated [60]. They must provide adequate "value for money" in comparison to traditional public procurement to be effective. In addition, the proper institutional capacities and processes must be in place. Based on experience, PPPs appear to be most suited for bus rapid transport (BRT), highly used and specific rail linkages, and shared-use

vehicle and bicycle systems. PPPs that are both effective and competitive should adhere to the following principles:

- Assessment of project feasibility and sufficient "value for money" (VfM) in comparison to conventional public procurement;
- Competitive bidding processes in tenders;
- Complete transparency of tender conditions and explicit rules on project cancellation and compensation;
- Clear responsibility and risk-sharing agreements;
- Pricing regulations to ensure revenue flows and attract new entrants;
- PPP operators' independence;
- PPP units to design, implement, monitor, and evaluate PPP projects

Even while it can be a prerequisite of receiving funding, PPP programs to invest in transportation infrastructure are not supported worldwide. On the positive side, a PPP program in the transportation sector can deliver infrastructure and services swiftly, efficiently, and to defined standards without requiring large government capital expenditures. As long as the infrastructure is built and services are delivered under objective standards, private providers have no risk of contract termination. A PPP program's downsides in the transportation sector are typically due to poorly specified or implemented contracts. Such a situation can result from a lack of flexibility, inefficient risk transfer, or a low return on investment [57].

The World Highways (2016) highlights the importance of giving risk capital or bank credit common-interest initiatives. In the EU, for example, it is explored through the use of project bonds and main risk-sharing instruments such as LGTT (loan guarantee instrument for the Trans-European Transport Network projects) to finance long-term transportation projects, including investors. PPPs and other private-sector funding mechanisms should be seen as complements rather than replacements for traditional public finance. In this sense, it is crucial to find the right mix of public and private assistance [67].

Furthermore, regarding the BMs analysed in section 8.2., PPPs can serve as a tool to mitigate the risk while looking for financing assistance and implementation. Some insights into how this sharing-mechanism tool can be implemented in the BMs are analysed in section 8.2. will be illustrated below [67].

First, it is crucial to assess the financial needs in **the capital intensity of business models; GECKO** research (a spin-off company of ETH Zurich) demonstrates how partnerships can adapt to varying financial needs. An innovation's capital-intensiveness affects how much collaboration and experimentation occurs in the first stages of development. On the other hand, authorities frequently react to less capital-intensive technologies (e.g., e-scooters) after introducing them on the streets. Thus, it is vital to take a more

forceful approach to guarantee that these technologies contribute to local mobility goals and do not create difficulties [68].

Another relevant topic is parking. According to (Dowling & Kent, 2015), the success of car-sharing is highly dependent on a series of complicated negotiations between public and private parties. Their research paper emphasized the importance of a **designated car parking space** for facilitating car sharing; for instance, applying behaviour change strategies and public education campaigns may encourage residents to adopt car sharing [69].

Car-sharing relies on parking as a tool to meet its sustainability goals. Dowling & Kent (2015) have demonstrated the possibilities for private provision of sustainable transportation while using different examples of car-sharing highlighted in their research [69].

To carry on with another prospect, Canales et al. (2017) explain the incentives for **pilots and partnerships** [70]. The authors suggest that national governments might incentivize communities to experiment with new mobility applications through pilot initiatives backed by collaborations with respectable organizations. A program that gives grants to assist communities in paying for novel mobility apps and monitors the pilot projects to be assessed is one mechanism for incentivizing this type of experimentation. A framework like this can aid national governments in identifying the most effective pilot initiatives and highlighting them as potential examples for other cities. In this regard, different scenarios will be depicted below about **pilot partnerships with ride-hailing and micro-mobility** companies in the United States (US).

Kortum (2021) analysed **a** 2018 survey of 44 public transport agencies in 22 states in the US [71]. The study focused on the nature of transport agency efforts to coordinate with ride-hailing companies. Moreover, how issues such as the Americans with Disabilities Act of 1990 (ADA) and Title VI compliance (providing ways for low-income minorities without bank accounts or smartphones to pay for transport services), data sharing, labor union concerns, and agency liability were being addressed.

According to the study, most (three-quarters) agencies intended to improve first- and last-mile transport connections in urban and suburban contexts. While one-third also wanted to improve or extend paratransport service and cut costs, approximately 20% wished to serve new areas without service and provide service to low- and middle-income and transportation-disadvantaged customers.

Due to major ride-hailing firms' refusal to provide ADA services and satisfy Title VI responsibilities, agencies enlisted other partners, such as wheelchair-accessible vehicle (WAV) providers or contact centers, to enable trips for non-smartphone users. Respondents also cited concerns regarding implications on unionized workers as critical issues. Most transportation agencies were able to address these issues, while several intended pilots were canceled.

To continue with micro-mobility, pilot initiatives by transport agencies to cooperate with cities and micro-mobility providers to promote first/last-mile connections to transport are being studied as part of the Transport Cooperative Research Program (TCRP).

The TCRP project's interim report and other reports show that efforts to provide first/last-mile connections have concentrated on providing the following actions:

1. Docking stations and parking near transport stops and stations;
2. 148 regulating sidewalk use and parking;
3. Providing bike lanes;
4. Implementing data-sharing requirements that facilitate planning and enforcement.

Rather than transportation agencies, local governments are leading most of these initiatives since local governments set criteria for micro-mobility businesses to operate.

Findings from the TCRP project show that several transport authorities are actively working with micro-mobility operators. In Minneapolis, pilot testing is underway to provide mobility hubs at metro stations (such as micro-mobility parking and bike recharge stations).

Drivers for success for Pilot projects:

The several roles for shared modes in urban, suburban, and rural regions are discussed by Kortum (2021) [71]. In terms of how shared mobility may serve travel across multiple regional geographic scales in connection to public transportation, there appear to be four distinct but related models to consider:

- **Paratransport** through ride-hailing and micro-transport, allowing demand-responsive transport (DRT) bookings to be made in as short as 15 minutes.
- **First/Last Mile Service** that extends transport service beyond the normal quarter- to half-mile walking distance to fixed-route transport (e.g., through the connection offered by ride-hailing, micro-mobility, and micro-transport both (1) along the established

feeder and heavily-traveled transport lines, and (2) beyond fixed-route transport service into regions too weakly inhabited to sustain fixed-route transport);

- **Off-Peak Services** in replacement of fixed-route service for low-income customers,
- It is possible that **low-density services** such as micro-transport and ride-hail providers can completely replace fixed-route transport services in some scenarios.

To summarize, the inflow of shared e-bikes, e-scooters, and e-mopeds can disrupt urban traffic flows (e.g., high-speed driving) and urban space utilization (e.g., parking on sidewalks), causing conflicts amongst road users. These tensions have arisen because projects have been implemented too quickly by the private sector and not necessarily per government goals. As a result, effective collaboration between cities and the private sector is becoming increasingly crucial to maximize new innovative mobility options. In this regard, PPP frameworks are an essential tool for attracting investments; however, following Polis (2021b) [72], this mechanism still encounters several challenges, including:

- Having a **clear sidewalk** is critical to building better connections with those who rely on shared micro-mobility. Although numerous parking pilots are now being tested, it remains a significant issue;
- **Cities are clamouring for more information**. No study has been done on the best methods for integrating mobility into the transportation environment;
- **Technical difficulties**. Cities have reported complications in developing technical solutions for regulating operators, especially in the area of parking;
- **Hybrid systems**. Because people want flexibility, a combination of free-floating and docked services is the best approach to provide micro-mobility services. However, it requires better parking and user education.

After analysing the benefits and challenges of PPPs models, it is concluded that collaboration between cities and the private sector is becoming increasingly essential to capitalize on the prospects of new and innovative transportation options. Following (Stournaras, 2019), the interconnectedness of economies and value chains makes collaboration with the private sector and institutions essential for increased capacity and change. It can also provide new technology, management, and organizational skills and increased capabilities [73]. Finally, to conclude with the section, some **final remarks** are presented below based on the outcomes of the POLIS' Working Group Governance & Integration [68]:

- New governance models are required when new mobility services arise, and old models must be reviewed to guarantee their long-term feasibility;
- The private sector also influences individual mobility behaviour. Long-term goals and company policies that promote and reward more environmentally friendly transportation choices are two ways companies may lead the transition;
- Reacting to regulatory reforms: As mobility regulations (such as data sharing) vary, agreements must be reviewed and modified.
- **As new services developed, COVID-19** witnessed new partnerships. Some changes will last, others may fade, but they have shown the need for more flexible public space usage, collaborations, and governing agendas.
- **SDGS.** (Stournaras, 2019) argues that PPPs can help achieve the UN's Sustainable Development Goals. Goal 17 of the 2030 Agenda for Sustainable Development asks for "effective public, public-private, and civil society partnerships" to improve the mechanisms of achieving the Sustainable Development Goals [73].

Loans, grants and loan guarantees

According to the European Investment Bank, investing in transportation will have to adapt and evolve to keep pace with the industry's growth and our growing awareness of and need for accessible, efficient, clean, and safe transportation options [58].

The majority of mobility service providers struggle to make profits due to intense competition for market share, the maturity of the services and technologies that underpin them, and the obstacles while accessing adequate financial instruments.

Traditional financial methods such as loans, grants, and loan guarantees are commonly used to attract private involvement in large-scale rail or metro projects that would otherwise be entirely owned and managed by public entities. Infrastructure banks or funds can serve as a bridge to disburse loans and guarantees in the meantime [60].

Fi-compass, an advisory services platform on financial instruments under the European Structural and Investment Funds (ESIF), defines **loans** as a commitment in which the lender agrees to make a specific amount of money accessible to the borrower. This amount of money is intended for a specific length of time, and the borrower agrees to return that amount within that time frame. On the other hand, a **guarantee** is defined as a formal agreement to assume whole or partial responsibility for a third party's debt or obligation, or

for that third party's effective execution of its duties, if an event, such as a loan default, happens that triggers such guarantee [74]. According to (European Commission, n.d.), to assist small firms in obtaining loans from banks, guarantees (issued by governmental, private, or mutual guarantee organizations) can compensate for the lack of collateral or creditworthiness by mitigating the bank's risk [75]. Lastly, according to the literature, **grants** are donations from one entity (usually a business, foundation, or government) to another organization (usually the grant recipient).

The European Investment Bank (2018) outlines in its research the suitability of public loans and subsidies for creating various Innovative Transport business models, such as the Usage-Based Payment business model. In this context, service providers are primarily focused on the Usage-Based Payment business model, which includes a wide range of mobility services. With businesses like Uber, Lyft, and BlaBlaCar, they are highly active in the sector of ride-sharing and ride-pooling. Several startups, including MaaS Global, Citymapper, and UbiGo, are investigating digital multimodal systems that assist users in planning and partially booking journeys by linking several means of transportation. They charge a commission or a mobility package cost for such services. Service providers are also considering improving their offerings by using the user data they gather and analyse [58].

In line with the previous research, grants and public loans are critical in enabling the business to take off and supporting R&D and development across all models. Sixty-six percent of the firms interviewed have used or plan to use grants, primarily at the seed stage and, to a lesser extent, in the growth stage.

Public debt instruments such as intermediated loans, direct loans, and project finance become more significant throughout the profit phase when business models are established, and firms produce regular, positive operational cash flows.

Seed-stage businesses are usually supported by public subsidies and guarantees from the European Commission or state programs, seed money and angel investments. Innovative transportation firms are searching for public funds at the European (e.g., Horizon 2020), Member State, and regional levels; however, specific grant programs aren't well-suited to the business profiles of service-oriented businesses. Furthermore, several accelerators get government financing and assist startups at the early stage.

As depicted below, Figure 8.3 illustrates the different financial instruments used in the various business phases.

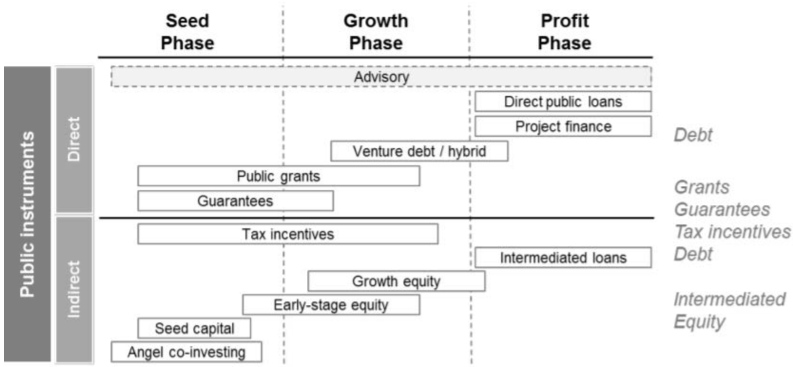

Figure 8.3. Available public instruments in the EU-28. European Investment Bank, 2018.

Therefore, organisations will need to assess their existing operations, practices, and functional abilities and identify new talents and resources required to compete effectively in the future mobility ecosystem [76].

Green bonds

A green bond is a debt instrument that may promote awareness for and finance climate change mitigation and adaptation initiatives. The proceeds from the bond are distributed to projects that provide environmental benefits based on predefined criteria [77], such as renewables, water and energy efficiency, bioenergy, and low carbon transports [78]. According to KPMG (2018), while banks issue most green bonds, companies are increasingly issuing their bonds [79]. Among those who have done so are notable brands in the technology, utility, automobile, and consumer products industries. Green bonds can also be used as a financial instrument by a banking institution to raise long-term financing. Any entity that has never issued a bond but has a reasonable prospect of being creditworthy may issue a green bond [80].

This financial instrument can attract institutional investors such as pension funds and insurance companies by tapping into the debt capital markets, which, according to Ang and Marchal (2013), are currently underutilized for green infrastructure investment [60]. Bonds continue to be the most popular asset type in pension funds (50%) and insurance firms' (61%) portfolios throughout OECD nations [77].

In 2007, the European Investment Bank (EIB) was the first multilateral development organization to issue a USD 1 billion climate-awareness bond. The World Bank issued a second green bond a year later to support climate mitigation and adaptation initiatives in its operating nations. Municipalities,

commercial banks, and some of the world's top corporations have since followed (Banga, 2019). The World Bank (2021) estimates that today, the green bond issuance has grown to $260 billion, with 20% of profits going to the transportation industry.

As previously mentioned, while banks issue most green bonds, progressively more and more green bonds are issued by corporations and cities or municipalities, and to showcase it, some examples will be shown below.

LeasePlan, a worldwide fleet management firm, has created the March 2020 Green Finance Framework, which allows issuing Green Bonds to finance and/or refinance 'Eligible Projects' that fall within the "Eligible Category" of Clean Transportation. Eligible Projects are characterized as those involving battery electric vehicles (BEVs), including micro-mobility vehicles [82].

An example of a region issuing green bonds is the case of the Community of Madrid. In 2020, the Community of Madrid ranked first in Spain for sustainable bond issuance, having issued 1,250 million euros over a ten-year period [83]. As a result, and as stated in the 2020 Inaugural Green Bond & Environmental Impact Report, the 700 million euros raised through the issuance of green bonds in 2020 facilitated the implementation (among others) of clean transportation measures, including the production and use of electric vehicles and charging stations, as well as the use of public transportation and bicycles.

According to Global Infrastructure Outlook, the transportation industry would need $50 trillion in investment by 2040, with a $10 trillion investment shortage. And to fill this gap, different funding methods can be employed. Green bonds, for example, are becoming essential even if conventional financing sources, government borrowing, and taxation are leveraged. The good news is that investors are interested in "sustainable investment," and the potential in the transportation industry remains untapped [77].

Following KPMG (2018), issuers and investors can minimize risks that might otherwise detract from the green bond's financial attractiveness by guaranteeing that their green bond is adequately structured, and that sufficient due diligence is in place. The following are some of the most common challenges in the green bond market [79]:

- The absence of a universal definition of "green." There is no widely acknowledged definition of what constitutes a bond being "green" or "not green." As a result, KPMG specialists advise bond issuers to establish rigorous green criteria in order to maintain investor trust and obtain funding;

- The requirement to understand how bond revenues are used. Green bond investors are growing more demanding, and they increasingly require independent verification that bond proceeds have been adequately controlled and administered;
- 'Greenwashing'. Bond issuers incur reputational risks if the expected environmental advantages are not accomplished. If the issuer violates agreed-upon green clauses, investors may demand penalties;
- The complicated green bond scene. Navigating this environment with so many distinct green bond principles and standards available, ranging from the Green Bond Principles to green bond indexes and sector-specific standards, can be difficult and takes in-depth competence.

8.5 CONCLUSION

Different financial instruments and mechanisms have previously been discussed in earlier sections and their associated benefits and drawbacks. Nonetheless, to increase private investment in sustainable urban mobility, some steps may be taken:

1. **Increase the number of investors.** Consider institutional investors, such as pension funds and insurance firms, in addition to banks, which have limited capacity to offer long-term financing. Climate investors can also bring additional financing sources.
2. Create **holistic investment strategies** instead of focusing on individual initiatives. To attract more considerable interest from the private sector is more strategic to launch a program considering its scalability instead of developing one single project [84].

Finally, some final remarks to accelerate the access to finance in the urban mobility scene are depicted below:

1. In terms of financial instruments, **guarantees and credit enhancements** may minimize financial and political risks that might otherwise dissuade the private sector [85];
2. **Public-private partnerships** can facilitate the exchange of knowledge, resources, and risks.
3. **Competitive advantage** and value proposition to attract strategic investment;
4. **Innovation** and willingness to challenge industry norms to enable the future of mobility;
5. Apply **new business models** and technologies to promote sector transformation.

Nevertheless, the access to finance may be affected by external factors like a poor financial infrastructure or structural and legal problems that have restricted the expansion of nonbank financial institutions, instruments, and markets. However, these factors are outside the scope of this book.

REFERENCES

[1] Forbes, (2020). "Transportation Business Models Are Broken. It's Time To Fix Them,". https://www.forbes.com/sites/timothypapandreou/2020/05/20/transportation-business-models-are-broken-its-time-to-fix-them/amp/.

[2] European Commission, (2019). "New technologies and business models - the future of road transport,". https://ec.europa.eu/jrc/en/facts4eufuture/future-of-road-transport/new-technologies-business-models.

[3] European Commission, (2020). "Sustainable and Smart Mobility Strategy,". https://eur-lex.europa.eu/legal-content/DE/TXT/?uri=CELEX%3A52020DC0789.

[4] H. Chesbrough, (2010). "Business model innovation: Opportunities and barriers," *Long Range Plann.*, vol. 43, no. 2–3, pp. 354–363, doi: 10.1016/j.lrp.2009.07.010.

[5] R. R. Nelson, (2005). *Technology, institutions, and economic growth.* Harvard University Press.

[6] D. J. Teece, (2007). "Explicating dynamic capabilities: The nature and microfoundations of (sustainable) enterprise performance," *Strateg. Manag. J.*, vol. 28, no. 13, pp. 1319–1350, doi: 10.1002/smj.640.

[7] S. C. Voelpel, M. Leibold, and E. B. Tekie, (2004). "The wheel of business model reinvention: how to reshape your business model to leapfrog competitors," *J. Chang. Manag.*, vol. 4, no. 3, pp. 259–276, doi: 10.1080/1469701042000212669.

[8] B. Cohen and J. Kietzmann, (2014). "Ride On! Mobility Business Models for the Sharing Economy," *Organ. Environ.*, vol. 27, no. 3, pp. 279–296, doi: 10.1177/1086026614546199.

[9] M. Kamargianni and M. Matyas, (2017). "The business ecosystem of mobility-as-a-service," in *96th Transportation Research Board (TRB) Annual Meeting, Washington DC,* vol. 96, no. January, pp. 8–12, [Online]. Available: http://discovery.ucl.ac.uk/10037890/1/a2135d_445259f704474f0f8116ccb625bdf7f8.pdf.

[10] T. Vaskelainen, (2014). "Sustainable business models-The case of car sharing," .

[11] J. Teece, D., (2010). "Business Models, Business Strategy and Innovation," *Long Range Plann.*, vol. 43, no. 2, pp. 172–194.

[12] Andrea Ovans, (2015). "What Is a Business Model?," https://hbr.org/2015/01/what-is-a-business-model.

[13] J. V. R. de Souza, A. M. de Mello, and R. Marx, (2019). "When is an innovative urban mobility business model sustainable? A literature review and analysis," *Sustain.*, vol. 11, no. 6, pp. 1–18, doi:

10.3390/su11061761.
[14] G. Cardeal, K. Höse, I. Ribeiro, and U. Götze, (2020). "Sustainable business models–canvas for sustainability, evaluation method, and their application to additive manufacturing in aircraft maintenance," *Sustain.*, vol. 12, no. 21, pp. 1–22, doi: 10.3390/su12219130.
[15] A. Osterwalder and Y. Pigneur, (2010). *Business model generation: a handbook for visionaries, game changers, and challengers*, vol. 1. John Wiley & Sons.
[16] S. Sarasini and O. Langeland, (2017). "Business model innovation for car sharing and sustainable urban mobility," *Nord. Energy Res.*, vol. 5, pp. 1–28, [Online]. Available: http://www.nordicenergy.org/wp-content/uploads/2017/05/IST-2017-Sarasini-Langeland.pdf.
[17] A. Burrows, (2015). "Journeys of the Future–Introducing Mobility as a Service. Atkins Global," *Atkins Glob.*
[18] G. Motta, D. Sacco, T. Ma, L. You, and K. Liu, (2015). "Personal mobility service system in urban areas: The IRMA project," in *Proceedings - 9th IEEE International Symposium on Service-Oriented System Engineering, IEEE SOSE 2015*, 2015, vol. 30, pp. 88–97, doi: 10.1109/SOSE.2015.15.
[19] S. Sarasini, L. Marcus, M. Karlsson, H. Strömberg, and M. Friman, (2016). "Integration as a conduit for sustainable forms of Mobility as a Service," in *23 rd ITS World Congress*, pp. 10–14, [Online]. Available: https://www.viktoria.se/sites/default/files/pub/viktoria.se/upload/publications/its_sarasini_et_al._2016.pdf.
[20] S. Sarasini, M. Linder, T. E. Julsrud, O. Langeland, and T.-E. Julsrud, (2016). "Integrating a business model perspective into sustainability transportions: A research agenda based on servitised mobility CRAFTTRANS View project SHIFT (Sustainable Horizons in Future Transport) View project Integrating a business model perspective into su," [Online]. Available: https://www.researchgate.net/publication/313367809.
[21] A. Spickermann, V. Grienitz, and H. A. Von Der Gracht, (2014). "Heading towards a multimodal city of the future: Multi-stakeholder scenarios for urban mobility," *Technol. Forecast. Soc. Change*, vol. 89, doi: 10.1016/j.techfore.2013.08.036.
[22] J. Clark and A. Curl, (2016). "Bicycle and car share schemes as inclusive modes of travel? A socio-spatial Analysis in Glasgow, UK," *Soc. Incl.*, vol. 4, no. 3, pp. 83–99, doi: 10.17645/si.v4i3.510.
[23] T. Litman, (2000). "Evaluating carsharing benefits" *Transp. Res. Rec.*, vol. 1702, no. 1702, doi: 10.3141/1702-04.
[24] V. Roblek, M. Meško, and I. Podbregar, (2021). "Impact of car sharing on urban sustainability," *Sustain.*, vol. 13, no. 2, doi: 10.3390/su13020905.
[25] T. Schiller, J. Scheidl, and T. Pottebaum, (2017). "Car Sharing in

Europe - Business Models, National Variations and Upcoming Disruptions," *Monitor Deloitte*, https://www2.deloitte.com/content/dam/Deloitte/de/Documents/consumer-industrial-products/CIP-Automotive-Car-Sharing-in-Europe.pdf.

[26] A. M. A. Vélez and A. Plepys, (2021). "Car sharing as a strategy to address ghg emissions in the transport system: Evaluation of effects of car sharing in Amsterdam," *Sustain.*, vol. 13, no. 4, doi: 10.3390/su13042418.

[27] Deloitte, (2017). "Car sharing in Europe. Business models, National Variations and Upcoming Disruptions," https://www2.deloitte.com/content/dam/Deloitte/de/Documents/consumer-industrial-products/CIP-Automotive-Car-Sharing-in-Europe.pdf.

[28] J. H. Kietzmann, K. Hermkens, I. P. McCarthy, and B. S. Silvestre, (2011). "Social media? Get serious! Understanding the functional building blocks of social media," *Bus. Horiz.*, vol. 54, no. 3, doi: 10.1016/j.bushor.2011.01.005.

[29] S. Satti, (2019). "Success Factors of Rideshare Business Model and Future Forecasts,". https://cabstartup.com/success-factors-rideshare-business-model-future-forecasts/.

[30] A. Asirin and D. Azhari, (2018)."Ride-sharing business model for sustainability in developing country: Case Study Nebengers, Indonesia," in *IOP Conference Series: Earth and Environmental Science*, vol. 158, no. 1, p. 12053, doi: 10.1088/1755-1315/158/1/012053.

[31] AppsRhino, (2020). "How Uber works and makes Money: Business and revenue model of Uber,". https://www.appsrhino.com/how-uber-works-and-makes-money-business-and-revenue-model-of-uber/.

[32] H. Tregidga, K. Kearins, and M. Milne, (2013). "The Politics of Knowing 'Organizational Sustainable Development,'" *Organ. Environ.*, vol. 26, no. 1, doi: 10.1177/1086026612474957.

[33] J. Eckhardt, J. Sochor, and A. Aapaoja, (2017)."Mobility as a Service Mobility as a Service," in *12th ITS European Congress*, no. August, pp. 2–4.

[34] A. Polydoropoulou, I. Pagoni, A. Tsirimpa, A. Roumboutsos, M. Kamargianni, and I. Tsouros, (2020). "Prototype business models for Mobility-as-a-Service," *Transp. Res. Part A Policy Pract.*, vol. 131, doi: 10.1016/j.tra.2019.09.035.

[35] P. Kao, C. Busquet, V. Lubello, M. Meta, and C. Van Den Heuvel, (2019). "Review of business models for new mobility services," .

[36] S. Shaheen and N. Chan, (2015). "Mobility and the sharing economy: Impacts synopsis," *Berkeley, CA Transp. Sustain. Res. Center, Univ. Calif.*

[37] International Association of Public Transport, (2019). "Mobility as a Service," doi: 10.1145/3308560.3317050.

[38] CIVITAS, (2020). "Civitas 2020 Innovation brief on Mobility as a Service," . http://sump-network.eu/fileadmin/user_upload/Innovation_Brief_Mobility_as_a_Service_22_08_2017_web.pdf.
[39] D. Zipper, (2020). "The Problem With 'Mobility as a Service,'" *Bloomberg CityLab*. https://www.bloomberg.com/news/articles/2020-08-05/the-struggle-to-make-mobility-as-a-service-make-money.
[40] H. K. W. Aasebø, (2019). "Shared Micro Mobility: What is happening in our streets? A study on Micro Mobility and Mobility Data." , [Online]. Available: https://www.duo.uio.no/bitstream/handle/10852/69645/7/AasebоHaakon.pdf.
[41] S. Shaheen, A. Cohen, N. Chan, and A. Bansal, (2019). "Sharing strategies: Carsharing, shared micromobility (bikesharing and scooter sharing), transportation network companies, microtransport, and other innovative mobility modes," in *Transportation, Land Use, and Environmental Planning*, Elsevier.
[42] S. Boglietti, B. Barabino, and G. Maternini, (2021). "Survey on e-powered micro personal mobility vehicles: Exploring current issues towards future developments," *Sustain.*, vol. 13, no. 7, doi: 10.3390/su13073692.
[43] J. Fong, P. Mcdermott, and M. Lucchi, (2019). "Micro-Mobility , E-Scooters and Implications for Higher Education," *Upcea*, no. May, [Online]. Available: https://upcea.edu/micro-mobility-e-scooters-and-implications-for-higher-education/.
[44] J. Hollingsworth, B. Copeland, and J. X. Johnson, (2019). "Are e-scooters polluters? the environmental impacts of shared dockless electric scooters," *Environ. Res. Lett.*, vol. 14, no. 8, doi: 10.1088/1748-9326/ab2da8.
[45] J. Eliasen, (2021). "The Future of Micromobility. How VCs and E-Scooters kicked off the… | by Jason Eliasen | The Startup | Medium," . https://medium.com/swlh/the-future-of-micromobility-2d4d96d4e2dd.
[46] McKinsey & Company, (2019). "Micromobility's 15,000-mile checkup," . https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/micromobilitys-15000-mile-checkup.
[47] S. Shaheen and M. Christensen, (2014). "Shared-use mobility summit: retrospective of north America's first gathering on shared-use mobility," *Transp. Sustain. Res. Cent.*
[48] E. Vitkauskaite and E. Vaiciukynaite, (2020). "Comparative study of business models of European micro-mobility online services," *Proc. Int. Conf. Electron. Bus.*, vol. 2020-Decem.
[49] P. DeMaio, (2009). "Bike-sharing: History, Impacts, Models of Provision, and Future," *J. Public Transp.*, vol. 12, no. 4, doi: 10.5038/2375-0901.12.4.3.

[50] E. Fishman, S. Washington, and N. Haworth, (2013). "Bike Share: A Synthesis of the Literature," *Transp. Rev.*, vol. 33, no. 2, doi: 10.1080/01441647.2013.775612.

[51] Y. Zhang and Z. Huang, (2012). "Performance evaluation of bike sharing system in Wuchang area of Wuhan, China," in *2012 6th International Association for China Planning Conference, IACP 2012*, doi: 10.1109/IACP.2012.6342972.

[52] S. A. Shaheen, S. (University of C.-B. Guzman, and H. (University of C.-B. Zhang, (2010). "Bikesharing in Europe, the Americas, and Asia: Past, Present, and Future," *Transp. Res. Rec. J. Transp. Res. Board*, vol. 2143, no. 1, pp. 159–167.

[53] L. Caggiani and R. Camporeale, (2021). "Toward Sustainability: Bike-Sharing Systems Design, Simulation and Management." Multidisciplinary Digital Publishing Institute.

[54] A. Hendrix, (2018). "Hybrid Bike Sharing," *Urban Sharing*. https://medium.com/urbansharing/hybrid-bike-sharing-90e2b835f106.

[55] UNECE, (2021). "Recommendations for Green and Healthy Sustainable Transport – 'Building Forward Better,'" *Recommendations for Green and Healthy Sustainable Transport – "Building Forward Better,"*. https://unece.org/sites/default/files/2021-04/2101940_E_PDF_WEB.pdf.

[56] A. Duțescu, (2019). "Financial instruments," in *Financial Accounting: An IFRS Perspective in Romania*.

[57] UNECE, (2017). *Innovative ways for Financing Transport Infrastructure*, no. ECE/TRANS/264.

[58] European Investment Bank, (2018). "Financing innovation in clean and sustainable mobility Study on access to finance for the innovative road transport sector,". https://www.eib.org/en/publications/access-to-finance-for-the-innovative-road-transport-sector.

[59] McKinsey & Company, (2021). "Shared mobility: Where it stands, where it's headed,". https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/shared-mobility-where-it-stands-where-its-headed.

[60] G. Ang and V. Marchal, (2013). "Mobilising private investment in sustainable transport: The case of land-based passenger transport infrastructure," .

[61] A. S. Jais and A. Marzuki, (2020). "E-Hailing Services in Malaysia : Current Practices," *J. Malaysian Inst. Planners*, vol. 18, no. 3.

[62] G. Nyikos, (2015). "The role of financial instruments in improving access to finance in less-developed regions - Combined Microcredit in Hungary," *2nd Jt. EU Cohes. Policy Conf. Challenges New Cohes. Policy 2014-2020 4th- 6th Febr. 2015 Riga, Latv.*, [Online]. Available: https://estif.lexxion.eu/data/article/8195/pdf/estif_2015_02-

009.pdf.
[63] A. Americo *et al.*, (2021). "Recommendations for Green and Healthy Sustainable Transport-" Building Forward Better"," .
[64] E. D. Sclar, M. Lönnroth, and C. Wolmar, (2014). *Urban access for the 21st century: Finance and governance models for transport infrastructure*. Routledge.
[65] World Bank, (2016)."Financial Access,". https://www.worldbank.org/en/publication/gfdr/gfdr-2016/background/financial-access (accessed Oct. 01, 2021).
[66] M. Siemiatycki, (2009). "Delivering transportation infrastructure through public-private partnerships: Planning concerns," *J. Am. Plan. Assoc.*, vol. 76, no. 1, doi: 10.1080/01944360903329295.
[67] World Highways, (2016). "Innovative financing mechanisms for sustainable roads funding,". https://www.worldhighways.com/feature/innovative-financing-mechanisms-sustainable-roads-funding.
[68] Polis, (2021a). "Public Private Partnerships: Local & Regional Scales,". https://www.polisnetwork.eu/news/public-private-partnerships-local-regional-scales/.
[69] R. Dowling and J. Kent, (2015). "Practice and public-private partnerships in sustainable transport governance: The case of car sharing in Sydney, Australia," *Transp. Policy*, vol. 40, doi: 10.1016/j.tranpol.2015.02.007.
[70] D. Canales *et al.*, (2017). "Connected urban growth: Public-private collaborations for transforming urban mobility," *Coalit. Urban Transportions. London Washington, DC. Available http//newclimateeconomy.net/content/cities-working-papers. Coalit. Urban Transportions c/o World Resour. Inst.*, vol. 10.
[71] K. Kortum, (2021). *The Role of Transport, Shared Modes, and Public Policy in the New Mobility Landscape*, no. 332.
[72] Polis, (2021b)."Public Private Partnerships: Shared Micromobility, taking stock,". https://www.polisnetwork.eu/news/public-private-partnerships-shared-micromobility-taking-stock/.
[73] Y. Stournaras, (2019). "Building public-private partnerships," no. October.
[74] European Investment Bank, (2015). "Financial Instrument products Loans, guarantees, equity and quasi-equity," [Online]. Available: https://www.fi-compass.eu/sites/default/files/publications/ESIF-factsheet-FI-products.pdf.
[75] European Commission, (n.d.). "Loans and guarantees." https://ec.europa.eu/growth/access-to-finance/funding-policies/loans-guarantees_en.
[76] Deloitte, (2016). "Financing the Future of Mobility,". https://www2.deloitte.com/content/dam/Deloitte/za/Documents/consumer-business/ZA_DeloitteDUP_Financing-the-Future-of-mobility_CIP_Auto_Nov16.pdf.

[77] World Bank, (2021).“Transportion towards sustainable mobility – Where is the financing?,” [Online]. Available: https://blogs.worldbank.org/transport/transportion-towards-sustainable-mobility-where-financing.

[78] E. Campiglio, (2016).“Beyond carbon pricing: The role of banking and monetary policy in financing the transportion to a low-carbon economy,” *Ecol. Econ.*, vol. 121, doi: 10.1016/j.ecolecon.2015.03.020.

[79] KMPG, (2018).“Issuing green bonds,” [Online]. Available: https://assets.kpmg/content/dam/kpmg/xx/pdf/2018/10/green-bonds-services.pdf.

[80] Sustainalytics, (2019). “Most common Questions for Green bond issuance,”. https://www.sustainalytics.com/esg-research/resource/corporate-esg-blog/most-frequently-asked-questions-green-bonds.

[81] J. Banga, (2019).“The green bond market: a potential source of climate finance for developing countries,” *J. Sustain. Financ. Invest.*, vol. 9, no. 1, doi: 10.1080/20430795.2018.1498617.

[82] LeasePlan, (2021). “LeasePlan ’ s 2020 green bond impact assessment report,” [Online]. Available: https://www.leaseplan.com/corporate/~/media/Files/L/Leaseplan/documents/leaseplan-green-bond-impact-assessment-final-report.pdf.

[83] Comunidad de Madrid, (2021). “Lideramos en 2020 el ranking español de emisión de bonos sostenibles,”. https://www.comunidad.madrid/noticias/2021/06/02/lideramos-2020-ranking-espanol-emision-bonos-sostenibles.

[84] World Bank, (2018). “Maximizing finance for sustainable urban mobility,”. https://blogs.worldbank.org/transport/maximizing-finance-sustainable-urban-mobility.

[85] World Bank, (2017).“Coming together is the way forward: Maximizing Finance for Development,”. https://blogs.worldbank.org/ppps/coming-together-way-forward-maximizing-finance-development.

RESOURCES AND FURTHER READING

Transport and Planning:

ACEEE (2019), *Sustainable Transportation Planning*, American Council for an Energy Efficient Economy (www.aceee.org); at https://database.aceee.org/city/sustainable-transportation-planning.

European Program for Mobility Management (www.epomm.eu) is a network of governments in European countries that are engaged in Mobility Management.

GIZ (2011), *Changing Course in Urban Transport – An Illustrated Guide*, Sustainable Urban Transport Project (www.sutp.org) Asia and GIZ; at https://bit.ly/3aYHdiB.

Hanna Hüging, Kain Glensor and Oliver Lah (2014), *The TIDE Impact Assessment Method for Urban Transport Innovations: A Handbook For Local Practitioners*, TIDE (Transport Innovation Deployment for Europe) Project (www.tide-innovation.eu); at https://bit.ly/2UkC25F.

Levinson, David and King, David (2020), *Transport Access Manual: A Guide for Measuring Connection between People and Places*, Committee of the Transport Access Manual, University of Sydney (https://ses.library.usyd.edu.au); at https://hdl.handle.net/2123/23733.

Litman, T. A. (2017). Economic value of walkability. Canada: Victoria Transport Policy Institute. https://vtpi.org/walkability.pdf

Litman, T. (2013). Comprehensive evaluation of energy conservation and emission reduction policies. Transportation Research Part A: Policy and Practice, 47, 153-166. https://www.sciencedirect.com/science/article/pii/S0965856412001619

Mehaffy, M. W. (2015). Urban form and greenhouse gas emissions: Findings, strategies, and design decision support technologies. Delft: Delft University of Technology. https://repository.tudelft.nl/islandora/object/uuid:08008807-2699-411b-9e21-d5e733a68ba4?collection=research

NACTO (2016), *Global Street Design Guide*, National Association of City Transportation Officials (www.nacto.org) and the Global Designing Cities Initiative (www.globaldesigningcities.org); at https://globaldesigningcities.org/publication/street-users.

OECD (2020), *Reversing Car Dependency*, International Transport Forum (www.itf-oecd.org); at www.itf-oecd.org/reversing-car-dependency.

SFPD (2018), *TDM Menu of Options*, San Francisco Planning Department (http://sf-planning.org); at https://sfplanning.org/transportation-demand-management-program.

Sum4All (2019), *Catalogue of Policy Measures Toward Sustainable Mobility* (CPM), Sustainable Mobility for All (www.sum4all.org); at https://sum4all.org/key-products.

UN-Habitat (2022). *Promoting Low Emission Urban Development Strategies in emerging economic countries (Urban-LEDS).* Website. https://unhabitat.org/programme/promoting-low-emission-urban-development-strategies-in-emerging-economic-countries-urban

UN-Habitat (2022). *UN-Habitat Sustainable Mobility Classroom.* Website. https://unhabitat.org/un-habitat-launches-open-sustainable-urban-mobility-classroom

WRI (2019), *Reducing Demand for Vehicle Trips in Cities – Learning Guide*, The City Fix (https://thecityfixlearn.org); at https://thecityfixlearn.org/en/learning-guide/reducing-demand-vehicle-trips-cities.

Financial Models:

A. Asirin and D. Azhari, (2018). "Ride-sharing business model for sustainability in developing country: Case Study Nebengers, Indonesia," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 158, no. 1, 2018, doi: 10.1088/1755-1315/158/1/012053.

Bloomberg, (2020). "4 Predictions for the Electric Scooter Industry." Available: https://www.bloomberg.com/news/articles/2020-01-27/where-the-electric-scooter-industry-will-go-next.

D. König, J. Eckhardt, A. Aapaoja, J. Sochor, and M. Karlsson, (2016). "Deliverable 3: Business and operator models for MaaS. MAASiFiE project funded by CEDR.," *Conf. Eur. Dir. Roads.*, no. 3, [Online]. Available: http://www.tut.fi/verne/aineisto/S1_Aapaoja.pdf.

GECKO, (2020). "Analysis of cooperation models among public and private parties," [Online]. Available: https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5cec0498d&appId=PPGMS.

NACTO, (2019). "Shared Micromobility in the U.S.: 2019." Available: https://nacto.org/shared-micromobility-2019/.

R. Shared and M. Section, (2019). "North America - Guidelines for Regulating Shared Micromobility," no. September, [Online]. Available: https://nacto.org/wp-content/uploads/2019/09/NACTO_Shared_Micromobility_Guidelines_Web.pdf.

R. Wauters, (2020). "Brussels-based Skipr scores €7 million for its B2B mobility-as-a-service solution". Available: https://tech.eu/brief/skipr-funding/.

S. Shaheen and A. Stocker, (2015). "Case study | Zipcar for Business Members Survey," no. July, p. 3. Available: http://innovativemobility.org/wp-content/uploads/2015/07/Zipcar_Corporate_Final_v6.pdf

Techcrunch, (2019). "Bird has 'positive unit economics' with its custom scooter model, CEO says," [Online]. Available: https://techcrunch.com/2019/07/12/bird-has-positive-unit-economics-with-its-custom-scooter-model-ceo-says/.

U. Sharing, "Making micromobility profitable." Available: https://urbansharing.com/.