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The first and last mile — the key to sustainable urban transport

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Executive summary

All cities face the challenge of developing and providing efficient, healthy and environmentally friendly mobility. City dwellers are more often exposed to air pollution, noise and heavy traffic than people living outside urban areas. Cities are also a prime source of greenhouse gas emissions, which contribute to climate change. A large part of these emissions comes from transport.

Moving away from inefficient and polluting transport modes is one possible way of reducing these societal burdens. Exploring 'first mile' and 'last mile' mobility options, which may be used to complete a journey by public transport, for example, can help make this shift happen by increasing the attractiveness and efficiency of sustainable modes of transport. 'Only mile' options for travelling very short distances can also help. We gather these first/last/only mile modes under the label F/L/O mile options.

This report provides a comprehensive overview of all main F/L/O mile options for passenger and freight transport. It describes their urban mobility and policy contexts and presents the current state of scientific knowledge on their environment and health effects. It also describes the limits of F/L/O mile options and the framework in which they can be most effective. The objective is to help policy makers, planners and transport users make well-informed choices.

F/L/O mile options — even if used in an urban context — are also relevant for longer distance transport, as they may influence the choice of transport modes for longer trips that originate or end in cities, both for passenger and freight transport. This also means that leadership at the city level can shape the mobility system beyond urban boundaries.

F/L/O mile options: an indispensable part of an efficient transport system

Making a transport system efficient means bringing together people or goods as early as possible in their journey. Transporting them separately implies a loss of efficiency and often increases negative environmental impacts. However, people or goods rarely travel between two mass transport hubs or stops. That is where F/L/O options come in. Such options allow people or goods to travel between their starting point (origin) and the start hub and/or between the end hub and their destination. At the same time, they make the transport system as efficient as possible from a financial, resource use and environmental point of view, while meeting any convenience requirements.

The report finds that better F/L/O mile connectivity in cities can significantly improve environment and health outcomes. However, realising this potential requires an in-depth understanding of the different options, their strengths and weaknesses, and how they affect the mobility system as a whole.

This is hardly ever simple because the environment and health effects of F/L/O mile options are determined by how they are used and what they replace. A simple example would be a short trip by electric kick scooter. If it replaces a motorcycle or a car trip, the environment and health effects are positive. If it replaces a trip by foot or by bike, the situation gets worse. More transport options can also lead to people making additional or longer trips, which again could make the situation worse.

The above example shows that new and innovative products or services do not make things better or worse by themselves. It is their real-life use within a dynamically changing context that determines the outcome. Technology needs to be aligned with sustainable mobility goals to make a positive contribution. Framework conditions, incentives and disincentives, and user attitudes also play a decisive role.

The report, therefore, takes a cautious view of the contribution that innovations such as delivery drones or autonomous vehicles will make to sustainable urban mobility. The report is equally cautious about our current ability to fully understand and predict their impacts. Therefore, public authorities should give some room to experimentation and focus on building a reliable evidence base before introducing regulation.

F/L/O mile options in urban passenger transport

'Good' F/L/O mile options try to make the whole passenger transport chain as seamless, fast and comfortable as possible. This means avoiding delays, waiting time and transfers, or if they cannot be avoided, making them as comfortable as possible.

Traditional F/L/O mile options are walking, cycling and other means of short distance transport, for example a metro journey that completes a train journey. Thanks to technology, new F/L/O mile options have become available for passenger transport. All kinds of vehicle sharing schemes have popped up involving bicycles, cars, electric kick scooters, etc. They are becoming increasingly convenient to use. Furthermore, technologies enable better integration of different transport modes and tariffs. Merging different modes of transport into one service to suit the mobility needs of individual customers is now an established business model, known as mobility-as-a-service (MaaS). In the future, autonomous vehicles could also have a role as an F/L/O mile option.

Public transport remains the backbone

Efficient transport requires bundling what is being transported. This is the single most important way of reducing the negative environment and health impacts of transport. Car traffic, for example, requires more space and resources per passenger-km than most other transport modes. Against this backdrop, the idea that fleets of autonomous cars will eventually do away with the need for public transport as we know it seems completely out of place.

Public transport is an essential component of any sustainable urban transport system. Good F/L/O mile options can make public transport more attractive and increase its use. However, F/L/O mile options cannot compensate for an underdeveloped public transport system. The importance of good physical services (infrastructure and vehicles) remains unchanged.

People switch if they experience sustainable transport as fast and convenient

People do not typically switch to sustainable modes of transport for their green credentials. They switch if the overall experience is fast and convenient. F/L/O mile options lead to more sustainable mobility if they make the public transport experience as good as or better than that of car use. Speed and convenience in this context equate to 'time costs', which is one element of the technical-economical heading 'generalised cost'. The other major element is financial cost. Generalised cost is the sum of the two.

For public urban transport, the price of a ticket (i.e. the financial cost to the user) is, most of the time, not the part that makes it uncompetitive compared with the car. The costs linked to time and convenience are often greater. Research shows that people assign considerable value to a fast, convenient and reliable transport experience. They also assign considerable penalties to unpleasant parts of the trip. A 1-minute delay is, for example, experienced as three to five times longer than 1 minute of vehicle travel time. The same goes for walking in a hurry or waiting in crowded conditions compared with vehicle travel time (Wardman, 2014). The variations in the subjective experience of the different parts of travel time illustrate well how important it is to provide seamless public transport while avoiding (stressful) interchanges.

Internalising external costs makes sustainable urban transport competitive

F/L/O mile options can help to make sustainable transport such as rail travel more attractive. However, this is often not enough to tip the balance. Sustainable modes of transport are often at a disadvantage because transport users do not pay for the damage done by their transport choices. This damage can be estimated and is referred to as 'external costs'. In the European Union, the total external costs of transport (excluding active modes such as cycling and walking, and aviation and maritime transport) amounted to EUR 841 billion or 5.6 % of gross domestic product in 2016. Road transport causes by far the highest external costs but there are no precise estimates of the share that can be attributed to urban transport (DG MOVE, 2019).

Different policy measures can internalise these costs. These include market-based instruments (e.g. taxes and charges) and regulatory instruments (e.g. urban access and parking restrictions). Just as the relative speed and convenience of different modes of transport are important, so too would the internalisation of external costs contribute to a more sustainable transport system. The generalised cost of using a car in the city will increase and public transport, in combination with F/L/O mile options, will become more attractive.

Active modes provide the greatest benefits

Walking or cycling the first, last or only mile provide the greatest societal benefits. They help people reach the World Health Organization's global recommendations on physical activity as well as making the urban mobility system more sustainable. The most basic and readily available F/L/O mile option is walking. Almost every public transport trip starts or ends with, at least, a short walk. Research indicates that the reach of the existing public transport system can be extended significantly simply by making walking to and from hubs and stops easier, less prone to barriers and more pleasant by creating attractive urban spaces that are well connected to public transport infrastructure.

Cycling is another transformative option. Various cities in Europe have shown commuting by bicycle can become the dominant mode of transport to and from work. Cycling is also a highly efficient F/L/O mile option, complementing train travel. Recent research suggests that electrically assisted bikes (Pedelecs) also belong in the active mobility category as they require a certain activity level. They open active mobility to a wider group of people and encourage longer commutes by bike.

F/L/O mile options in urban freight transport

F/L/O mile options in urban freight transport can significantly reduce the environment and health burden of the transport of urban goods. This is very relevant as the effects of traffic noise, air pollution and congestion are most acute in cities.

The passenger and the freight last mile are different

F/L/O mile options make sustainable urban passenger transport more attractive for the transport user. In contrast, they do not necessarily make sustainable urban freight transport more attractive for the senders and recipients of goods, because sustainable last mile logistics nearly always incur an extra cost. The challenge is to see how the cost might be accepted.

The reason for the cost is an extra trans-shipment introduced in a consolidation centre at the periphery of the urban area that guarantees maximum environmental efficiency. The large lorry delivers its goods at the consolidation centre instead of entering the city to make its deliveries. Smaller, less polluting vehicles then pick up the goods that have been brought in by different lorries and deliver those in a more sustainable way. Therefore, they group the goods of the different lorries and deliver them over shorter routes. In that way, the city distribution trips are optimised and environmental impacts minimised. The extra trans-shipment requires, however, extra time and cost, and often reduces the economic efficiency. The lack of economic efficiency is the main reason for the very limited presence of consolidation centres in European urban areas.

There are ways to tackle the cost challenge in sustainable urban freight transport

- **Create micro-hubs**

Creating micro-hubs often reduces the positive environmental impact but increases the economic viability, compared with a large consolidation centre. Parcel lockers, proximity delivery points and places where goods are trans-shipped to a more flexible micro-vehicle can all be labelled 'micro-hubs'. Parcel lockers and proximity delivery points are places where the logistics agent drops the goods and where the final recipient picks up the goods. A typical example of a trans-shipment to a more flexible vehicle is PostNL, a company that brings mail and parcels to micro-hubs in different neighbourhoods of Amsterdam. From these hubs, parcels and mail are distributed by cargo bikes. Using the cargo bikes from one large urban consolidation centre would be too expensive.

- **Choose the right niche market**

A high concentration of delivery points in combination with many small deliveries made by different carriers represents a niche where urban consolidation has a good chance of succeeding. In this situation the potential economies of scale provided by a consolidation centre will be largest. As a consequence, the chance that a profitable consolidation centre can emerge increases. The case study on Gothenburg's shopping centre in Section 6.6 illustrates this.

- **Provide added value for the consolidation centres' clients and make clients pay for it**

This added value can consist, for example, of improved return logistics, inventory control, changes in delivery frequencies to meet receivers' needs, or an attractive fee charged to the senders for transporting the last mile. One of the only larger successful examples of a consolidation centre in Europe, 'Binnenstadservice', succeeded in providing and selling added value to its clients.

- **Change the regulatory framework by internalising external costs**

By internalising external costs, urban logistics with F/L/O options become relatively cheap compared with classical delivery. It is difficult to internalise external costs completely. Therefore, other regulatory measures often partially internalise implicit and partially external costs. These measures can take different forms, such as congestion charges, road user charges, time-based access restrictions and access rules.

The impact of innovative freight F/L/O options remains unclear

Innovations linked to (urban) logistics include the use of drones and delivery robots (also referred to as droids) that can make journeys from and to the consolidation centres. Today it is unclear how important the role of these F/L/O options could become in future and what the environmental effects could be. It seems likely that drones and droids will only be able to serve a narrow segment of the urban logistics market (i.e. last mile delivery to a single or few recipients with low payload). They will also compete for limited urban space. Drones require space to take-off and land, and droids will compete for space on sidewalks with pedestrians. For that reason, some cities, such as San Francisco, already restrict the use of these types of vehicles. In addition, the use of 3D printing could influence urban logistics.

1 Introduction

1.1 The challenge of urban transport

Transport generates important benefits for its users and for society in general, but it also generates costs for society, in the form of congestion, accidents and harm to the environment. Society is faced with huge challenges in these areas. In the case of environmental impacts, these are related to climate change, air pollution, noise pollution, and other problems with the living environment, the uptake of land and habitat fragmentation. Health problems are also directly or indirectly linked to these impacts.

In urban transport, these challenges are often exacerbated by the concentration of the people and activities typical in a city. However, the same concentration of people and activities in urban areas also offers opportunities to lower the negative impacts of transport.

Globally, cities 'account for 60 to 80 percent of energy consumption and at least 70 percent of carbon emissions' (UNDP, 2019). The evolution of urban mobility is key to changing this reality by allowing cities to become more energy efficient and to reduce their greenhouse gas emissions.

One can expect some of these challenges to change over time, as cities and their demand for mobility will continue to grow. At the same time, the environmental performance of vehicles will also improve. In this context the mobility system will need to evolve. This report discusses how first/last/only mile options can be allies in enabling an evolution that mitigates the negative impacts of transport.

1.2 First/last/only mile options

Various ways exist to reduce the environmental and other societal costs of transport, often categorised as 'avoid-shift-improve' (EEA, 2010). The 'avoid' approaches address transport energy use and environmental impact by reducing the number and/or length of trips. 'Improve' refers to ways of reducing the energy consumption and environmental impact of all travel modes by increasing the uptake of environmentally friendly fuels and vehicles. The 'shift' approaches contribute to environmental sustainability by shifting transport from less to more environmentally friendly and energy efficient modes, such as a shift towards transport by rail, inland waterways or cargo bike, or a different logistical organisation in the case of freight transport. For passenger transport this could involve a shift to, for example, walking, cycling, rail, metro, tram or bus/coach transport. Many cities have engaged in urban planning in order to encourage this shift by implementing transit-oriented development. That is a type of urban development that maximises the amount of residential, business and leisure space within easy reach of public transport. Having an extended service area for the public transport services evidently increases the potential of these modes. Other policies to attain this shift can work through, for example, pricing and parking management or by improving the conditions for the use of environmentally friendly transport modes by providing better infrastructure and services. However, public transport, which belongs to this group of environmentally friendly modes, rarely provides a door-to-door solution and is also more inflexible.

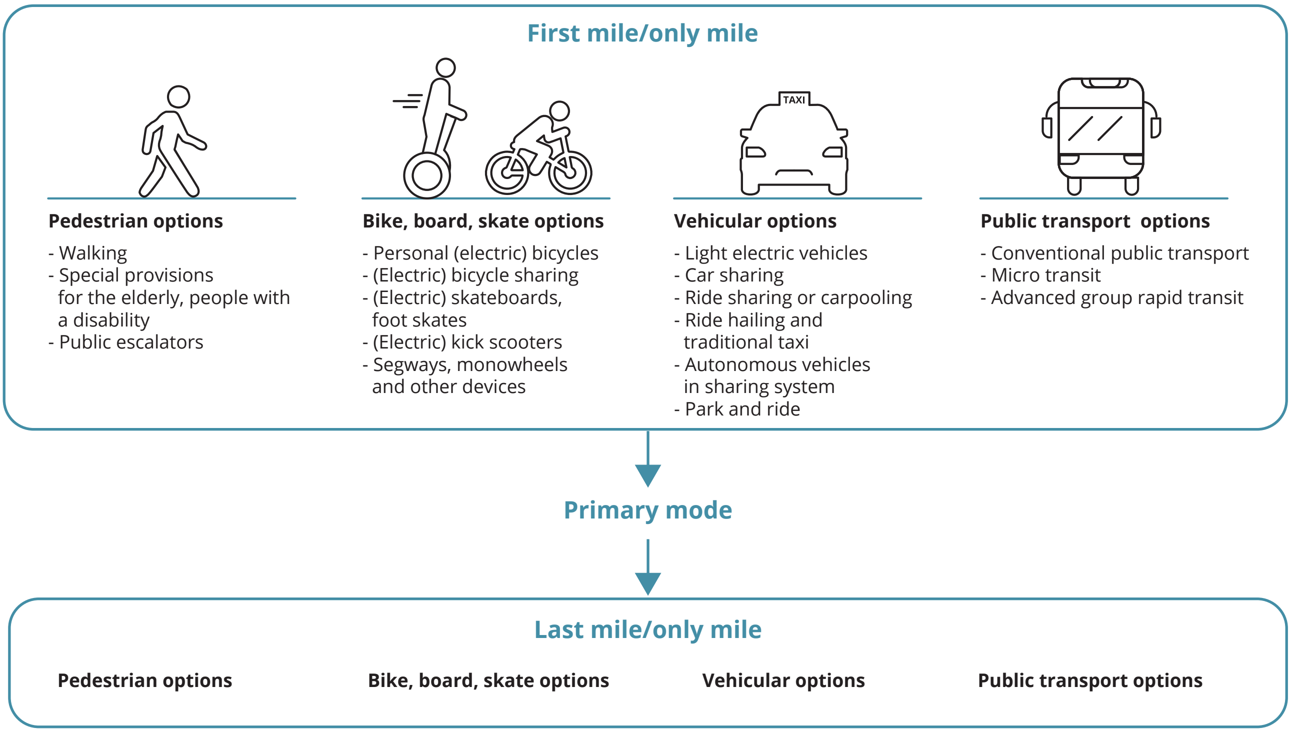
Although bus and rail services might cover the main part of a trip, people need to first walk, drive or use another method to get to and from the nearest station or stop. The first and last leg of the trip are referred to as the 'first mile/last mile'. In the case of freight transport the last mile delivery is defined as the movement of goods from a transport hub to the final delivery destination. Transport options for the first and last legs of trips can also offer solutions for short-distance or 'only mile' trips. Hence, in the rest of this report the term 'first/last/only mile' options will be used (referred to as F/L/O mile options). The focus in this report is on the role that F/L/O mile options can play in making transport in an urban context more environmentally sustainable, by promoting sustainable modes or by reducing the environmental impacts of less sustainable modes.

Good first and last mile options can make it easier to cover the distance before and after the main part of the trip and increase the flexibility of the supply of sustainable modes, thereby improving their attractiveness and increasing their service area. They allow more destinations to be reached within the same time budget. As urban areas are focal points in the transport network, F/L/O mile options — even if they are used in an urban context — are also relevant for longer distance transport, as they may influence the choice made for longer distance trips both for passenger and freight transport.

Technological innovations as well as new business models are changing the landscape for F/L/O mile options. For passenger transport this leads to a wide variety of options, ranging from more traditional to cutting-edge transport services. These can be classified in various ways, as in Figure 1.1, for example, which considers examples of F/L/O mile options by modal group: (1) pedestrian options; (2) bike/board/skate options; (3) vehicular options; and (4) public transport options. The last two classes merit some further explanation. The vehicular options include options that use small, multi-passenger vehicles, which provide route and time flexibility, direct travel from origin to destination and which use the existing road network. The public transport options use larger, multi-passenger vehicles, in which people in the group do not know each other, there is no full flexibility of time or route and there is no direct travel from origin to destination. In this case one therefore still needs to travel to and from the transit stop. Note that as the transport market is in constant evolution, the list of solutions shown in Figure 1.1 is not meant to be exhaustive.

Some of the options, such as walking and cycling, are not new but still have the potential to grow. Other options are still in their early stages, and their future uptake and timing is still more uncertain. This is the case for light electric vehicles, of which several examples already exist ([1]) but which are not yet widely used. It is also the case for autonomous vehicles, which are still in the early stages of the development phase (see also Chapter 5).

Figure 1.1 F/L/O mile options for passenger transport



Source: EEA own elaboration.

([1]) Small electric vehicles that are between a conventional electric bicycle and a small car, e.g. golf cart-like vehicles, the Renault Twizy or the Podbike.

Despite the term F/L/O mile for passenger transport, the scope of this report will be the short distances of up to about 5 km that are covered either in a trip of its own ('only mile') or made to complete a 'main' trip, which can be done by public transport or coach but also by car (e.g. in the case of car sharing or park and ride). This main trip can be purely urban, interurban or from the suburbs into the urban area.

Urban freight transport is related to the movement of goods into, out of, and within urban areas and is closely linked to national and international freight transport flows. This report focuses on the urban part of the freight flows — while keeping in mind these links. The modal shift from road transport over longer distances to rail and inland waterways is, however, outside the scope of this report ([2]). For urban freight transport the major client sectors — which are sometimes interrelated ([3]) — are (1) retail (including e-commerce), (2) express, courier and postal deliveries, (3) hotels, restaurants and catering, (4) construction, and (5) waste (MDS Transmodal Ltd and CTL, 2012). In most, but not all ([4]), cases it operates on a purely commercial basis. Very often, the F/L/O mile in urban freight transport or urban logistics completes another trip. That other trip is, in most cases, made by a truck that brings goods close to or into the city to a consolidation centre. This report focuses on the options that are available to handle the transport to and within the city centre, as well as the reverse process, where transport flows generated within the city have destinations outside the city.

As the freight transport market has its own characteristics and requirements, specific solutions are needed. Based on a literature review, Ranieri et al. (2018) distinguish the following types of F/L/O mile solutions for freight transport:

- innovative vehicles — electric or autonomous, but also drones and robots;
- proximity stations or points — depot stations, parcel lockers;
- collaborative and cooperative solutions — for example freight pooling, transport of parcels by public transport, new delivery agents;
- innovation in public policies and infrastructures.

These and other F/L/O mile options for freight transport are discussed further in Chapter 5.

1.3 Structure of the report

This report is structured in the following way. Chapter 2 starts by sketching a picture of passenger and freight transport in the EU and the challenges created by them, both in general and in an urban context. On the one hand these are environmental challenges related to the emissions of greenhouse gases and air pollutants, noise pollution and the uptake of land. But on the other hand, broader challenges arise, including traffic accidents, congestion and impacts on physical activity. All of this takes place in a context of urbanisation and of technological, economic and societal changes. Furthermore, the scientific understanding and public awareness of the problems at stake will be expected to grow further.

Although local and national authorities have a large role to play in encouraging sustainable urban mobility, EU-level policies and funding programmes have also been developed for this purpose. Chapter 3 gives an overview of EU policy developments and initiatives for urban mobility and transport in general, as well as a number of cross-cutting European policies with relevance for urban mobility.

Chapter 4 provides an introduction to how F/L/O mile options may help to reduce the environmental burden of passenger and freight transport in cities.

After giving a short historical overview, Chapter 5 presents various F/L/O mile options for passenger and freight transport. For passenger transport a typology of the various options is provided, and various new technologies and innovations are introduced. These include the sharing of cars and other vehicles, ride sharing, mobility-as-a-service and autonomous vehicles. For freight transport, the focus lies on the role of urban consolidation centres and that of new technologies and innovations, including the use of drones, delivery robots and 3D printing.

In Chapter 6, the environmental and health impacts of the F/L/O mile options are then explored in more detail. Reference is made as much as possible to existing studies that provide quantitative evidence. This is complemented by a qualitative assessment.

Chapter 7 provides the conclusions and lessons learnt that will be of interest to policymakers.

([2]) See EEA (2014) for a further discussion of these issues.
([3]) As for example in the case of sectors (1) and (2).
([4]) For example, waste transport is often done by the public sector.

Box 1.1 Country groupings

Throughout the report, abbreviations are used to refer to specific country groupings. The following definitions apply:

- EU-13: Bulgaria, Croatia, Cyprus, Czechia, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia and Slovenia;
- EU-15: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden and the United Kingdom;
- EU-28: EU-15 and EU-13;
- EU-27: EU-28 excluding Croatia;
- EEA-33: EEA member countries (EU-28, Iceland, Liechtenstein, Norway, Switzerland and Turkey).

2 Environmental and health impacts of urban transport

Summary

- Passenger and freight transport in the EU create many challenges, both in general and in urban areas. There are various environmental costs related to land transport and its emissions of greenhouse gases and air pollutants, noise pollution and the uptake of land. Transport also gives rise to broader challenges, of which traffic accidents and congestion are the most important.
- In 2016, the total external costs of transport (excluding the active modes, aviation and maritime transport) in the EU-28 amounted to EUR 841 billion or 5.6 % of gross domestic product (GDP).
- The trend towards urbanisation, accompanied by the growing economic and political importance of cities and urbanised areas, the ageing of the EU population, technological advances, the development of new business models and a change in attitudes and preferences among transport users and citizens in general will all have an impact on urban mobility and the challenges mentioned above.

2.1 Introduction

This chapter first gives an overview of urban and non-urban land transport in the EU for both passenger and freight transport (Section 2.2). Section 2.3 then describes the costs related to the various environmental challenges caused by land transport and its emissions of greenhouse gases and air pollutants, noise pollution and the uptake of land. In addition, land transport is related to broader challenges, including traffic accidents, congestion and the lack of physical activity. These are described in Section 2.4. Section 2.5 gives an insight into the relative magnitude of the different negative impacts of transport. Finally, Section 2.6 sketches the broader context in which the transport system functions, as well as a number of developments that are relevant for the challenges to which transport contributes.

2.2 Urban and non-urban land transport in the EU

In 2016, a total of 6 063 billion passenger-kilometres were travelled in the EU-28 by land transport using motorised transport modes. This is an increase of 12 % compared with 2000 (EC, 2018d). The average number of kilometres (km) travelled per person by these modes has increased from 30.4 km/day to 32.6 km/day in the same period. The share of cars in passenger-km by land transport has remained more or less constant, at a share of around 80 %. The shares of the other motorised modes are as follows: 9.1 % for bus and coach, 7.4 % for rail, 2.1 % for powered two-wheelers and 1.7 % for tram/metro. In 2000, these shares were respectively 10.2 %, 6.9 %, 1.9 % and 1.5 %.

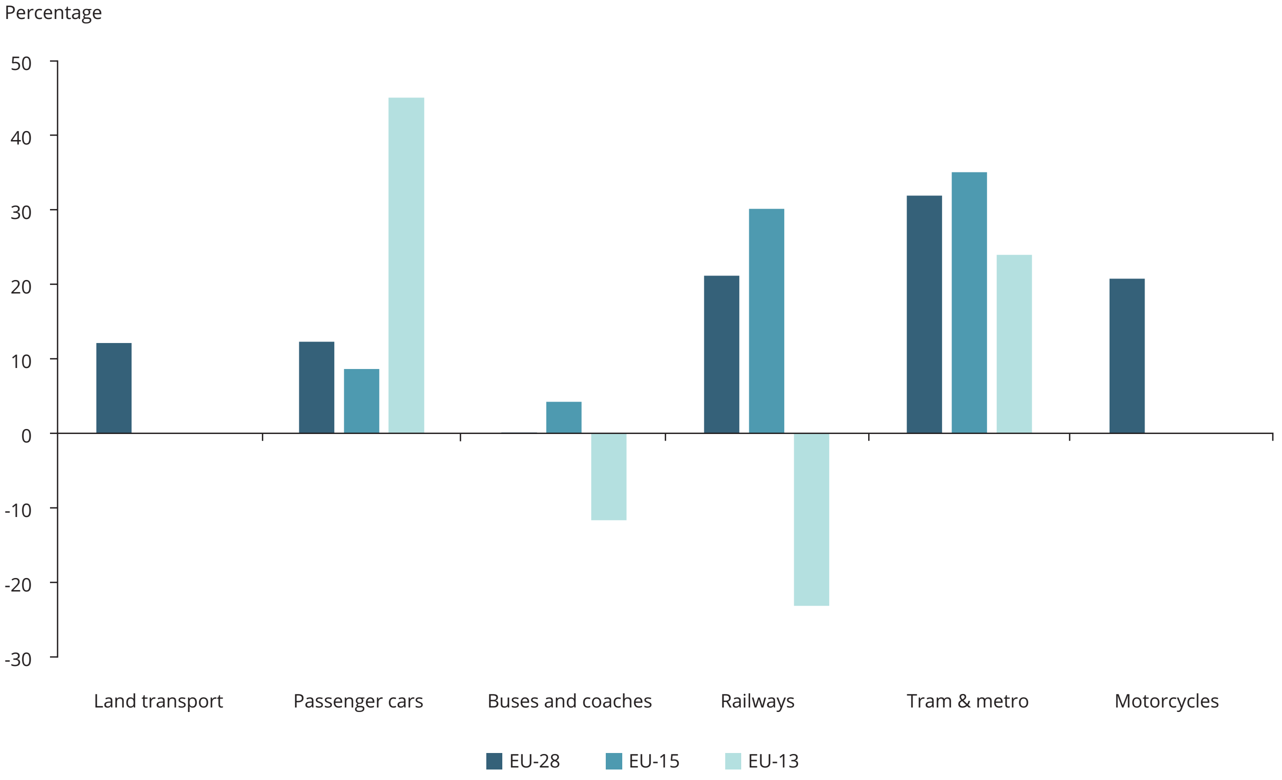
Since 2000, passenger transport volumes (in passenger-km) across the various motorised land transport modes have changed, as shown in Figure 2.1, for the EU-28 as a whole and for the EU-15 and EU-13 countries:

For rail transport, the growth has been highest for high-speed rail, for which passenger-km nearly doubled between 2000 and 2016, with the highest increase having been in the period 2000-2011, during which the high speed rail network was extended from 2 707 to 6 807 km (Pastori et al., 2018). The use of conventional rail transport (in passenger-km) has increased by 6.5 %.

F/L/O mile options offer the potential to increase the share of the non-car modes and to thus improve the environmental sustainability of passenger transport. These non-car modes also include active modes such as walking and cycling, but time series data for the use of these modes are not yet available.

A study by Steenberghen et al. (2017) estimates that the median daily distance travelled per person in Europe

Figure 2.1 Evolution of passenger-kilometres by mode between 2000 and 2016



Source: EC (2018d).

is 1.06 km/day for walking (based on 14 countries) and 0.80 km/day for cycling (based on 15 countries). The study estimates that in 2014, walking and cycling accounted for approximately 340 billion passenger-km, of which more than half (57 %) was walking. Using these rough estimates, walking and cycling accounted for about 5.5 % of land transport passenger-km in 2014.

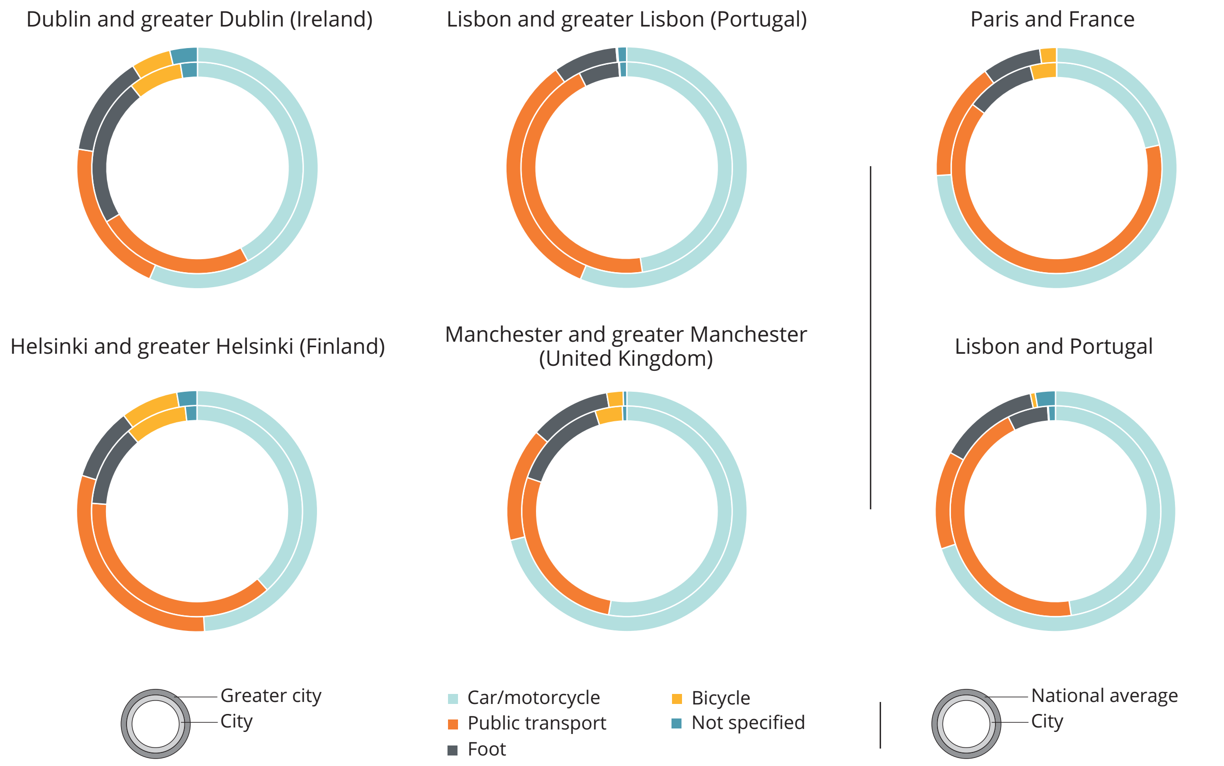
EU-wide data on the relative importance and characteristics of transport within cities, between cities and outside cities are unfortunately not available. However, some data sources for selected urban areas, discussed below, can shed light on differences in mobility patterns in the transport market segments. As F/L/O mile options are considered here in view of their contribution to a shift to more sustainable modes, this section zooms in on modal shares.

Typically, public transport, walking and cycling are used more in urban areas, which are consequently less reliant on cars than non-urban regions are (Debyser, 2014). Car use is also typically lower in larger cities with good public transport services.

To illustrate this, Figure 2.2 presents the modal shares for journeys to work in 2011 in a selection of cities and their surrounding areas. In addition, for two cities (Paris and Lisbon) modal shares are compared with the national averages. The good service quality of public transport in these two large cities is one of the factors leading to a large uptake of public transport. In the periphery of big cities, or in smaller towns and suburbs, the car typically takes up a larger share, as is illustrated below for four cities: Dublin, Lisbon, Helsinki and Manchester (Eurostat, 2016). But also, in these four cases the modal share of cars is smaller than the country average in 2011, which ranged from 83.9 % (Portugal) to 85.4 % (United Kingdom). For four selected EU Member States, Eurostat (2016) also found that the share of walking and cycling in commuting trips tends to be lower in the biggest cities than in cities that have relatively compact centres ([5]).

([5]) In these four countries the highest shares for commuting by foot were recorded in Ruse (Bulgaria; 2011 data), Weimar (Germany; 2012 data), Poitiers (France; 2010 data) and Póvoa de Varzim (Portugal; 2011 data).

Figure 2.2 Journeys to work by mode of transport in selected cities and EU Member States, 2011



Source: Eurostat (2016).

Another source of information is the European Metropolitan Transport Authorities (EMTA) barometer of public transport that compares transport systems in 26 main cities and metropolitan areas ([6]) in the EU and Canada. Figure 2.3 shows the modal share of sustainable transport modes for metropolitan areas and main cities for 2017 and relates this to urban density. It refers to the modal share of trips (rather than passenger-km ([7])). The sustainable transport modes are defined here as walking, cycling and public transport.

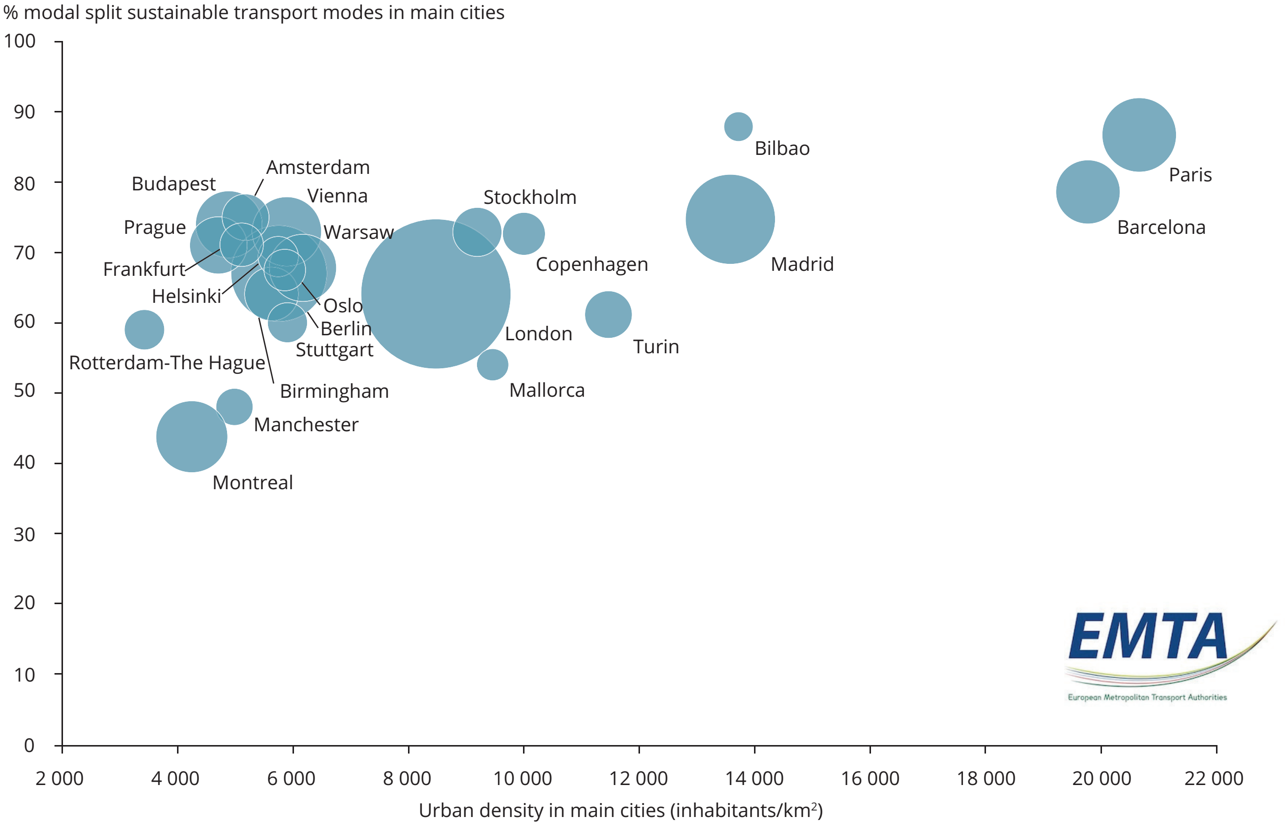
On average, 33 % of trips in the selected metropolitan areas are made on foot or by bicycle, 20 % by public transport and 47 % by private motorised transport. In the main cities the average share of walking and cycling and of public transport is higher, at respectively 40 % and 27 %, and the average share of private transport is 33 %. Urban density (inhabitants/km^2) in metropolitan areas is lower than in the main cities, which is one of the factors that explains the lower use of sustainable modes in those areas. Higher densities lead to more concentrated transport demand, making public transport provision more efficient and therefore more interesting. The density levels at which this occurs depends on the public transport modes being considered and their frequency and also on general city characteristics (EEA and FOEN, 2016; Seto et al., 2014). Higher densities also reduce travel distances, increasing the travel opportunities offered by cycling and walking.

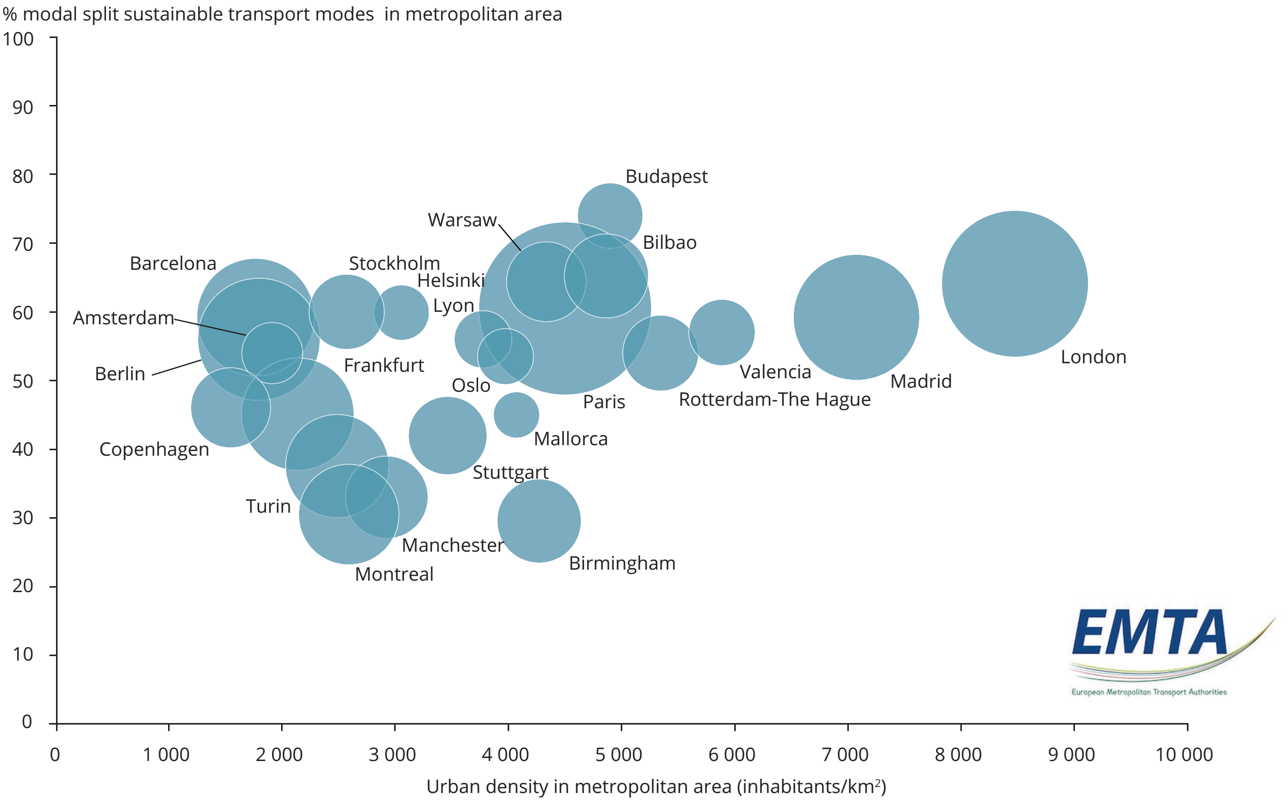
For freight transport, in 2016 a total of 2 478 billion tonne-km were transported by road, rail, inland waterways and pipelines. This is 13.8 % higher than in 2000. In 2016, 72.8 % of tonne-km transported by these modes were by road transport, compared with 69.4 % in 2000 (EC, 2018d). In 2017, 6.6 % of road tonne-km were related to distances of less than 50 km and 36 % travelled over distances of between 50 and 300 km. Tonne-km over distances of less than 50 km grew less than average between 2013 and 2017: by 1.6 % compared with the average of 11.8 % (Eurostat, 2018b).

([6]) The EMTA barometer makes a distinction between 'main cities' and 'metropolitan areas'. The former are typically the most important city in an area or the capital of the region. The latter are a group of municipalities or administrative units that have strong links for mobility, provision of urban services, etc. In addition, these areas fall under the competence of the public transport authority.

([7]) The modal share in passenger-km differs from the modal share in trips, as the average distance per trip varies across modes.

Figure 2.3 Urban density versus modal share of sustainable transport modes in a selection of main cities and metropolitan areas





Note: The size of the circles indicates the size of the population in the main cities or metropolitan area.

Source: EMTA (2019).

No EU-wide data exist on the relative magnitude of urban freight transport and its evolution over time. From observations it can be concluded that most urban freight is transported by road (EEA, 2013). For example, in London road had a modal share of about 89 % in the weight of goods lifted to, from and within London in 2012. In that year light and heavy goods vehicles accounted for 13 % and 4 % respectively of the vehicle-km travelled by all motorised road vehicles in that city (Allen et al., 2014). In the Île-de-France region in 2013, each week 4 260 000 freight movements were estimated to take place, of which 61 % were made by road vehicles of less than 3.5 tonnes, including two- and three-wheelers, which had a share of 4 % (Serouge et al., 2014). The annual growth in freight transport (measured in tonnes) in the area is 1.5 %, which is expected to continue until 2025 (Île de France, 2014).

2.3 Costs related to environmental challenges

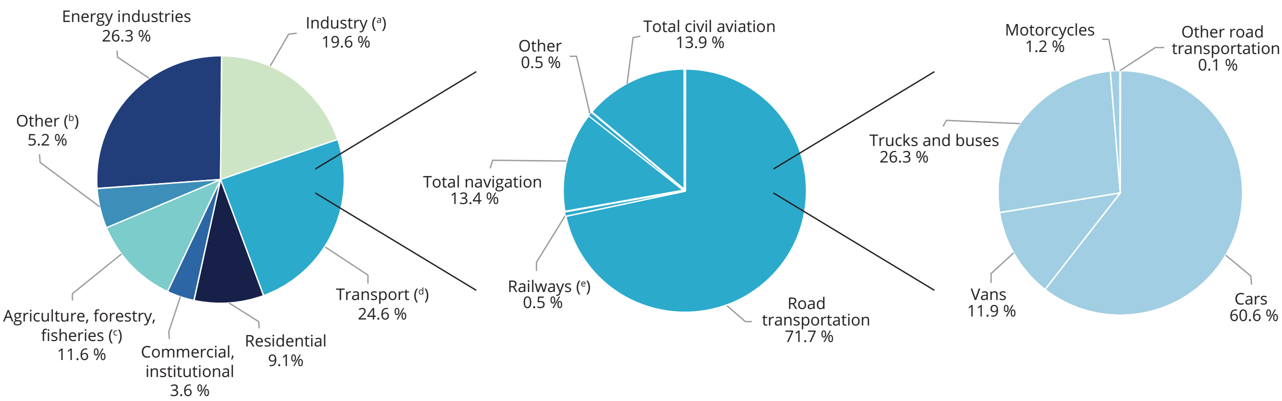
From the previous paragraphs it can be concluded that there is a large modal share of passenger cars in passenger land transport and of the road modes in land freight transport.

These means of transport provide many benefits to their users. However, the current transport patterns have also brought substantial challenges, both environmental challenges and others. The costs related to environmental challenges are discussed in this section. They are caused by the emissions of greenhouse gases and air pollutants (both well-to-tank and tank-to-wheel emissions), noise pollution and habitat fragmentation. Among the non-environmental challenges that are discussed in Section 2.4, traffic accidents and congestion are the most prominent.

2.3.1 Greenhouse gas emissions

Transport is a major contributor to greenhouse gas (GHG) emissions in the EU-28. As shown in Figure 2.4, transport (including air transport emissions) was responsible for 24.6 % of total emissions in 2017. Within the transport sector (including air transport and maritime emissions), road transport accounts for 71.7 % of emissions. Within road transport, cars account for 60.6 % of emissions, vans for 11.9 % and trucks and buses for 26.3 %. Using the cost avoidance approach (DG MOVE, 2019), it was estimated that the central value of the short- to medium-term cost (up to 2030) of GHG emissions

Figure 2.4 Transport emissions as a share of total EU-28 GHG emissions, and road transport emissions as a share of EU transport GHG emissions (2017)



Notes: Total GHG emissions include international aviation and indirect CO_2, and exclude LULUCF (land use, land–use change and forestry) and international maritime emissions.

(a) Emissions from manufacturing and construction, industrial processes and product use

(b) Emissions from fuel combustion in other (not elsewhere specified), fugitive emissions from fuels, waste, indirect CO_2 and other

(c) Emissions from fuel combustion and other emissions from agriculture

(d) Excluding international maritime (international traffic departing from the EU), including international aviation

(e) Excluding indirect emissions from electricity consumption

Source: EEA (2019a).

is EUR 100_{2016} (i.e. EUR 100 at 2016 value) per tonne of CO_2 equivalent (CO_2e). The central value for the long-term cost (up to 2060) is EUR 269_{2016} per tonne of CO_2e.

It is estimated that 23 % of transport CO_2 emissions occur in cities ([8]). Improving urban mobility can, therefore, contribute to a significant reduction in the GHG emissions from transport.

One of the factors that may contribute to lower GHG emissions is a modal shift towards less GHG-intensive transport modes and fuels. For the F/L/O mile options to contribute to the reduction of GHG emissions, the focus should be on those options that are associated with the lowest GHG emissions. Figure 2.5, taken from Biedka et al. (2017), compares the average well-to-wheel (WTW) CO_2e emissions per passenger-km of different passenger transport modes and vehicles in a medium city area ([9]). The WTW CO_2-equivalent emissions of private transport modes (passenger cars, mopeds and motorbikes) are mainly dependent on the fuel type and the speed travelled (reflected here by the difference between the peak and off-peak period). For passenger cars the average WTW emissions are the highest for petrol cars. For hybrid and electric cars the WTW CO_2e emissions are substantially lower.

For public transport the type of vehicle and the fuel used are also important. However, when comparing public transport with car transport, there is a larger difference between the emissions per passenger-km in the peak period than in the off-peak period. For buses the difference in speed also plays a role, and the main explanation for the differences between peak and off-peak periods is the higher occupancy rates during the peak period. In the peak period the emission factors for public transport are generally much lower than those for private motorised transport, except that they are similar for light rail (tram/light rail transit, metro) and hybrid and electric cars. In the off-peak period the relative advantage of public transport falls, and for tram/light rail and metro and midi buses the emission factors per passenger-km come close to or in some cases even exceed those of conventionally fuelled cars.

The authors note that vehicle type and occupancy level are more influential than the CO_2 intensity of fuels. F/L/O mile options can be relevant in this context to help increase occupancy levels of the public transport modes, especially during non-peak hours.

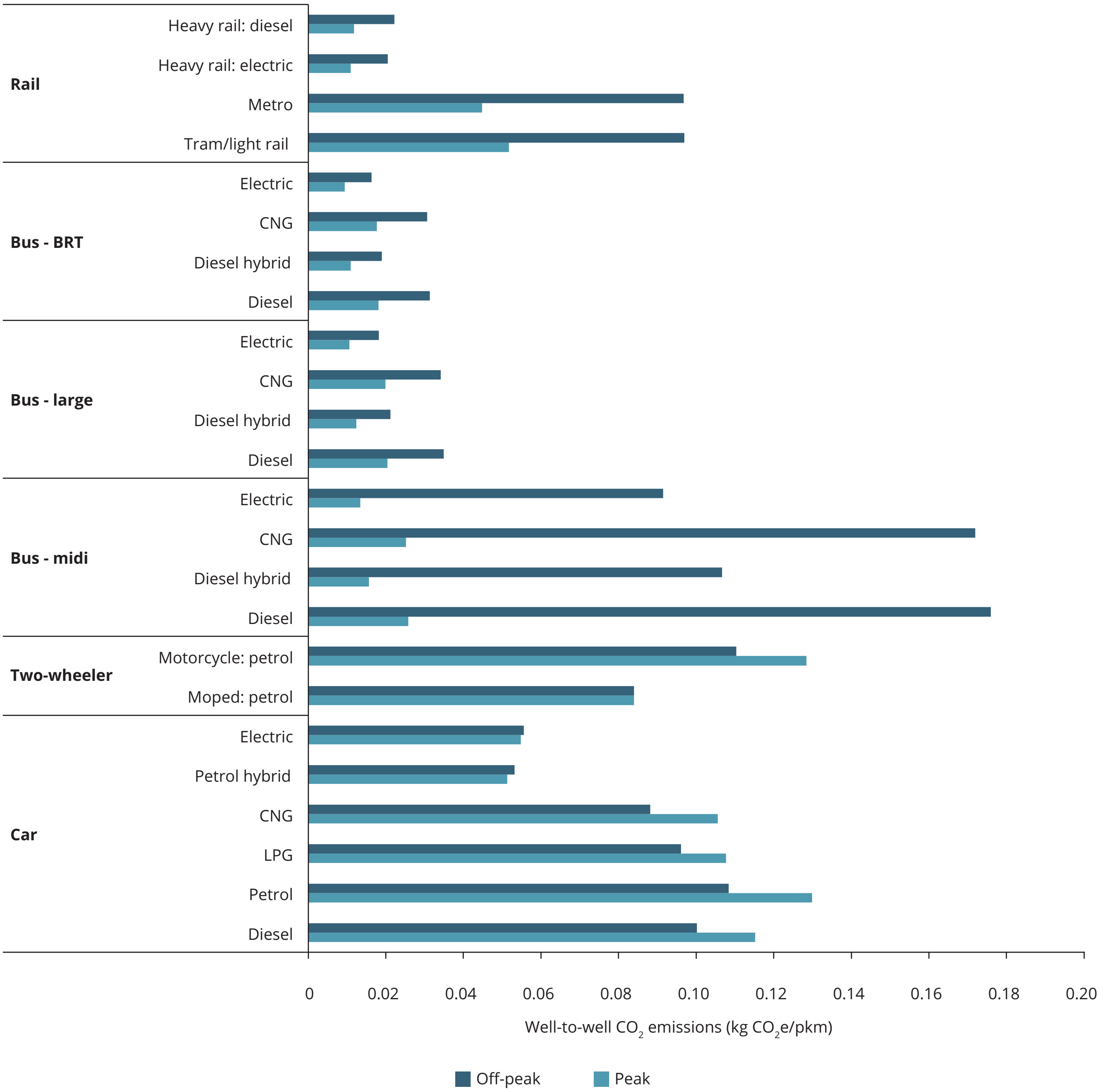
Electric bikes (e-bikes), electric motorcycles and electric kick scooters have not yet been considered by Biedka et al. (2017).

It should be noted that the WTW CO_2e emission factor of electrically powered vehicles depends heavily on the way in which electricity is generated. The emission factors given by Biedka et al. (2017) are based on the EU electricity mix (low voltage) for 2009 as reported in the Joint Research Centre report (JRC, 2014). This means that the emissions of electrically powered vehicles have reduced in the meantime due to the effect of the EU emissions trading system (EU ETS) on the power sector.

([8]) Figure taken from EC (2016a) — according to the EU reference scenario 2016, based on PRIMES-TREMOVE model developed by the National Technical University of Athens (ICCS-E3MLab).

([9]) Overall, in Biedka et al. (2017), the emission intensities per passenger-km in metropolitan areas are found to be similar to those calculated for medium cities. In the study the differences between the two relate to different occupancy rates and different travel speeds.

Figure 2.5 Average well-to-wheel CO_2e emissions for a medium city

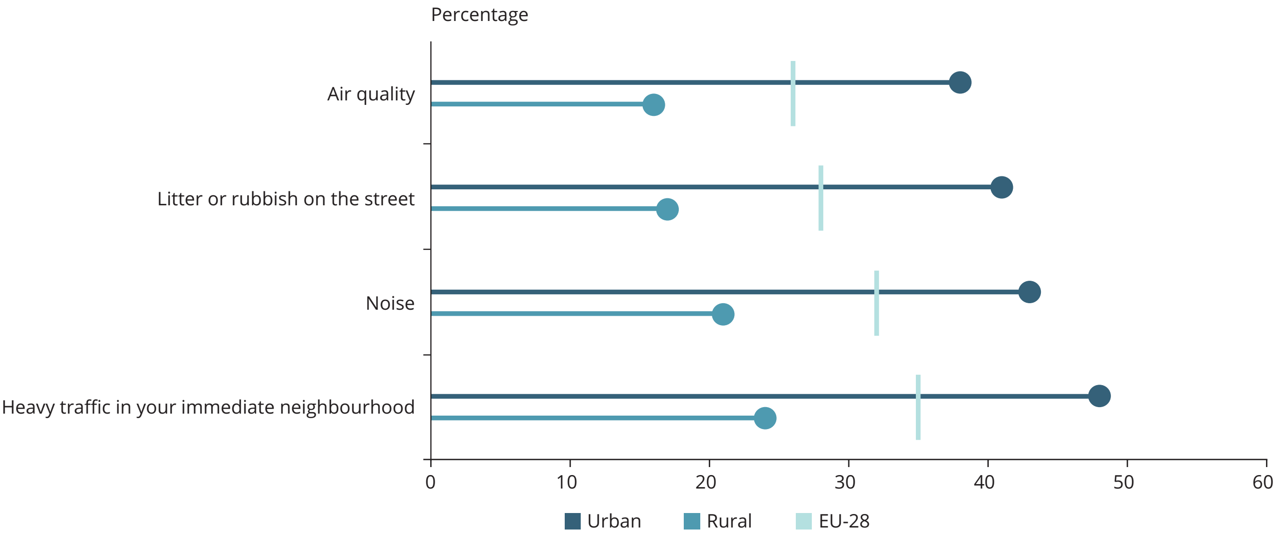


Notes: BRT, bus rapid transit; CNG, compressed natural gas; LPG, liquefied petroleum gas.

Heavy rail refers to conventional rail (and thus excludes high-speed rail); the study assumes the following number of passengers per vehicle: heavy rail 750 (peak) and 400 (off-peak); metro 473 (peak) and 220 (off-peak); tram/light rail 128 (peak) and 68 (off-peak); BRT 105 (peak) and 56 (off-peak); large bus 75 (peak) and 40 (off-peak); midi bus: 45 (peak) and 6 (off-peak); motorcycle 1.1; moped 1; car 1.7.

Source: Biedka et al. (2017).

Figure 2.6 People reporting neighbourhood problems



Source: Eurofound (2017).

2.3.2 Local and regional environmental problems

Perception of EU citizens and people's preferences and values regarding environmental problems

Several surveys shed light on the perception of EU citizens and on people's preferences and values regarding environmental problems ([10]). All of them indicate that environmental problems are a concern, and that the share of people who perceive that there are problems is higher in cities. Moreover, from the European Quality of Life Survey, which has been repeated over time, it can be concluded that the awareness of urban citizens regarding air pollution has grown over time. If citizens are aware that sustainable transport modes contribute to a better urban environment, and that F/L/O mile options can make these modes more attractive, the growing awareness of local environmental problems means that there may be growing public support for developing further these F/L/O mile options.

In the **European Quality of Life Survey (EQLS)** people were asked whether they experienced four neighbourhood problems, including problems related to heavy traffic, litter, noise and air pollution. It also presents the differences between rural and urban areas (Eurofound, 2017).

Among the neighbourhood problems that were explored, heavy traffic was found to be the most common problem. As shown in Figure 2.6, 35 % of the respondents reported 'major' or 'moderate' problems for this category. The next most prevalent category, indicated by 32 % of the respondents, was noise, especially in urban areas ([11]), where 43 % reported problems (in cities or city suburbs this was even higher at 46 %). Problems with air quality were reported by 16 % of respondents in the open countryside, compared with 38 % in urban areas (and 46 % in cities or city suburbs).

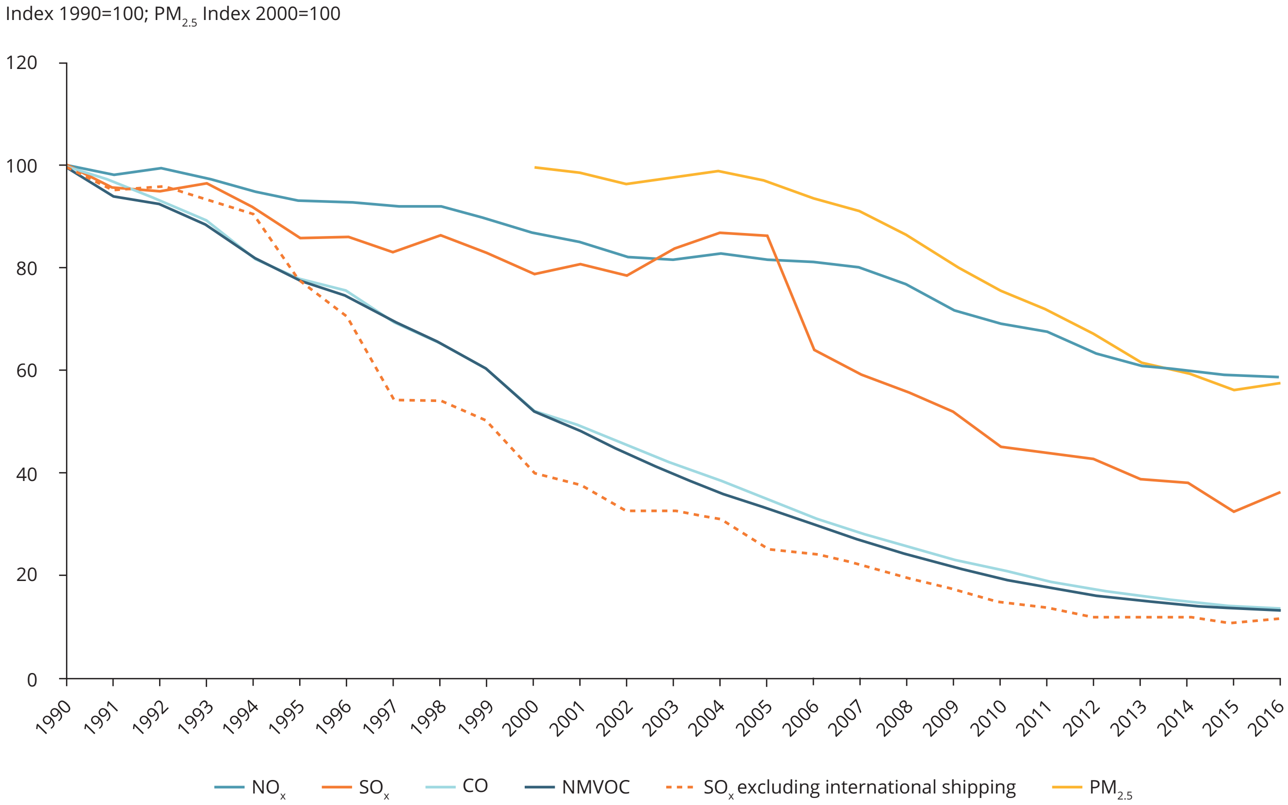
Between the previous EQLS in 2011 and the latest edition in 2016, the average awareness of air quality problems had not changed. However, a different pattern is seen for cities on the one hand and rural settings or smaller towns on the other hand. In cities and city suburbs the proportion of people reporting that they experience problems with air quality increased from 40 % in 2011 to 46 % in 2016. In towns, villages and the countryside the share of people reporting problems remained either unchanged or decreased somewhat.

Exposure to air pollution

Air pollution negatively affects the health of the European population. Exposure to air pollution leads

([10]) These include the EU Survey on Income and Living Conditions, the European Quality of Life Survey and the Flash Eurobarometer 366 on the quality of life in European cities.
([11]) In Eurofound (2017), urban areas include cities and city suburbs on the one hand and medium to large towns on the other hand. Cities refer to densely populated areas, while towns refer to intermediate density areas.

Figure 2.7 Trend in emissions of air pollutants from transport (EEA-33)



Source: EEA.

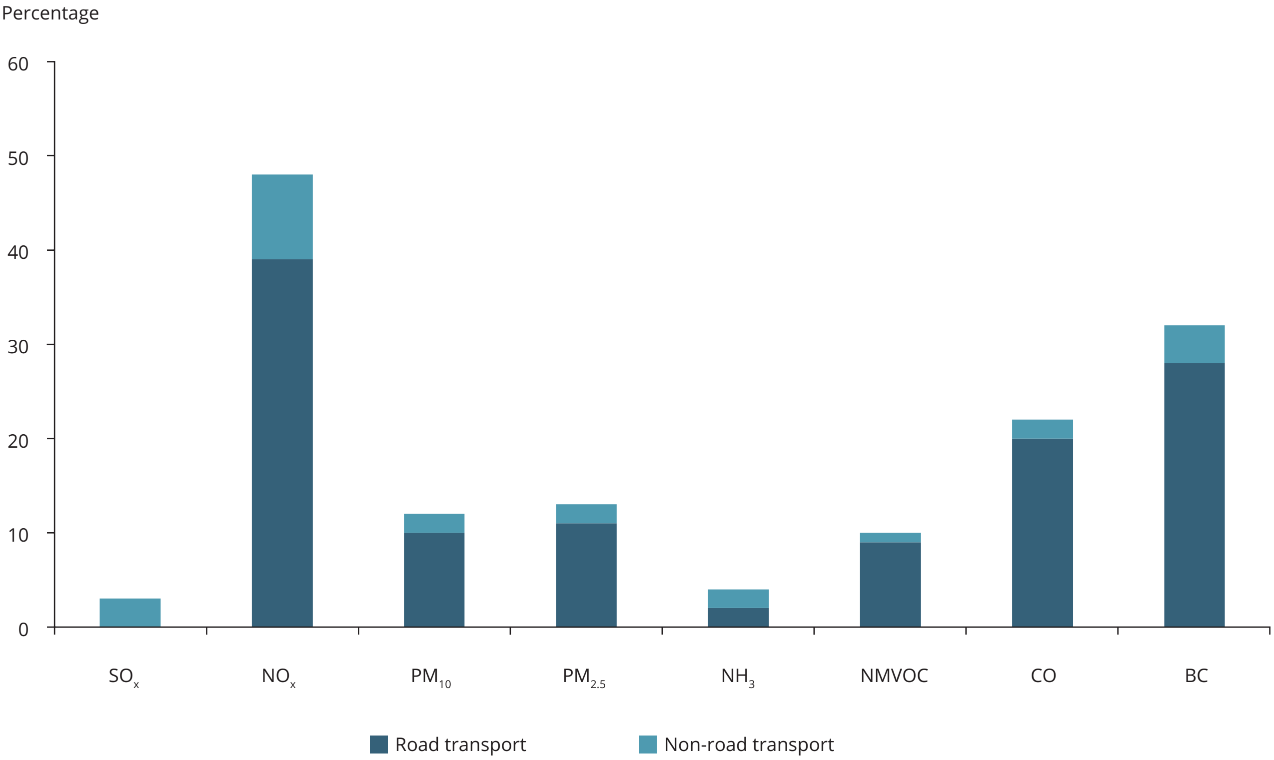
to cardiovascular and respiratory diseases (including lung cancer), important healthcare costs and lost working days. There is emerging evidence that it may also affect diabetes and neurological development in children (WHO, 2019b). Exposure to air pollution is the most important environmental cause of premature deaths in the EU. Exposure to fine particulate matter ($PM_{2.5}$) is responsible for almost 400 000 premature deaths per year in the EU, with approximately 76 000 premature deaths being caused by nitrogen dioxide (NO_2) (EEA, 2018a). A significant share of EU citizens living in urban areas is still being exposed to air pollution concentrations that do not meet the EU's air quality standards and the more strict World Health Organization (WHO) air quality guidelines (EEA, 2018a, 2018c).

For the period 2014-2016, the situation was as follows (EEA, 2018b):

- 6 to 8 % of EU-28 citizens living in urban areas were exposed to concentrations of $PM_{2.5}$ that exceed the EU limit, whereas 74 to 85 % were exposed to concentrations that were greater than the WHO guideline value.
- For particulate matter of 10 microns or less in diameter (PM_{10}), the respective exposure estimates were 13 to 19 % above the EU limit and 42 to 52 % above the WHO guideline value.
- For ground-level ozone (O_3), the estimates were 7 to 30 % above the EU target value and 95 to 98 % above the WHO guideline value.
- For NO_2, estimates were 7 to 8 % above both the EU limit and the WHO guideline values.
- The same EEA report (2018b) points out that 'it is unlikely that the air quality standards for NO_2, PM and ground-level O_3 will be met in all Member States by 2020 because of continuing widespread exceedances in many urban areas. Achieving air quality standards in line with the more stringent WHO guidelines is much further away for most air pollutants.' There is therefore a continuing need to improve the air quality in the urban environment, to which F/L/O mile options can contribute.

This is in spite of the significant progress that has been made in the transport sector since 1990 in reducing the emissions of many air pollutants (Figure 2.7).

Figure 2.8 **Contribution to EU-28 emissions of air pollutants from road and non-road transport in 2016**



Note: BC, black carbon.

Source: EEA (2018a).

In the EEA-33, emissions from all transport types have fallen since 1990, in spite of higher transport demand. Between 1990 and 2016, transport emissions of nitrogen oxides (NO_x) decreased by 41 %, those of sulphur oxides (SO_x) by 63 %, carbon monoxide (CO) by 86 % and non-methane volatile organic compounds (NMVOCs) by 87 %. By 2016, emissions of $PM_{2.5}$ had decreased by 40 % compared with 2000 levels.

Figure 2.8 shows that, for the EU-28, road transport (including both urban and non-urban transport) was the largest emitter of NO_x in 2016, with a share of 39 %. Road transport also emits PM_{10} and $PM_{2.5}$, having contributed 10 to 11 % to each in 2016. For these two pollutants fuel combustion in the commercial, institutional and households sector is the largest source of emissions. The contribution of road transport to ambient NO_2 and PM concentrations, especially in urban areas, is higher than its share of emissions, because the emissions from road transport take place close to the ground and are dispersed over densely populated areas (EEA, 2018a).

DG MOVE (2019) have derived estimates for the EU-28 and individual Member States for the unit costs of air pollutant emissions, based on a cost of damage approach (see Table 2.1 for EU-28). These estimates take into account costs related to health effects, crop losses, material and building damage and biodiversity loss. It is important to note the high cost of damage for $PM_{2.5}$ and NO_x in metropolitan and city areas where transport is a major source of these emissions.

Exposure to noise

Noise pollution, or exposure to ambient sound levels that are beyond the usual comfort levels, can affect quality of life and lead to cognitive impairment in children, high stress levels, sleep disturbance and negative health impacts, such as problems with the cardiovascular and metabolic systems. Noise also has an impact on wildlife, as animals are stressed by noisy environments (Shannon et al., 2016).

Long-term exposure to environmental noise contributes to at least 49 000 new cases of heart disease per year in Europe, which leads to 12 000 premature deaths. In addition to this, it is estimated that 22 million people suffer severe annoyance and 6 million adults suffer severe sleep disturbance. 13 000 school children may suffer learning impairment due to aircraft noise. Road

Table 2.1 Average cost of damage of transport emissions of air pollutants (EU-28)

Pollutant	Location	Average cost of damage (EUR_{2016}/kg)
NO_x	City	21.3
	Rural	12.6
$PM_{2.5}$	Metropolitan	381
	City	123
	Rural	70
PM_{10}	All	22.3
SO_2	All	10.9
NH_3	All	17.5
NMVOC	All	1.2

Note: Rural area = outside cities; metropolitan area = city/agglomeration with more than 0.5 million inhabitants; transport excludes maritime transport.

Source: Based on DG MOVE (2019).

traffic is the most important source of noise pollution both inside and outside urban areas (EEA, 2019c). F/L/O mile options may help to reduce these noise levels. Railways and aircraft also lead to noise problems at specific locations.

It is estimated that some 100 million people in the EEA-33 member countries are exposed to day-evening-night level (L_{den}) noise levels ([12]) of at least 55 dB from road traffic. More than 73 million of these people live in urban areas. About 32 million people are exposed to very high L_{den} levels of at least 65 dB. In the case of railway and aircraft noise more than 19 million and 5 million people, respectively, are exposed to $L_{den} \geq 55$ dB. In addition, in this case the majority of people affected live in urban areas, but the impacts are spread more equally inside and outside urban areas (EEA, 2019b).

Road traffic is the most important source of noise during the night. More than 76 million people in the EEA-33 member countries (excluding Turkey) are exposed to high night-time noise levels from road transport, more than 14 million in the case of railways and about 1.6 million in the case of aircraft noise (EEA, 2018e).

The recently published handbook on external costs (DG MOVE, 2019) presents estimates for health and annoyance costs due to transport noise exposure, based on a damage cost approach. The cost factors vary according to the noise class (measured in L_{den} (A-weighted dB) and transport mode. For exposure to road transport noise in the EU-28, the annual costs per decibel per person range from EUR 17_{2016}, for people exposed to road noise levels of between 50 and 54 dB, to EUR 72_{2016}, for people exposed to noise of 75 dB and higher.

2.3.3 Land take and habitat fragmentation

The growth of urban areas is a dominant trend regarding land use in Europe. In 2014, almost three-quarters of the EU population resided in an urban area, with 41.6 % living in cities and 31.0 % in towns and suburbs (Eurostat, 2016). Over the past 50 years, the urban population has grown continuously, with the highest increase being in towns and suburbs, and in newly developed residential zones near existing cities. Several factors underlie this change, including the availability of relatively cheap transport by private car, the price of land, individual housing preferences in relation to housing costs, demographic changes, cultural attitudes, the services offered by urban areas, and land use planning policies (EEA and FOEN, 2016).

Transport infrastructure takes up land and its design and use alters the quality and connectivity of habitats and can create physical barriers to the movement of plants and animals between habitats (EEA, 2015). Large parts of Europe have become highly fragmented because of an expansion in urban and transport infrastructure. Areas that are under great pressure from fragmentation are often found around large urban centres and along major transport corridors. The fragmentation pressure, however, differs a lot across EEA member countries. The highest pressure is observed in the Benelux countries, Malta, Germany and France, where areas with high and very high fragmentation ([13]) account for 60 % to 93 % of the land surface area. More than 30 % of croplands and around 25 % of grasslands in the EEA member countries are highly or very highly fragmented by urban and transport expansion, whereas this share is 12 % for forests. Other ecosystems (e.g. heathlands, scrub and

([12]) L_{den} is a long-term average indicator designed to assess annoyance by noise. It refers to an annual average day, evening and night period of exposure. It is a descriptor of noise level based on energy equivalent noise level (Leq) over a whole day with a penalty for night time and evening noise.

([13]) The degree of fragmentation is measured by the number of meshes or landscape patches per 1 000 km². This indicator increases as more barriers fragment the landscape. With high and very high levels of fragmentation, the number of meshes per 1 000 km² ranges from 50 to 250, and to more than 250, respectively.

tundra ecosystems, and mires, bogs and fens) are less fragmented (EEA, 2018d).

Land transport infrastructure concerns not only the roads and railways but also parking spaces. In the EU-28, there were about 500 cars per 1 000 inhabitants in 2016 ([14]). A survey of six EU countries ([15]) that explored driving and parking patterns (Pasaoglu et al., 2012) found that the average driver drove between 1 and 2 hours per day. This implies that for most of the day cars are parked ([16]). A lot of land is therefore used for parking, some of which could alternatively be converted to infrastructure for non-motorised mobility (and F/L/O mile options) or to other uses that make living surroundings more sustainable and attractive (green spaces, playgrounds for children, etc.).

2.4 Broader challenges

2.4.1 Lack of physical activity

The dominance of the car in passenger transport contributes to a lack of physical activity, one of the causes of obesity (Gray et al., 2018). A larger uptake of more active transport modes may incorporate more physical activity in people's lives. This is important because weight problems and obesity are rising in most EU Member States, with 51.6 % of the EU's population (aged 18 years and over) being overweight in 2014 and 15.4 % being obese ([17]).

Obesity affects quality of life and is a serious public health problem. It is linked to an increased risk of chronic diseases such as cardiovascular disease, type 2 diabetes, hypertension, coronary heart disease, certain cancers and psychological problems. For society as a whole, it has substantial direct and indirect costs and consequences for public spending (Eurostat, 2019).

2.4.2 Traffic safety

The EU has adopted Vision Zero — to reduce road deaths to almost zero by 2050. It has set interim targets for 2011-2020 (recently extended until 2030) to reduce fatalities by 50 % compared with the 2010 baseline and a separate target to reduce serious injuries by 50 % by 2030 (see the Declaration of Valletta by EU transport ministers (EC, 2018c)). At present, the EU still is far from reaching these traffic goals. In 2017, about 25 300 people died in road traffic accidents in the EU and about 1.35 million people were injured (EC, 2018a).

Of the people that were victims of fatal road accidents in 2016, 47 % were car users, 22 % were pedestrians, 8 % were cyclists and 14 % were motorcyclists. Figure 2.9 shows the distribution of fatalities inside and outside urban areas. About 38 % of road fatalities occur inside urban areas. As can be expected, most fatalities involving pedestrians, bicycles and mopeds occur in urban areas. In urban areas 57 % of fatalities involve road users, and 67 % of fatalities that involve these road users occur inside urban areas.

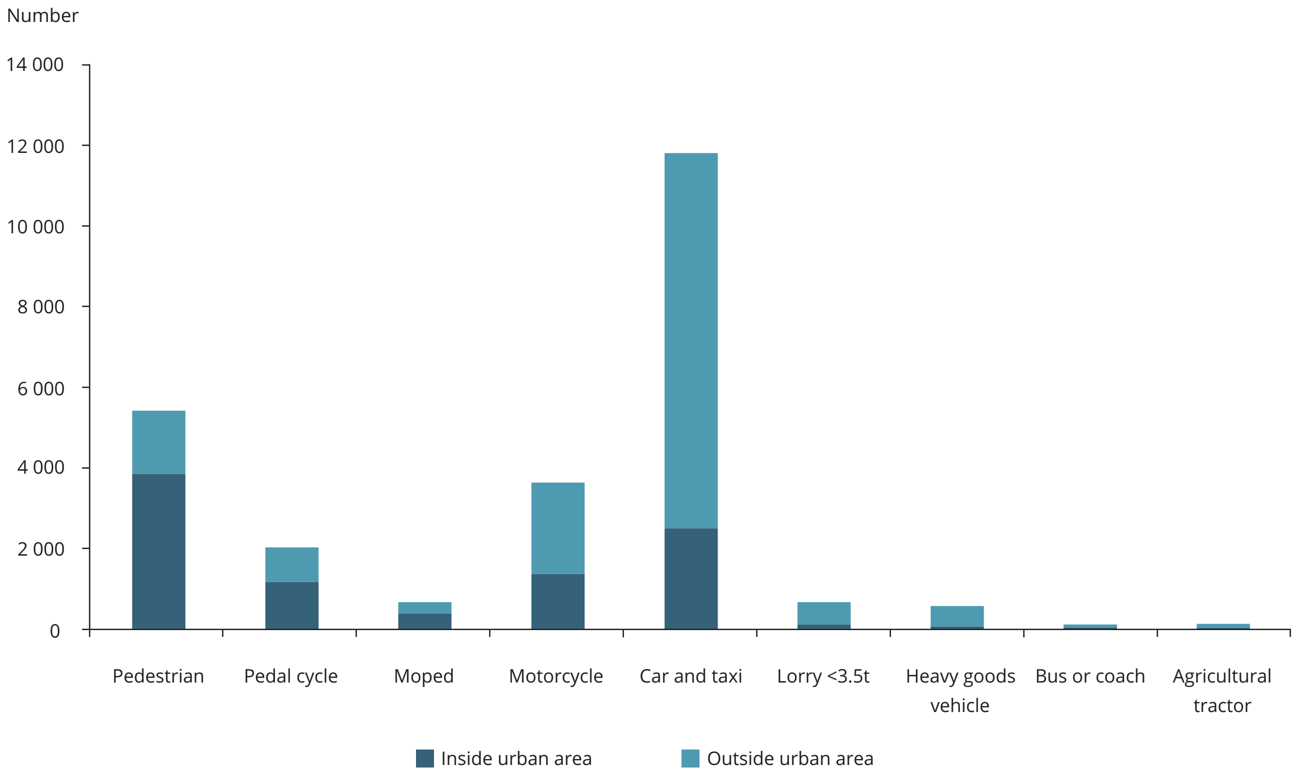
Given that pedestrians and cyclists are estimated to account for about 5.5 % of passenger-km (see Section 2.2) and they constitute 30 % of the victims of fatal road accidents, their average accident risk is higher than that of, for example, car users. Another consideration is that cyclists often are seriously injured in accidents in which no motorised road users are involved. For example, evidence for 2015 from the Netherlands indicates that of the seriously injured cyclists in 2015, almost 80 % were injured in an accident in which no motorised vehicle was involved. However, 70 % of the fatalities among cyclists in the same year involved a motorised vehicle (SWOV, 2019). If a larger uptake of F/L/O mile options leads to more walking, cycling or use of electric kick scooters, care should be taken that this does not lead to more victims of traffic accidents. On the other hand, for the accidents among pedestrians and cyclists that are caused by collisions with cars and trucks, reduced use of these modes may reduce the risk exposure of pedestrians and cyclists.

2.4.3 Congestion

The high levels of road traffic compared with road capacity at certain locations and times of day lead to congestion, substantial time losses and a lack of travel time reliability. Figure 2.10 presents the hours spent in traffic congestion by the average driver per year, for the EU Member States in 2017. These represent costs to the road users, as they could have spent their time either more productively or in activities that are more agreeable. For the countries for which information is available for both 2015 and 2017, the hours spent in

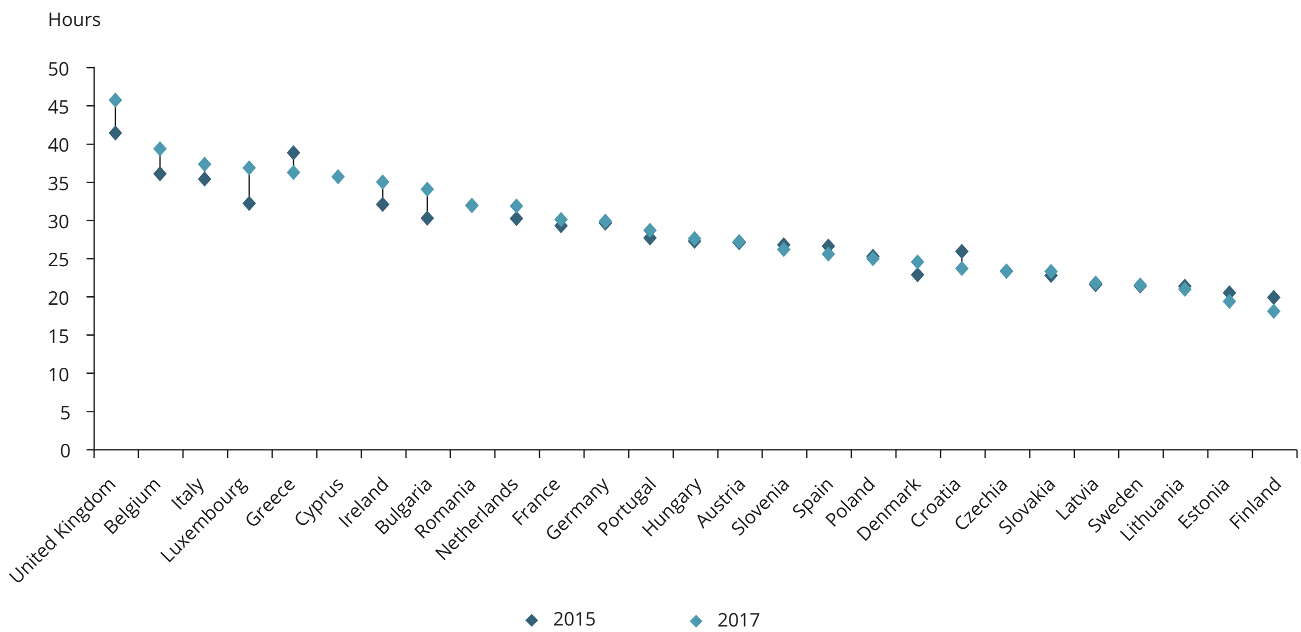
([14]) See EC (2018d, Section 2.6, Means of transport).
([15]) France, Germany, Italy, Poland, Spain and United Kingdom
([16]) The survey is not at vehicle level and does not take into account that several people may use a vehicle.
([17]) Eurostat, online data code hlth_ehis_bm1e: overweight = body mass index (BMI) of at least 25; obese = BMI of 30 and over.

Figure 2.9 Road fatalities by type of area and transport mode in the EU-28 (2016)



Source: ERSO (2018).

Figure 2.10 Hours spent by the average driver in road traffic congestion, annually



Note: No data available for Malta.

Source: EC (2019b).

traffic congestion increased in 16 countries, while they fell in 10 countries.

Congestion problems are significant in and around cities. Table 2.2 provides an estimate of the average time lost in traffic congestion within the 15 urban areas in Europe with the highest congestion according to the INRIX Global Traffic Scorecard. In 2018, the most congested urban area in the EU according to this ranking was Rome, where commuters lost an average of 254 hours per year as a result of congestion at peak times compared with free-flowing traffic.

When analysing the traffic corridors with the worst delays in selected countries in the EU for 2015, Eurostat (2016) points out that in those Member States where the capital city is dominant and the pattern of urban development is monocentric (e.g. France and the United Kingdom), the five lengthiest traffic delays were all in and around the capital. By contrast, in countries with more polycentric patterns of urban development, for example Germany and Italy, some of the corridors with long traffic delays were outside the capitals.

Apart from the time costs and associated economic costs, congestion also worsens environmental costs because stop-start traffic increases the fuel consumption of internal combustion engine vehicles, thereby leading to higher emissions of GHG and air pollutants. It also increases the time during which transport users that are stuck in traffic are exposed to air pollution.

The costs associated with congestion are substantial. According to the European Commission's Directorate-General for Mobility and Transport, DG MOVE (2019), the delay costs caused by road transport in the EU-28 amounted to some EUR 271 billion for 2016, of which 74 % were related to road passenger transport.

2.5 Relative importance of the different external costs of transport

The recently published handbook on the external costs of transport (DG MOVE, 2019) gives an indication of the relative importance of the various external costs of transport (Figure 2.11). The total external costs of transport (excluding the active modes, aviation and maritime transport) in the EU-28 amount to EUR 841 billion or 5.6 % of GDP, when account is also taken of congestion costs. When considering the total of passenger and freight transport the most important cost category is accident costs, which equate to 34 % of the total costs, followed by the congestion costs (32 %). The costs of greenhouse gas emissions and air pollution respectively contribute to 10 % and

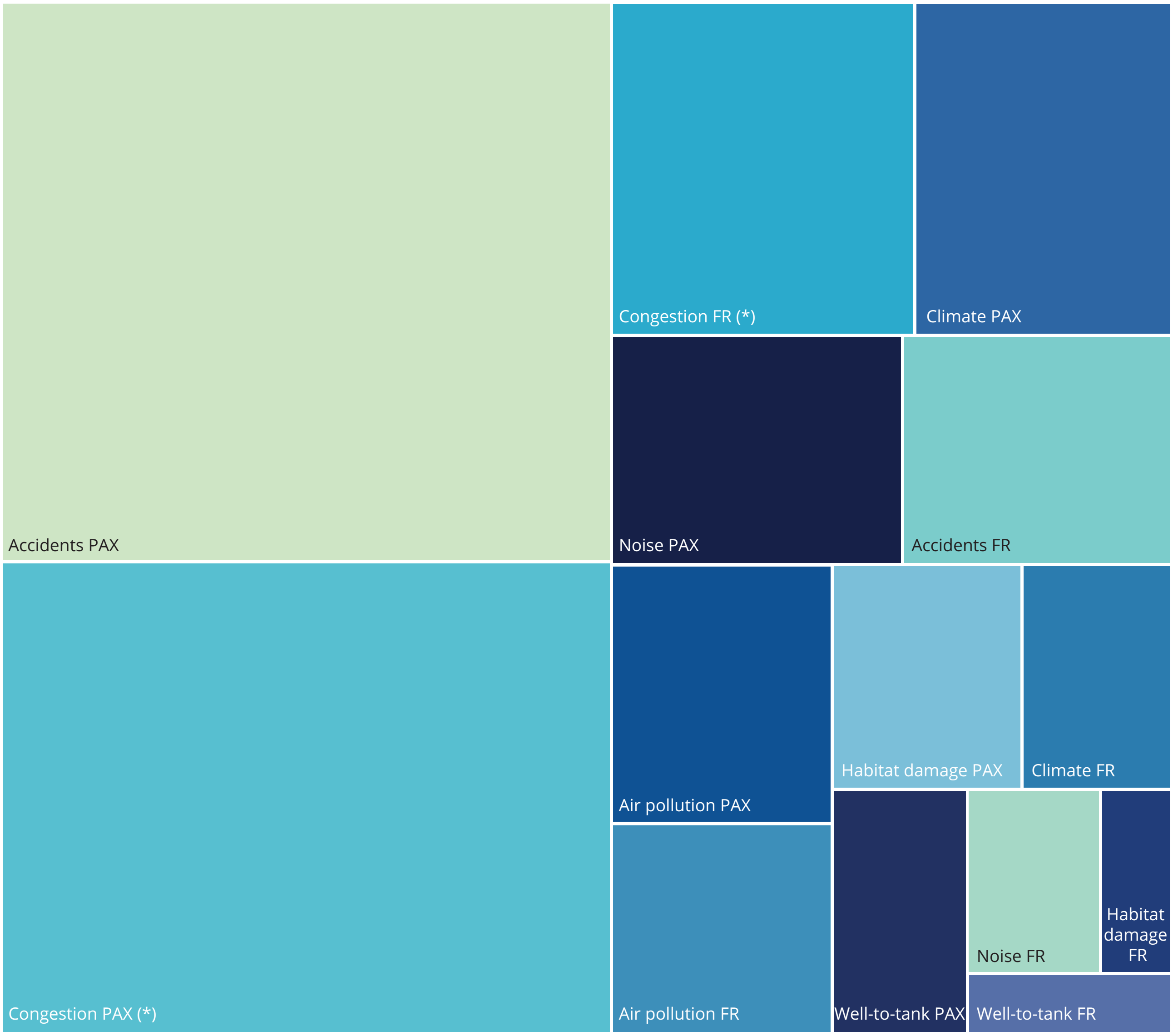
Table 2.2 The 15 urban areas in Europe with most hours lost in congestion (2018)

Urban area	Hours lost in congestion	Change compared with 2017 (%)
Rome (IT)	254	+16
Dublin (IE)	246	-4
Paris (FR)	237	+7
London (UK)	227	+1
Milan (IT)	226	+6
Bordeaux (FR)	223	+12
Florence (IT)	195	+3
Brussels (BE)	195	+1
Belfast (UK)	190	-10
Naples (IT)	186	-3
Warsaw (PL)	173	+7
Turin (IT)	167	-2
Edinburgh (UK)	165	-10
Montpellier (FR)	163	+9
Budapest (HU)	162	+11

Note: Urban area = the geographical scope of a city as defined by its road network density; hours lost in congestion = the total number of hours lost in congestion per commuter during peak commute periods compared with free-flowing conditions.

Source: INRIX Research (2019).

Figure 2.11 Share of the different cost categories in the total external costs of transport in 2016 (EU-28)



Note: PAX, passenger transport (cars, buses, coaches, motorcycles and rail); FR, freight transport (light commercial vehicles, heavy goods vehicles, rail and inland navigation); (*), congestion in terms of delay costs generated by road vehicles.

Source: Based on DG MOVE (2019).

9 % of the total costs, noise costs contribute 8 % and habitat damage accounts for 5 % of the total costs. Well-to-tank emission costs due to energy production and distribution account for 4 % of the costs. However, the share of the various externalities varies between the transport modes. For road transport, accident and congestion costs are the main externalities, whereas, for rail transport, noise costs have the largest share of the total external costs (about 35 %).

2.6 Ongoing developments with an impact on these challenges

A number of ongoing and expected developments (Franckx and Mayeres, 2015; Turro et al., 2018) can be identified that may have a direct and indirect impact on urban mobility and the challenges that were identified above.

- In the period between 2004 and 2014, in which the overall population growth in the EU was modest, urbanisation has been progressing, with most predominantly urban regions in the EU having had population growth rates that were higher than the national averages. Outlooks for the period up to 2050 predict that this pattern will continue, albeit not at an equal pace for all predominantly urban areas (Eurostat, 2016). Simultaneously, the economic and political importance of cities and urbanised areas is expected to increase. Other things being equal, this may increase the demand for urban mobility and the challenges for the urban mobility system. It may also offer opportunities because the higher densities in urban areas create an environment in which public transport can be supplied in an efficient way and in which active modes can be an attractive transport option.

- The share of the population aged 65 years and over is increasing in every EU Member State, and this trend will continue in the future (Eurostat, 2018a). In the context of F/L/O mile options this imposes requirements on the quality, comfort and accessibility (physical accessibility to 'traditional' mobility services and digital accessibility to 'new' mobility services that are supported on electronic platforms) of the services that they offer.

- Technological, economic and societal developments may change the urban mobility system. The technological advances include, for example, a still larger role for information and communications technology, digitalisation, new propulsion systems, the uptake of alternative fuels, and the introduction of autonomous vehicles. The economic developments include new business models, such as mobility-as-a-service, the role of e-commerce, changes in the labour market (such as platform work, or increased use of teleworking). The societal developments refer to possible changes in attitudes regarding sharing versus owning vehicles, a growing preference for local goods and services and a changing awareness of the external costs of transport. It may also involve greater public support for the effective enforcement of regulations and objectives (as regards safety, environmental goals and standards, etc.). In many cases the extent to which these developments will take place, and the pace at which this would happen if they do, is still uncertain, albeit not to the same degree for all of them. Some of them may mitigate the challenges associated with urban mobility, as described in this chapter, whereas others may increase the challenges in the absence of an appropriate policy framework (see EEA (2016)). Many of these developments may also support the attractiveness of F/L/O mile options, for example continuing digitalisation, the development of autonomous vehicles and the changing attitudes towards sharing. This will be explored further in Chapter 5.

- Increased scientific insights into the external costs of transport (as incorporated, for example, in the regular updates of the EU handbook on the external costs of transport — for the most recent version, see DG MOVE (2019) — and the health impacts of inactive lifestyles.

3 EU and international policy context

Summary

- Offering good urban mobility services while mitigating the environmental problems caused by transport and addressing accident and congestion problems, is a common challenge for cities all over Europe. Local and national authorities play a major role in addressing these issues.
- At EU level, several policies and funding programmes have been developed to stimulate sustainable urban mobility approaches and innovative solutions, of which first/last/only mile (F/L/O mile) options form a part.
- Transport in and to/from cities is also affected by more general EU transport policies and strategies that are not specifically formulated for this transport segment. While in some cases they strengthen the uptake of F/L/O mile options (e.g. through better pricing of transport use), most of these policies provide extra ways to achieve the environmental objectives for transport, in addition to F/L/O mile options.

3.1 Introduction

Offering good urban mobility services, while mitigating the environmental problems caused by transport and addressing accident and congestion problems, is a common challenge for cities all over Europe. Local and national authorities play a major role in addressing these issues. Also at EU level, policies and funding programmes have been developed to stimulate sustainable urban mobility approaches and innovative solutions ([18]), of which F/L/O mile options form a part.

3.2 Policy developments in transport and urban mobility

Figure 3.1 presents an overview of EU policy developments in urban mobility since 2001 that have led to the EU's current urban transport policies.

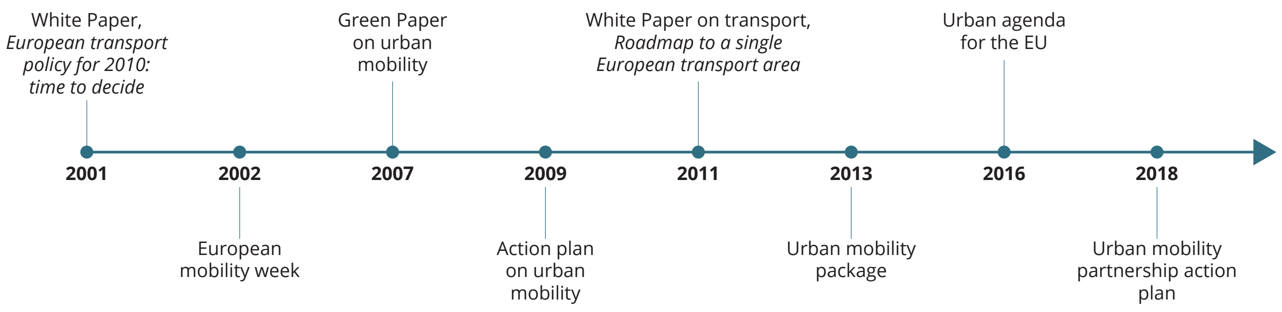
The 2001 White Paper, *European transport policy for 2010: time to decide* (EC, 2001), promoted regulated competition, modal integration, multimodality and bottleneck elimination, user- and real cost-focused transport policy, alternative fuels and transport globalisation. One of the main messages of the 2001 white paper was that, in addition to facilitating the growing demand for transport, a modern transport system must be sustainable from economic, social and environmental viewpoints.

The European mobility week was established in 2002. Since then 'it has sought to improve public health and quality of life through promoting clean mobility and sustainable urban transport. The campaign gives people the chance to explore the role of city streets and to experiment with practical solutions to tackle urban challenges, such as air pollution' (European Mobility Week, 2019). It increases awareness and fosters knowledge about the negative impacts of transport, especially in the urban environment. F/L/O mile options were promoted by many of the annual campaigns, as illustrated by the themes of the last three editions: 'Safe walking and cycling' (2019), 'Mix and move' (2018) and 'Sharing gets you further' (2017).

The 2005 thematic strategy on the urban environment (EC, 2005) identified a number of environmental problems that could be improved by the development and implementation of sustainable urban transport plans. In its strategy, the European Commission

([18]) The EU legislation and policies page on the Eltis website provides more information on current EU policies and funding sources: http://www.eltis.org/discover/legislation-polices

Figure 3.1 Overview of EU policy developments in urban mobility



committed itself to preparing guidance on how to prepare such sustainable urban transport projects.

The 2007 Green Paper on urban mobility (EC, 2007) identified a number of core elements of sustainable urban mobility, namely the need to make towns and cities and their transport systems more fluid, greener, 'smarter', more accessible, and safer. The stakeholder consultation that ensued indicated that there is a role for the EU in supporting local authorities that are facing challenges of EU and global dimensions and in enabling and encouraging the development of a new culture for urban mobility in Europe. The consultation process also shed light on specific areas in which action at the EU level offers added value.

The 2009 action plan on urban mobility (EC, 2009) operationalised EU urban mobility policy by providing a framework for 20 EU-level actions, grouped in six thematic areas. The thematic areas covered are:

- the promotion of policy integration;
- citizen-focused policies;
- greening urban transport;
- strengthening funding;
- sharing experience and knowledge;
- optimising urban mobility.

The integration of environmental considerations within the transport sector was significantly extended with the publication in 2011 of the White Paper on transport — *Roadmap to a single European transport area — towards a competitive and resource efficient transport system* (EC, 2011d). It presented a roadmap of 40 concrete initiatives to build a competitive transport system that increases mobility, removes major barriers in key areas and fuels growth and employment. Along with the *Roadmap for moving to a competitive low carbon economy in 2050* (EC, 2011b) and the *Energy roadmap 2050* (EC, 2011c), it was developed in line with the objective of reducing Europe's total greenhouse gas (GHG) emissions by 80 to 95 % by 2050 compared with 1990 levels. The 2011 transport White Paper focused strongly on the oil dependence of the transport sector and its contribution to GHG emissions and included quantitative targets requiring the transport sector to achieve an overall reduction in GHG emissions of 60 % by 2050.

The White Paper highlighted the dimensions of clean urban transport and integrated urban mobility. Out of its 10 goals, two explicitly refer to urban mobility:

- Halve the use of 'conventionally fuelled' cars in urban transport by 2030; phase them out in cities by 2050.
- Achieve essentially CO_2-free city logistics in major urban centres by 2030.

Three initiatives of the 2011 White Paper are particularly relevant in this context:

- establishing procedures and financial support mechanisms at the European level for preparing urban mobility plans (initiative 31);
- the development of a package for urban road user charging and access restriction schemes (initiative 32);
- producing best practice guidelines to better monitor and manage urban freight flows (initiative 33).

Although urban mobility is addressed specifically in these goals and initiatives, for many of the other goals and initiatives in the White Paper there is also an interaction with urban mobility.

The 2011 transport White Paper was accompanied by an impact assessment (EC, 2011a), which concluded that the EU 'had not succeeded in containing the growth in the economic, environmental and social costs of mobility while simultaneously ensuring that current and future generations have access to safe, secure, reliable and affordable mobility resources to meet their own needs and aspirations'. According to the impact assessment report, the underlying reasons for this unsustainability can be identified in market and regulatory failures in the areas of:

- charges and taxes that do not reflect the social costs of transport;
- not fully exploiting the potential of research and innovation;
- insufficient and inefficient supply of transport services;
- a need for a new and integrated policy approach to urban mobility.

The European Commission presented in 2012 an independent review of the implementation of the 2009 action plan on urban mobility and in 2013 followed up with a public consultation to explore the way forward. This led to the adoption of the urban mobility package (UMP2013) in 2013 (EC, 2013). It sets out how the European Commission will strengthen its actions on sustainable urban mobility in areas where there is EU added value. The European Commission also encouraged Member States to take more decisive and better coordinated action. The European Commission — together with cities, Member States and stakeholders — has been implementing the UMP2013 since 2014.

For EU-level action, the following areas were identified as having significant EU added value: ensuring a broad debate about urban mobility across the EU; facilitating the exchange of experiences and best practices; catalysing research and innovation; and providing financial support for urban transport projects, particularly in the less-developed regions.

The UMP2013 is structured around four main pillars:

- sustainable urban mobility plans (see Box 3.1);
- coordinating public and private sector intervention;
- reinforcing EU support by (1) sharing experiences, showcasing best practices, and fostering cooperation; (2) focusing research and innovation on delivering solutions for urban mobility challenges; (3) providing targeted financial support; and (4) reinforcing the international dimension;
- involving Member States in the urban mobility field by inviting them to ensure that action on urban mobility is coordinated within their country and across EU countries, in order to avoid fragmentation in the deployment of technologies and policy-based measures.

Moreover, the UMP2013 put forward specific recommendations for coordinated action between all

Box 3.1 Sustainable urban mobility plans

A sustainable urban mobility plan (SUMP) 'has as its central goal improving accessibility of urban areas and providing high-quality and sustainable mobility and transport to, through and within the urban area. It regards the needs of the ''unctioning city'' and its hinterland rather than a municipal administrative region'(see annex of (EC, 2013)).

A study by the Joint Research Centre (Lopez-Ruiz et al., 2013) estimated the potential reductions in CO_2 emissions achieved through 21 policy measures found in SUMPs. Assuming that the measures are implemented all over the EU, an emission reduction of 7 to 8.8 % compared with 2010 would be realised.

The CIVITAS SUMPs-UP and PROSPERITY projects (Durlin et al., 2018) identified a total of 1 000 SUMPs across Europe in 2017, compared with 800 in 2013. A total of 290 of these SUMPs are second- or third-generation plans that follow-up on previous plans. The SUMPs-UP project identifies that the major contributors are countries in which the adoption of a SUMP is imposed by law and supported by significant initiatives.

Learning from the practical experience of cities that have implemented SUMPs, the guidance materials provided by EU-funded projects (including CIVITAS) and the new mobility developments and societal changes, the guidelines on SUMPs are currently being revised. The process should be finalised in 2019.

levels of government and between the public and the private sector in four fields:

- **Urban logistics:** the logistics processes need to be improved in order to optimise the exchange of goods and information and to contribute to the economic performance of cities. Important challenges faced by urban logistics are emissions and road congestion.

- **Urban access regulations:** such regulations can help to improve urban accessibility, to mitigate negative effects such as emissions and accidents, and to optimise the use of existing infrastructure, while also raising revenue.

- **Urban intelligent transport systems (ITS):** realising the full potential of urban ITS is expected to deliver benefits in all UMP2013 areas of intervention, including demand and traffic management, urban logistics, access restrictions, traffic safety and improved public transport services.

- **Urban road safety:** this field covers planning, driver behaviour, infrastructure, vehicles, and emergency response issues that should contribute to improving the safety of vulnerable road users.

The implementation progress of the EU transport policy, as envisaged in the 2011 White Paper, was assessed in 2016 (EC, 2016b). At the time of the assessment, around 64 % of the White Paper initiatives were completed or well advanced, 31 % were ongoing or making slow progress and 5 % of the initiatives had not commenced or had been cancelled. As far as the three urban mobility-related initiatives were concerned, urban mobility plans showed greater progress than the road charging and urban logistics ones.

The urban agenda for the EU was established in May 2016, through the Pact of Amsterdam. It placed cities at the forefront of EU policy design and implementation. The agenda is also aligned with other international agreements such as the United Nations Sustainable Development Goals (SDGs), and in particular SDG 11, which aims to make cities and human settlements inclusive, safe, resilient and sustainable, and the Paris Agreement on climate change.

At the Paris climate conference (COP 21) in December 2015, 195 countries adopted the first ever universal, legally binding global climate deal. The Paris Agreement (UNFCCC, 2015) sets out a global action plan to put the world on track to avoid dangerous climate change by limiting global warming to well below 2 °C above pre-industrial levels and by pursuing efforts to limit the temperature increase to 1.5 °C above pre-industrial levels. The agreement recognises the role of non-party stakeholders in addressing climate change, including cities, other subnational authorities, civil society, the private sector and others.

The urban agenda for the EU focuses on the regulation, funding and knowledge aspects of urban policy, and looks towards the establishment of territorial cohesion. It is structured with 12 priority themes, with urban mobility being one of them. Groups of experts were established and designated as partnerships, with representatives from different territorial, hierarchical and stakeholder levels, that produced non-binding action plans with concrete proposals.

The urban mobility partnership action plan was finalised in 2018, and it is structured on two recommendations related to the involvement of local and regional authorities in the EU financial planning process and to the improvement of cross-border mobility. Moreover, nine actions were proposed, many of which have direct or indirect relevance for F/L/O mile options. For example, this is the case for the actions regarding the evaluation of best practices in convenient access to public transport, the development of guidelines on infrastructure for active mobility, the promotion of sustainable and active mobility behaviour, and the exploration of the deployment of new mobility services.

Transport in and to/from cities is also affected by more general EU transport policies and strategies that are not specifically formulated for this transport segment, such as the Eurovignette Directive and its ongoing revision; the air pollutant and greenhouse gas emission standards for cars, vans and heavy-duty vehicles; the directive on alternative fuels infrastructure; the revised Clean Vehicle Directive; and the Environmental Noise Directive. Several of these EU-level policies have been part of the three mobility packages that were adopted during 2017-2018, including a wealth of initiatives in the transport sector that were announced in the 2016 European strategy for low-emission mobility. Regarding the environmental dimension, these policies reduce the environmental impacts of transport either by reducing transport demand ('avoid' policies), by shifting towards more sustainable transport modes ('shift' policies) or by improving the environmental sustainability of transport modes ('improve' policies). Although in some cases they strengthen the uptake of F/L/O mile options (e.g. through better pricing of transport use), most of these policies provide ways to achieve the environmental objectives for transport that are not linked to F/L/O mile options.

3.3 Cross-cutting policies and wider European initiatives

Urban transport and transport in general falls under a number of cross-cutting pieces of EU legislation that aim to reduce environmental impacts from across all economic sectors. The following are examples of such initiatives.

A new National Emissions Ceiling (NEC) Directive (2016/2284/EU) entered into force on 31 December 2016. Replacing earlier legislation (Directive 2001/81/ EC), the new NEC Directive sets 2020 and 2030 emission reduction commitments for five main air pollutants. It also ensures that the emission ceilings for 2010 set in the earlier directive remain applicable to Member States until the end of 2019.

In May 2019 the EU completed the update of its energy policy framework in a way that will facilitate the clean energy transition and make it fit for the 21st century (EC, 2019a). All aspects of the new energy legislative framework — the clean energy for all Europeans package — and all of the new rules have been formally adopted. The package will be a significant step towards creating the energy union and delivering on the EU's Paris Agreement commitments.

In November 2018, the Commission adopted the communication *A clean planet for all: a European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy at the request of the European Parliament and the European Council* (EC, 2018b). It provides a vision for reducing EU greenhouse gas emissions to net-zero level through a positive long-term transformation, leading to a smarter, more circular and resource-efficient economy, increasing EU competitiveness and protecting the health of EU citizens.

The long-term vision reinforces the message of the 2016 European strategy for low-emission mobility that achieving such emission reductions in transport will require an integrated system approach. This includes promoting (1) overall vehicle efficiency, low- and zero emission vehicles and infrastructure, (2) a long-term switch to alternative and net-zero carbon fuels for transport, and (3) the increased efficiency of the transport system — by making the most of digital technologies and smart pricing and by further encouraging multi-modal integration and shifts towards more sustainable transport modes. Changes in behaviour and consumer choice to shift from private transport to low-carbon public transport, shared mobility and zero-carbon mobility (cycling, walking) are also key. Rethinking mobility will deliver tangible benefits, including clean air, reduced noise and more liveable urban spaces.

Alongside the EU's activities that this chapter focussed on, there is also an important initiative involving a larger group of countries in wider Europe (see Box 3.2).

3.4 Other supportive actions

Two important urban mobility initiatives are CIVITAS and the European Local Transport Information Service (ELTIS), the urban mobility observatory. In addition, through other initiatives such as the Covenant of Mayors and the European Innovation Partnership on Smart Cities and Communities and Urban Innovative Actions, the European Commission supports cooperation from public and private stakeholders (EC, 2016a). Sustainable mobility is also an important area of cooperation between regional and local governments across Europe and supported through programmes such as Interreg Europe, which is financed by the European Regional Development Fund (see Box 3.3).

The European Court of Auditors estimates that more than EUR 60 billion in EU funding is available for urban mobility projects from 2014 to 2020 (ECA, 2019). The main sources are:

- the European Regional Development Fund and the Cohesion Fund with EUR 32 billion;
- the Connecting Europe Facility with EUR 24 billion; and
- Horizon 2020 with EUR 8 billion for transport research, including urban mobility.

Box 3.2 The Transport, Health and Environment Pan-European Programme

Since its creation in 2002, the Transport, Health and Environment Pan-European Programme (THE PEP) has brought together the key stakeholders in the 56 countries of wider Europe to work towards the common purpose of sustainable, clean and healthy transport (WHO Europe and UNECE, 2018).

THE PEP supports the translation of international commitments into national and local actions. In doing so, it brings together officials from the transport, health and environment sectors, and from local authorities, private companies, intergovernmental and non-governmental organisations and other stakeholders. The Environment and Sustainable Transport Divisions of the United Nations Economic Commission for Europe (UNECE) and the World Health Organization Regional Office for Europe (WHO/Europe) jointly service THE PEP.

Over 15 years after its creation, THE PEP is still showing its relevance as a platform to facilitate and support change towards sustainability and to aid member states in their efforts to implement their commitments to sustainable and healthy transport. Especially relevant are their commitments to implement the 2030 Agenda for Sustainable Development and its Sustainable Development Goals, the Paris Agreement on climate change and the New Urban Agenda.

Through a dynamic network of representatives of member states, academia, civil society and experts, THE PEP has been engaging all three sectors, enabling governments to make progress in improving their understanding of the challenges to health and the environment in relation to transport. The fields in which THE PEP has been most active include the following:

- It promotes active mobility, including walking and cycling. Under preparation is the first pan-European master plan on cycling promotion.
- It supports eco-driving or how to drive ecologically. Guidelines under preparation also focus on electric cars and how to increase the lifespan of their batteries.
- It identifies green jobs that can be derived from investment in sustainable transport. Currently under investigation is the potential for creating new jobs when investing more in public transport and electric vehicles.
- It supports the integration of transport planning into land use planning. Currently in preparation is a handbook on sustainable transport and urban planning.
- It supports sustainable mobility in sustainable tourism. A project linking 11 destinations (called 'pearls') along the Danube river has just concluded. The 11 destinations committed to ensure the provision of sustainable mobility between the destinations and within them.

3.5 Review and evaluation

The evaluation of the UMP2013 is currently ongoing and also covers the EU financial support for urban mobility projects and the European mobility week (EC, 2018e). The aim is to assess whether the provisions in the UMP2013 are sufficient to achieve its objectives, in order to get a better insight into its strengths and weaknesses and to evaluate the extent to which it contributes to the EU's transport and decarbonisation objectives. In April 2019, the European Court of Auditors also launched an audit of the effectiveness of the EU's action and funding on urban mobility, the results of which are expected to be published in 2020 (ECA, 2019).

Box 3.3 Sustainable mobility for the last mile in tourism regions

Tourism accounts for around 8 % of global greenhouse gas emissions and transport is a significant contributor (Lenzen, M. et al., 2018). Despite the increasing share of aviation, car-based mobility is still dominating the tourism sector.

One determining factor for the choice of transport mode is the availability of sustainable transport options at the last stretch of the journey, i.e. from the hubs/regional railway stations to the final destination, the 'last mile'. Especially in rural tourism destinations, the last mile is often the missing link. However, experiences have shown that flexible transport systems embedded in regular public transport are a useful enhancement in many cases: to cover the 'last mile' in the travel chain of tourists and to provide an alternative to car use for the daily mobility of inhabitants.

The project LAST MILE (2016-2020) — initiated by the Austrian Ministry of Sustainability and Tourism and funded by INTERREG EUROPE — aimed to find innovative and flexible solutions for sustainable regional mobility systems such as on-demand call/dial systems, car-sharing and bike-sharing systems or seasonal transport solutions. Led by the Environment Agency Austria, partners from six European countries (Austria, Bulgaria, Luxembourg, Poland, Slovakia and Spain) have exchanged and analysed the framework and barriers as well as good examples for the implementation of flexible transport systems and have developed regional action plans, resulting in policy recommendations for the different levels.

All partner regions could provide various good examples of the successful implementation of flexible mobility solutions for the last mile. Many solutions result from bottom-up initiatives that adjusted the model of operation to current needs and expectations of residents and other target groups. However, such initiatives often necessitate broad compromises related to insufficient legal regulations and the lack of comprehensive organisational and financial support. Additionally, transport organisers do not usually have experience in implementing flexible transport systems in their overall public transport system.

The experiences and work of the partnership led to recommendations; mainly that it will be necessary to create the proper legislative and financial framework by integrating flexible transport systems into guidelines and respective laws, as well as into funding instruments at the different levels. There is also the need to consider flexible transport systems in the relevant strategic documents at regional and local level, e.g. in SUMPs. Finally, awareness raising and the involvement of relevant stakeholders is essential for success.

More information about the LAST MILE project is available at www.interregeurope.eu/lastmile.

LAST MILE
Interreg Europe

European Union
European Regional
Development Fund

4 Determinants of modal choice and the role of first/last/only mile options

Summary

- For passenger transport, good first/last/only mile (F/L/O mile) options have the potential to modify the inherent characteristics of public transport and to reduce the generalised costs of trips made by public transport, thereby making it more attractive.
- 'Good' F/L/O mile options try to make the whole passenger transport chain as seamless, fast and comfortable as possible. This means avoiding delays, waiting time, transfers or, if they cannot be avoided, making them as comfortable as possible.
- Economic efficiency is already well integrated into freight transport within the current policy context for pricing and regulation. In urban logistics, F/L/O mile options will often increase the generalised cost. The urban logistics option in combination with the F/L/O mile option will normally make sense from a societal point of view, but is often challenging from a cost-efficiency perspective in the current framework of prices.

4.1 Introduction

This chapter situates the role of F/L/O mile options to reduce the environmental burden of urban passenger (Section 4.2) and freight transport (Section 4.3) within the larger 'avoid-shift-improve' framework.

4.2 First/last/only mile options as means of reducing the environmental burden of urban passenger transport

The role that F/L/O mile options can play in increasing the environmental sustainability of urban passenger transport can be illustrated by a simplified urban passenger transport market (Figure 4.1).

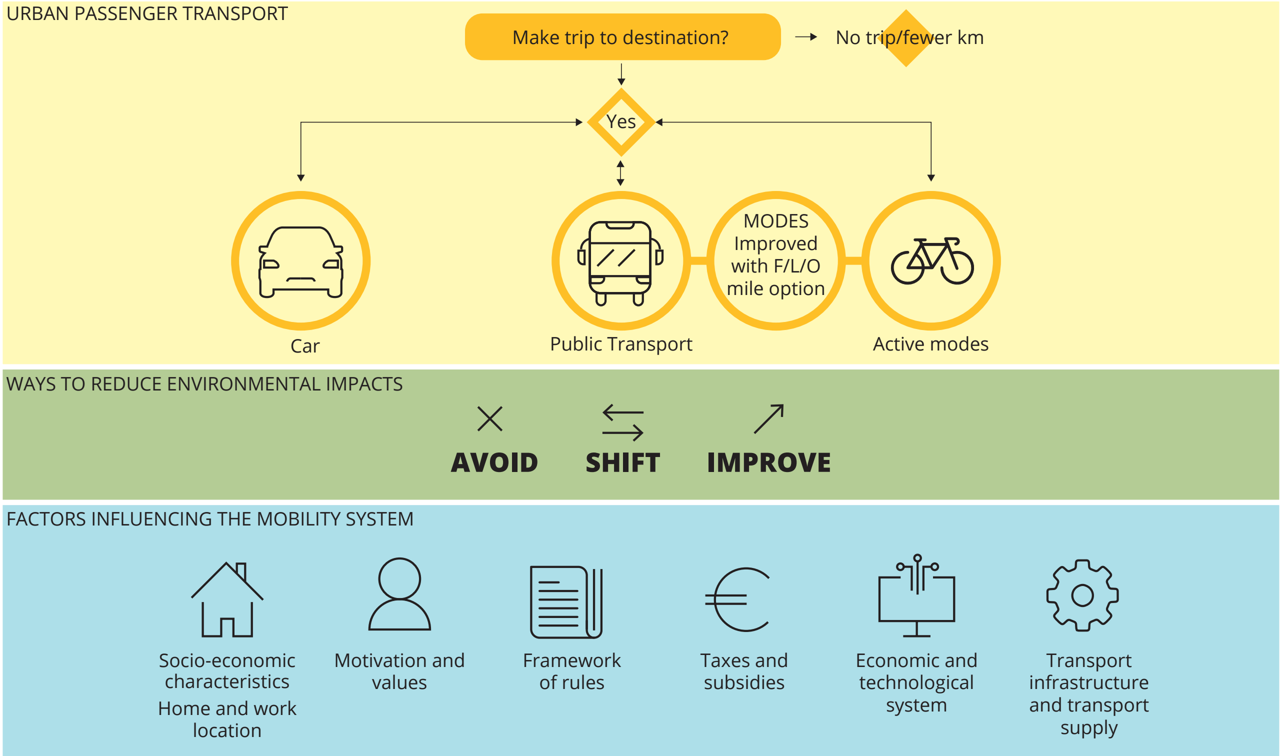
The yellow box in Figure 4.1 presents the transport market and green box identifies different ways to reduce the environmental impacts of urban passenger transport. The blue box contains factors that influence this system:

- the socio-economic characteristics of the population (age, gender, economic characteristics, etc.), as well as their home location and job location (the latter if they are employed);
- values and motivations: factors related to lifestyle, culture, environment, behavioural aspects and awareness raising campaigns;
- the regulatory framework: for example, land use and spatial planning regulation, parking restrictions, energy efficiency and emissions regulations;
- price policy and taxation/fiscal regimes: parking fees, fuel taxes, congestion charging, fiscal treatment for (company) cars, etc.;
- the broader economic and technological system: economic performance, degree of globalisation, and available technological solutions;
- the transport infrastructure and supply: capacity and quality of the infrastructure, level and quality of supply of transport services, quality of information about transport supply, and costs of transport services (before taxes and subsidies — these are included as a separate category).

These factors are sometimes interrelated; for example, the home location of travellers is influenced by land use policies, and their economic status is influenced by the broader economic system. To simplify the figure these linkages are, however, not indicated.

In the green box, three types of approaches are distinguished that can reduce the potential environmental impacts of mobility and transport, according to the avoid-shift-improve framework.

Figure 4.1 Situating F/L/O mile options in the mobility universe



Source: EEA own elaboration.

- **Avoid** means that transport is avoided. People can decide not to make a trip or to make a shorter trip. This reduces the transport volume and can be the consequence of external factors that are indicated in the blue boxes, such as cultural changes or technological innovations (e.g. in the case of e-meetings or the wider availability of services provided to citizens over the internet). It can also be the result of policy measures, such as changes in the supply of transport, increasing prices and promoting better land use.

- **Shift** means that environmental sustainability is improved by shifting between modes, from a less sustainable mode (e.g. the car) to a more sustainable mode (e.g. public transport). F/L/O mile options are very relevant here because they can help to make public transport more attractive. For shorter (or 'only mile') distances, F/L/O mile options can also be an environmentally friendly mode in themselves.

- Currently, the dominant mode for making a journey is the car.

- Note that the arrows between the different modes and the 'Yes' box go in both directions, as the attractiveness of transport modes also influences the decision to make a journey and where to travel to.

- **Improve** means that a transport mode uses a cleaner technology or fuel to improve the sustainability of that mode or that the environmental performance is improved, for example by increasing the occupancy rate (as in the case of carpooling) and eco-driving.

The provision of F/L/O mile options is thus one possible way to reduce the environmental and other burdens of transport. It improves the inherent characteristics of sustainable transport modes and may also provide an attractive sustainable mode in itself. This report focuses on the improvement of public transport, but F/L/O mile solutions can also improve car transport, for example by the provision of park and ride facilities, which may reduce car-km travelled.

Attractive F/L/O mile options can make sustainable transport modes more attractive by reducing the generalised cost for their users. The generalised cost is a concept that reflects, on the one hand, the monetary costs of the transport modes and, on the other hand, the value that transport users give to other characteristics of the modes, which are also expressed in monetary terms. Generally, these include the different components of the journey time. Other characteristics, such as reliability or the risk of accident or damage, could also be included.

The extent to which this lower generalised cost will lead to a higher demand for sustainable transport modes also depends on the specific situation. For example, in a city with a lot of congestion, road pricing and/or high parking costs (because of parking charges and/or parking search time), more people are likely to shift to sustainable modes than in a city without congestion and with plenty of cheap parking space.

In order to make sustainable transport modes more attractive, the subjective journey time is a very significant factor. The subjective journey time is the time as perceived by travellers. It can be different from the objective journey time. This is explained further below for different parts of the public transport journey. Attention is also paid to the walking time experienced.

4.2.1 Different perceptions of journey time depending on different journey parts

F/L/O mile options generally reduce door-to-door travel time. It is, however, important to know that not all types of travel time are perceived in the same way.

Table 4.1 illustrates how different convenience attributes of travelling are valued and how relatively uncomfortable certain parts of the journey are perceived. It is taken from an overview given by Wardman (2014). For example, a 1-minute delay counts as 3-5 minutes of additional perceived travel time in the perception of public transport users. In other words, the perceived or subjective time taken for a journey for which the transport time is reduced by 5 minutes, but for which the delay is increased by 5 minutes, will increase by 10-20 minutes. This implies a considerably higher generalised cost and a considerable decrease in the attractiveness of that travel mode. Other parts of a journey that are not appreciated at all by users are waiting in crowded conditions, walking in crowded conditions or walking with more than normal effort.

Somewhat lower penalties are associated with walking and waiting in normal conditions, having to stand while travelling, and displacement time and headway ([19]). The inconvenience caused by displacement time is higher for longer journeys, and the inconvenience related to headway is higher for shorter journeys, in which people would like to make their journeys without having to do much planning and also expect to make them more frequently than longer journeys. Transfers get a penalty of 5-15 minutes of subjective travel time. Some, but less, inconvenience is associated with the availability of information. In the latter case expectations might, however, also increase when information systems develop further.

This is important information when looking for interesting F/L/O mile options. To make public transport in combination with F/L/O mile options more attractive, it is important to reduce the combined journey time of public transport and F/L/O mile options, and giving priority to reductions in travel time linked to transfers, delays and waiting time. If they cannot be avoided, they should be made as comfortable as possible. In other words, it is important to provide a seamless, reliable, fast and comfortable alternative to the car.

In general terms, over short distances, the use of a bicycle (or a car) can be more appreciated than using public transport, as public transport always involves some waiting and walking time, even if the total travel time is similar. A public bike sharing system can therefore have both a negative and a positive impact on public transport use. It provides an F/L/O mile option, but at the same time it provides an attractive option for short distances. Some research confirms this. For example, Campbell and Breakwood (2017) observed a significant decrease in the number of bus users on routes where a bike sharing system was implemented. This is not necessarily a problem, especially on routes where public transport is close to capacity.

The Dutch railways (Nederlandse Spoorwegen) applied this knowledge when setting up their shared bicycle scheme (OV fiets) that focused on the last mile for railway passengers. With the combination of bicycle and train, they reduced total public transport journey time by nearly one third, 67 minutes compared with 96 minutes (Van Zeebroeck, 2017). The time gains came from the use of a bicycle for the first and last mile instead of public transport. Cycling normally requires only half the travelling time compared with taking a

([19]) Displacement time refers to the disutility of not departing at the preferred time; headway refers to the disutility associated with less frequent services, which also imply more planning and time spent in obtaining information.

Table 4.1 Overview of importance of convenience multipliers

Convenience term	Indicative multiplier
Late time	3.0-5.0
Walking with more than normal effort	4.0
Waiting in crowded conditions	2.5-4.0
Walking in crowded conditions	2.0-3.5
Walking and waiting in normal conditions	1.75-2.0
Standing (depending on conditions)	1.5-2.0
Headway	0.5-0.8
Displacement time	0.4-0.6
Interchange penalties	5-15 minutes
On-vehicle information	<< 1 minute
Off-vehicle information	<< 1 minute

Source: Wardman (2014).

bus, not taking into account penalties for waiting time or stressful transfers. Another advantage of using the bicycle for first and last mile trips is that those waiting times and stressful transfers are avoided.

4.2.2 Different perceptions of journey time and distance depending on the environment

For pedestrians, the walking environment influences the perceived walking distance. The main influencing variables are the variability of the walking environment and the positive emotions it generates. These variables together may increase the acceptable walking distance by 70 %. The catchment area for a bus stop is three times larger in a 'human-scaled' environment than in a more car-oriented environment. As at least some walking is involved in most public transport trips, shortening the perceived walking distance can therefore have a positive effect on public transport use (Hillnhütter, 2016).

It seems logical that similar effects may occur for other modes. For example, nicer cycle routes may attract more cyclists and reduce their perceived travel times.

4.3 First/last/only mile options as means of reducing the environmental burden of urban freight transport

In freight transport, the majority of goods are transported by carriers (transport by third parties). These carriers have a clear incentive to maximise the load factor of their vehicles, and, if they operate well, they aim for maximum efficiency. Also if a company delivers its goods itself, for cost-efficiency purposes it will try to use the available capacity as efficiently as possible. Given the economic constraints with which companies are faced, they will try to consolidate their transport flows as much as possible.

In freight transport, depending on the type of goods transported, there are cases in which the accepted delivery times are longer than in the case of passenger transport, which offers more possibilities to make its organisation more efficient. For the transport of individual parcels or small quantities of parcels, bundling and unbundling are logically part of the transport organisation. Goods, unlike passengers, often do not go directly from A to B, except for full load shipments or shipments for which the cost of bundling is too high. Freight transport will consider F/L/O mile options when making a decision about the most efficient transport process. In that case goods are taken from their origin (first mile), bundled in logistic centres, transported over a longer distance in a bundled form, unbundled in another logistic centre and delivered to their destination (last mile).

The first and last mile usually involves transport by heavy- or light-duty vehicles. As will be discussed below, a number of F/L/O mile options exist that can improve environmental sustainability at this stage.

Economic efficiency is already well integrated into freight transport. This is related to a certain extent to environmental efficiency, as the number of kilometres/parcel transported is minimised to the extent that is acceptable for the client and carrier. It is important to mention that these decisions are taken within a given policy context. For example, if transport prices increase, one can expect that further efforts will be undertaken to increase efficiency compared with the current situation.

Bundling, where economically beneficial in combination with first and last mile logistics, is already part of the freight transport process. To reduce further the burden from freight transport in urban areas, an additional transfer can be introduced. This transfer has the objective of reducing the distance travelled through the urban area. A transfer can also be made to cleaner vehicles. Such transfers will normally make sense from a societal point of view, but they are often not cost-efficient in the current framework of prices. It is this kind of last and first (urban logistical) mile that is the topic of this report.

As a consequence, achieving a shift in urban freight logistics becomes less straightforward, as it implies an artificial loading and unloading at extra cost. This will be discussed in the next chapter.

5 First/last/only mile options and their role in the transport system

Summary

- First/last/only mile (F/L/O mile) options are not new. They have evolved throughout the last two centuries and are still evolving. The idea behind them is always the same. Efficient transport requires bundling or consolidation of people or goods. Bundled transport can only be organised between hubs or stops. To reach the hub or stop, an F/L/O mile option is necessary.
- Thanks to technology, new F/L/O mile options are becoming available for passenger transport. There are many kinds of shared vehicles, such as bicycles, cars and electric kick scooters. These are increasingly convenient to use. Furthermore, technologies allow better integration of different transport modes and tariffs, which enable mobility-as-a-service (MaaS). In future, autonomous vehicles could also have a role as an F/L/O mile option.
- In freight transport, urban consolidation centres, on the periphery of the urban area, in combination with efficient urban distribution vehicles are of central importance. Urban consolidation centres bundle goods so that they can be distributed in a more efficient way. The societal burden of urban freight transport can be reduced in this way.
- Variants on the large urban distribution centres exist. Micro-hubs such as parcel lockers, proximity delivery points and places where goods are trans-shipped to a smaller vehicle that is more flexible to use in an urban area (e.g. cargo bikes), are examples of this. E-commerce is an important driver in the growth and evolution of urban logistics.
- Innovations linked to (urban) logistics include the use of drones and delivery robots (droids) that can make journeys from and to the consolidation centres and the use of 3D printing.

5.1 Introduction

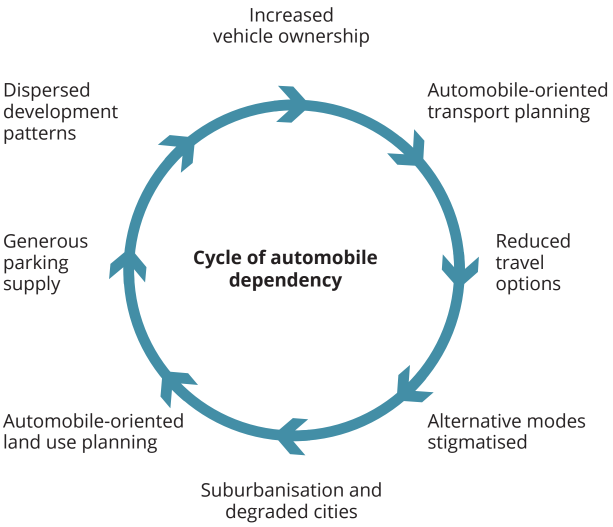
This chapter first presents a short historical overview of passenger transport, and freight transport and logistics, in view of F/L/O mile options. It also addresses a number of future challenges for both of these transport markets (Sections 5.2 and 5.3). Next, different F/L/O mile options are presented. For passenger transport, a general typology of options is presented in Section 5.4. Both sections also pay attention to new technologies and innovations. For freight transport, Section 5.5 discusses different types of urban consolidation centres.

5.2 Passenger transport: history and evolution

At the end of the 19th century, before the breakthrough of the car, but at a time when public transport was available, 'people lived where there was a supply of public transport and public transport was where people lived'. This statement is somewhat exaggerated but illustrates the fact that urban sprawl was less developed and people lived relatively closer to public transport stops. Weighted urban proliferation, an index for urban sprawl, for example multiplied by five between 1880 and 2015 (EEA and FOEN, 2016). This was a perfect situation for bundling the larger transport flows in large public transport infrastructure. F/L/O mile services were provided by smaller public transport infrastructure, bicycle or foot. This was possible thanks to the concentration of societal functions, housing and working. In Flanders (Belgium), for example, it had been a particular policy in the 19th century to build rail infrastructure to enable workers to live in the countryside (near a railway or tram station). The aim was to avoid overpopulation in cities (De Vos, 2015).

With the breakthrough of the car, mainly after the Second World War, smaller public transport units disappeared, and people no longer needed to live near public transport stops to go to work. The car gained market share thanks to its convenience. This is well

Figure 5.1 Self-reinforcing cycle of increased automobile dependency and sprawl



Source: Litman (2019).

illustrated in Figure 5.1 (Litman, 2019). Car ownership increases and influences land use, causing urban sprawl, which in its turn increases car ownership.

Over time it has become clear that the breakthrough of the car also had its drawbacks, in the form of new challenges, such as congestion, and its contribution to climate change and poor air quality, as explained in Chapter 2. Therefore, authorities in several places in Europe are trying to reduce car dependency in favour of public transport use and to incentivise low- and zero-emission vehicles. The latter option is only effective in combatting climate change and poor air quality. To (re)attract people to public transport, F/L/O mile options will be crucial because of important changes in land use.

5.3 Freight and logistics: history and future challenges

5.3.1 Original concept and evolution

The last mile problem first became a field of study within telecommunications and then within logistics and transport (King, 2016). To solve this challenge in a resource-efficient way, the principle is always to 'bundle whenever you can for as long as you can and do the bundling and unbundling via efficient hubs'. In the logistics sector, the bundling and unbundling principle is also translated as 'connecting individual sender and receiver via hubs'. Bundling means that goods that need to be transported over (partly) the same route are put together. Unbundling means separating the goods that have been transported together, to bring them to their different final destinations.

Even before logistics became a field of study in the 1970s and 1980s, the bundling-unbundling principle was already being applied, as it is a consequence of improvements in economic efficiency. Depending on societal challenges, changes in the environment, costs of technologies, etc., the practical implementation of the principle has evolved over time and is still evolving.

For example, in economies that were based on heavy industry where the production of goods was concentrated in large centres, ships and trains were important. Bundling and unbundling needs, however, were relatively limited.

As the economies and technologies evolved, the origins and destinations of production and consumption became more scattered. Bundling and unbundling for/of ship, rail and road transport became more necessary. With this evolution and given the transport prices at that time, road transport provided an answer to the changes in the patterns of production and consumption. It became the first choice for the more 'scattered delivery of goods'.

There was, and still is, a kind of virtuous circle between road transport and scattered goods delivery. Road transport facilitates the geographical dispersion of production and consumption, while keeping the possibility of direct transport between origin and destination. This is thanks to the fact that 'full road transport units' are much smaller than 'full rail or ship transport units' and have door-to-door prices that are generally lower than those of rail transport. In the road transport sector, however, the principle of bundling and unbundling also remains absolutely pertinent, as does the organisation of last mile logistics, as lots of shipments are not full loads. Logistics operators will try to avoid the last mile stage, as it is the least efficient stage and is responsible for up to 28 % of the total delivery cost (Ranieri et al., 2018).

5.3.2 E-commerce: a future challenge in urban freight logistics

E-commerce is a rapidly growing business. A study for the European Commission (Kalevi Dieke et al., 2019) estimates that the business-to-consumer (B2C) e-commerce markets of both goods and services in the EU Member States and EEA member countries increased revenue from EUR 200 billion in 2013 to EUR 490 billion in 2017. The revenues in the parcel market were estimated to be EUR 65 billion in 2017. The Benelux countries, Germany, Austria, France, Ireland and the United Kingdom are important markets, with more than 16 parcels delivered per capita/year. The B2C market is growing rapidly and carriers are rapidly adapting their services, by establishing parcel shops, introducing Saturday deliveries, etc. For traditional postal companies, it is an opportunity to compensate for decreasing traditional mail delivery.

An important challenge is the tendency towards ever smaller individual final delivery units, leading to an increase in the number of units to be delivered. In addition, the increase in consumer choice of the most rapid and convenient way of delivery adds to the challenge. Figure 5.2 illustrates this for Germany. 90 % of Germans living close to a delivery point ask for the more convenient option, namely delivery to a private address. Failed deliveries, return operations and increased packaging further reduce the efficiency of online shopping.

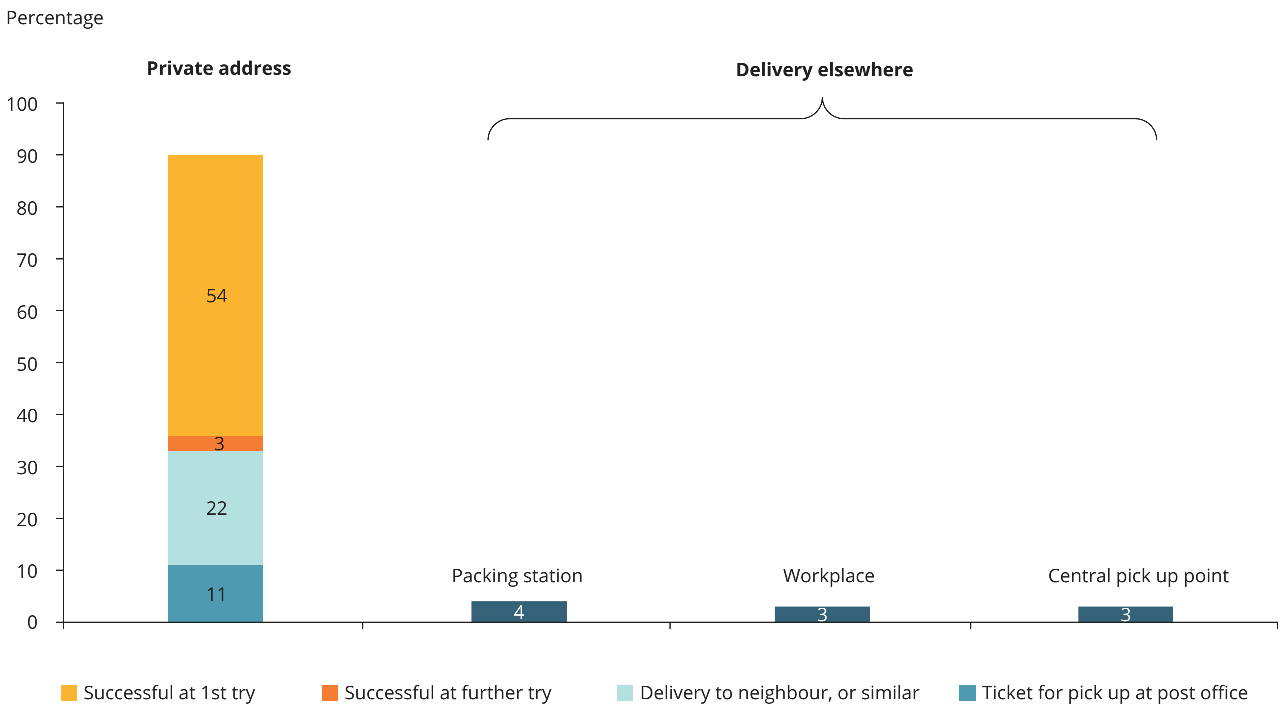
When e-commerce was in its infancy, it was sometimes suggested that the transport system would be made more efficient by replacing individual consumers' journeys with more efficient delivery services. However, today it is unclear how e-commerce affects the environmental impacts of shopping (see Section 6.3).

As a result of these challenges, Kalevi Dieke et al. (2019) also expect that the delivery value chain will change:

- There will be investments in an increasing number of often smaller depots that are close to densely and highly populated areas. These depots will be able to sort and deliver in a more flexible and rapid way.

- There will be innovations in the last mile of e-commerce deliveries to consumers. The main issue here is to find a balance between cost-effectiveness and recipients' convenience. Finding this balance is becoming more difficult as (seasonal) fluctuations in demand increase, resulting in bottlenecks in operational capacity.

Figure 5.2 Forms of deliveries used by customers in Germany



Source: Morganti et al. (2014).

- The satisfaction of the recipients' wish for convenience and the constant search for cost reductions in a market that is subject to heavy competition clearly present a huge logistics challenge. This could lead to further variety of delivery solutions. Delivery platforms orchestrating the different players in the delivery supply chain could be an important element here, mainly in the densely populated areas. A delivery platform is a digital platform or market place where couriers, people who deliver, and senders (or receivers) meet. Both reach an agreement on the terms of delivery in that marketplace.

5.4 First/last/only mile options and innovations in passenger transport

5.4.1 Typology

Passenger F/L/O mile options can be classified in different ways:

- By mode: this was seen in the typology presented in Chapter 1 and includes pedestrian, bike/board/skate, vehicular and public transport options.

- Drive yourself versus being driven: drive yourself options include car sharing, bike sharing, electric kick scooter sharing and walking. Being driven options include buses (traditional), carpooling, taxi and autonomous vehicles.

- Active mobility (walking and cycling) versus non-active mobility (other modes): this is a particularly important classification from a societal benefits point of view, as more than half of the population in the World Health Organization (WHO) European region is not active enough to meet health recommendations. Lack of physical activity is estimated to contribute to 10 % of European deaths. The trend in Europe is towards being less active and not more (WHO, 2019a). In this context, the health gains of more active modes of transport can be important.

- Using one's own means of transport (foot, car, bicycle, etc.) versus someone else's (car sharing, ride hailing, ride sharing as passenger, etc.).

- Low-technology solutions (foot, bicycle) versus higher technology solutions (mobile app based sharing solutions, electric kick scooters, autonomous vehicles). A further distinction could be made between well-established technologies and newer technologies.

5.4.2 Role of new technologies and innovation

For passenger transport, constraints drive innovation and technology creates innovation opportunities. In particular, the development of information technology and its applications enable localisation, tracking and tracing, digital coding (adaptable at a distance) and fast data treatment. Data can now be accessed from almost anywhere and smartphone ownership has become ubiquitous among mobility users. These developments provide many opportunities for F/L/O mile options. New options can be created and existing options can be improved. Some examples are below. These include shared mobility, mobility-as-a-service and autonomous vehicles.

Shared mobility

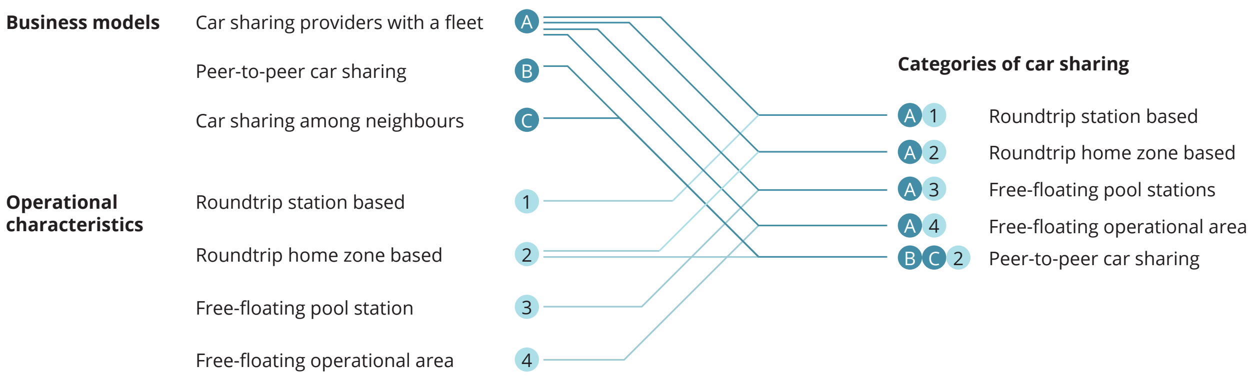
Although shared mobility is not new, technology and innovation have made its organisation and provision much easier. Payments, locking and unlocking of vehicles, etc., are becoming possible/much easier thanks to new technology. Before the information technology revolution, sharing a vehicle was mainly possible among family members, colleagues, friends or neighbours. Now anyone with an interest in sharing can, in principle, do so. As a result, shared mobility now exists in different forms and variants. The next paragraphs shed light on three forms: (1) car sharing; (2) ride sharing or carpooling; and (3) bicycle or other vehicle sharing.

Car sharing

In car sharing, a group of people use a car that belongs to someone else, a company or a private person. Figure 5.3 illustrates different types of car sharing. Classifications can be based on the business model and operational characteristics.

Concerning business models, the car sharing provider has a fleet of cars. These cars are available to the public under certain conditions, such as by paying rent. In the other models, cars are the property of citizens that rent cars to one another in peer-to-peer car sharing. In that case, there is generally an intermediary that provides an application and some other services (e.g. insurance) to facilitate the organisation of car sharing. The intermediary takes a commission on the rent. A particular case of peer-to-peer car sharing is car sharing among neighbours or friends where practical arrangements are made without an intermediary.

Figure 5.3 Overview of business models, operational characteristics and categories of car sharing



Source: Rodenbach et al. (2018).

Concerning the operational characteristics, four main models exist:

- The round-trip station-based model is where the start and end of the trip are the same parking place.
- The round-trip home-based model is where the shared car is picked up and brought back to the same area in the city. There is usually no reserved parking place.
- The free-floating pool stations model is where the shared car is picked up and brought back to a (different) reserved parking place.
- The free-floating operational area is where the shared car is picked up and brought back to a large operational area. This area is usually a whole city or it can in some cases involve different cities.

Different combinations of business models and operational characteristics provide different categories of car sharing. Not all combinations are possible. For the peer-to-peer models, cars need logically to be brought back to a place close to the vehicle owner, their private parking place or an undetermined parking place in the area.

Ride sharing or carpooling

In ride sharing, different people or groups of people share the car with the vehicle owner. The organisation of short- and long-distance carpooling is often slightly different:

- Short-distance carpooling is typically done by commuters that all make an at least partly similar journey. It can be facilitated by a company, a group of companies situated in the same area, or a non-profit organisation via an app or a database.
- Long-distance carpooling is typically managed by an intermediary that manages an app and takes a commission on the transaction.
- Ride hailing is the Uber-like service. Although the first two types do not have much relevance for use in combination with public transport, this may be relevant for ride hailing. This is explored further in Section 6.2.

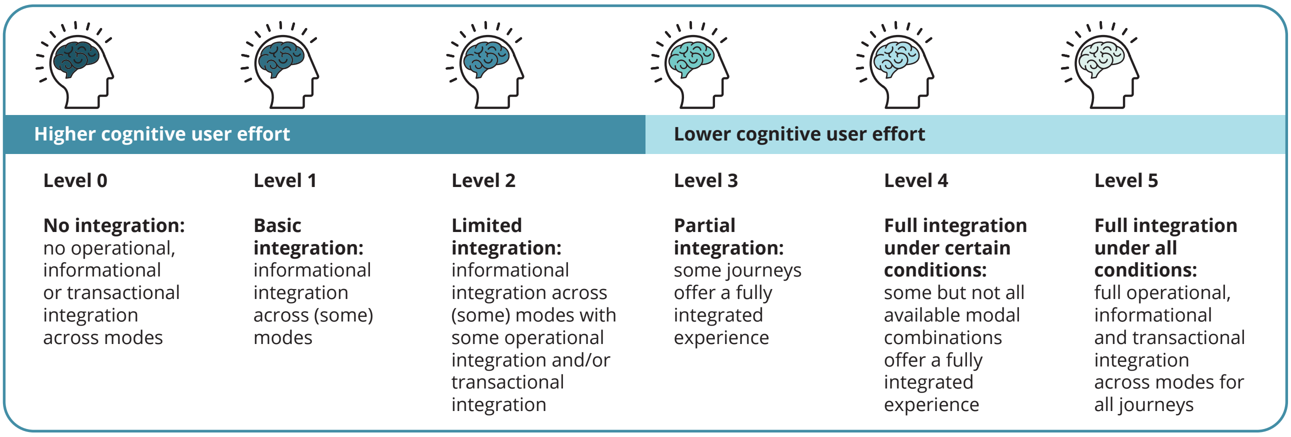
Bicycle or other vehicle sharing

Several options described above for car sharing are also possible with other vehicles, such as bicycles or electric kick scooters, except for the fact that peer-to-peer sharing is of less interest, as the investment in a bicycle is quite small.

Mobility-as-a-service

Mobility-as-a-service (MaaS) integrates existing transport services based on information technology. This usually includes ticketing and invoicing. MaaS also supports planning, reservation, and providing travel information and route adaptations where necessary. In that way, MaaS facilitates the integration of F/L/O mile options with public transport and contributes to the provision of seamless sustainable transport options via 'one-stop shopping'. In other words, MaaS will or can reduce the cognitive effort needed to use public transport, as is illustrated in Figure 5.4.

Figure 5.4 Levels of MaaS integration



Notes: Cognitive user effort: the effort involved in relying upon the mobility system beyond the private car to fulfil mobility goals; operational integration: interchange penalties are low and door-to-door journey experience is 'seamless'; informational integration: journey planning and execution information for available modes is offered through one interface; transactional integration: payment and any required booking and ticketing is offered through one interface.

Source: Lyons et al. (2019).

According to Geier (2019), MaaS can potentially provide a mobility system that:

- is better adapted to different lifestyles;
- makes the cost of mobility more transparent (thanks to tariff integration, monthly payment, etc.);
- provides better answers to societal needs (thanks to data analysis);
- makes efficient use of the available capacity of different transport networks.

The potential contribution to a more sustainable mobility system is addressed in the assessment section of this report (Section 6.2).

To organise MaaS services, an extra layer is added to the mobility system, which comprises a broker or integrator. The mobility broker integrates all available mobility solutions into a service that best fits its clients. Often such an integrator has access to data on the mobility profile of the client and can make proposals that best fit the clients' profile. The broker or integrator has a crucial role to play. Depending on the regulatory framework, it can be a private player operating within a set of standards set by the public authorities or a public player. One could also envisage solutions in which the public authority establishes a public digital infrastructure that can be used by all stakeholders interested in being mobility brokers.

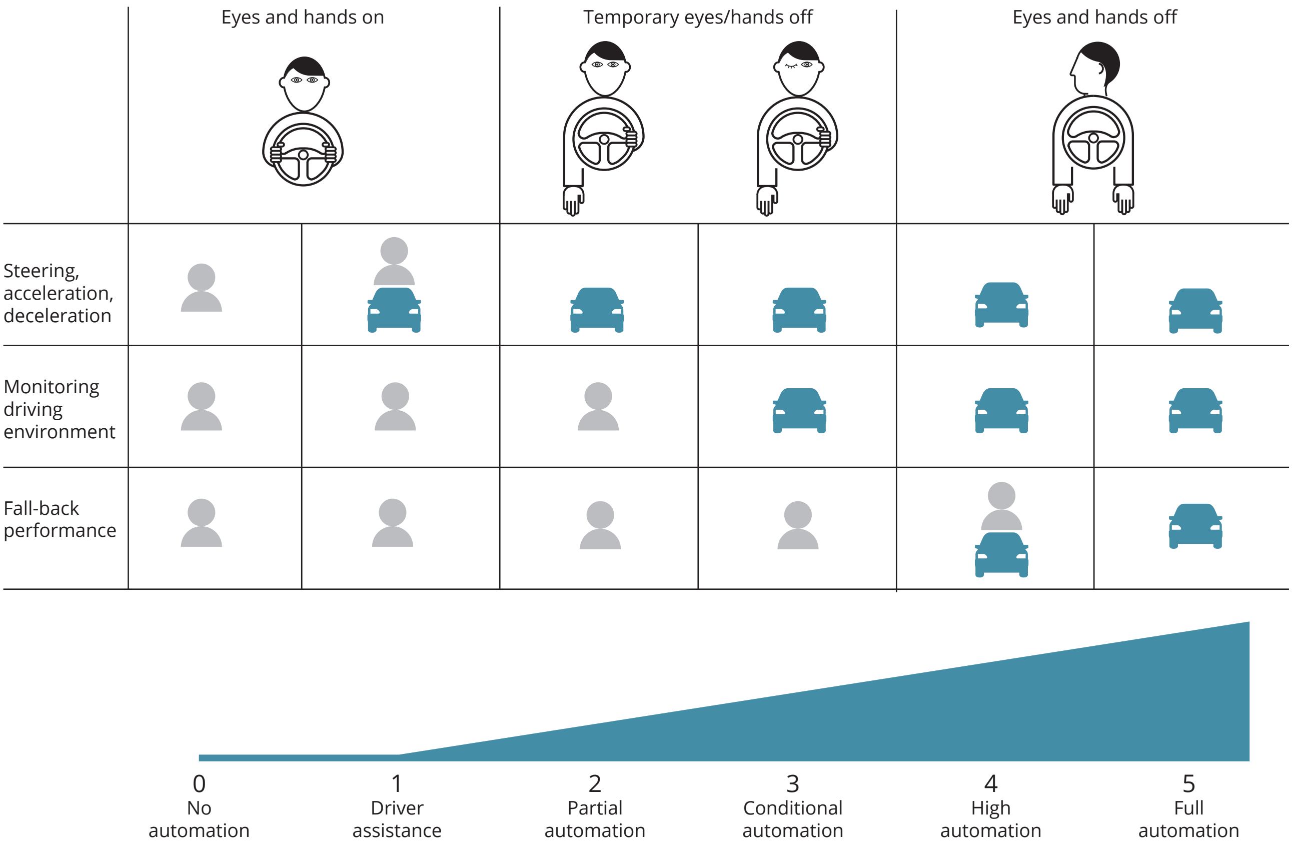
To achieve a successful MaaS system, it is important that all mobility providers are treated equally. If the largest mobility provider in an area takes up the role of broker and has disproportionate power, smaller mobility providers may hesitate to join the structure, as they may fear unfair competition, which would reduce the value of the MaaS. Being the broker can give a competitive advantage, as the broker has access to all the travel data of people using MaaS. Payments could also be made via that broker, which increases its advantage.

Autonomous vehicles

Fully autonomous vehicles (Society of Automotive Engineers, SAE, level 5) are vehicles that no longer need a driver. Today tests with driverless cars are ongoing, but such vehicles are not yet market ready. A report by Mintsis et al. (2018) gives an overview of the developments that have taken place in this field and of those that are ongoing.

Several different classifications of automated driving exist. Currently, the automation levels defined by SAE International in its J3016 standard (SAE International, 2018) is one of the most frequently used classifications in the community. This standard defines six levels of automation, starting from manual

Figure 5.5 Different levels of automated driving



Source: Own elaboration based on EP (2019).

driving (level 0) up to full automation on all roadways and in all environmental conditions (level 5). These levels are illustrated in Figure 5.5.

At present, the first level 3 systems are reaching the markets. In these systems the vehicle itself monitors the environment and 'fulfils all aspects of the dynamic driving task'. In the event that the system is not able to handle a situation, the human driver must 'respond appropriately to a request to intervene' (which is called a transition of control).

In addition, with the advent of technologies that allow more connectivity, vehicles have begun to communicate with each other (termed vehicle-to-vehicle, V2V) and with the infrastructure (termed vehicle-to-infrastructure, V2I). This has made it possible for vehicles to work together, share information, etc., which has led to an additional classification. Cooperative automated vehicles are AVs that are equipped with the 4G cellular or ITS-G5 communication technology for V2V and V2I.

The potential impacts of (shared) autonomous vehicles are assessed in the next chapter.

5.5 First/last/only mile options and innovations in freight transport

5.5.1 Typology: general

Chapter 1 made reference to Ranieri et al. (2018), who provided a typology of different solutions to reduce the societal burden of urban logistics. Most of those can also be linked to last mile logistics:

- proximity stations or points — e.g. parcel lockers;
- collaborative and cooperative solutions;

- innovation in public policies and infrastructures — urban pricing being an example of a possible public policy and intelligent transport systems being an example of infrastructure;
- innovative vehicles — e.g. electric or autonomous vehicles but also drones and robots.

Last mile logistics are part of the first two solutions. In the case of the third solution, certain policies and legislation can facilitate the organisation of last mile logistics. The use of innovative vehicles can be combined with last mile logistics, but that is not a necessity.

The idea behind last mile logistics is that it 'reduces freight traffic in a target area by consolidating cargo at a terminal or consolidation centre. The idea is that carriers that might otherwise make separate trips to the target area with relatively low load factors, would instead transfer their loads to a (neutral) carrier that consolidates the cargo and conducts the last leg of the deliveries' (Holguin-Veras et al., 2018).

5.5.2 Consolidation centres

There are different varieties of consolidation centre. The most common types are listed below. While the societal benefits are undeniable, it is however often difficult to attract sufficient users because of cost constraints.

Urban consolidation centres outside the urban area

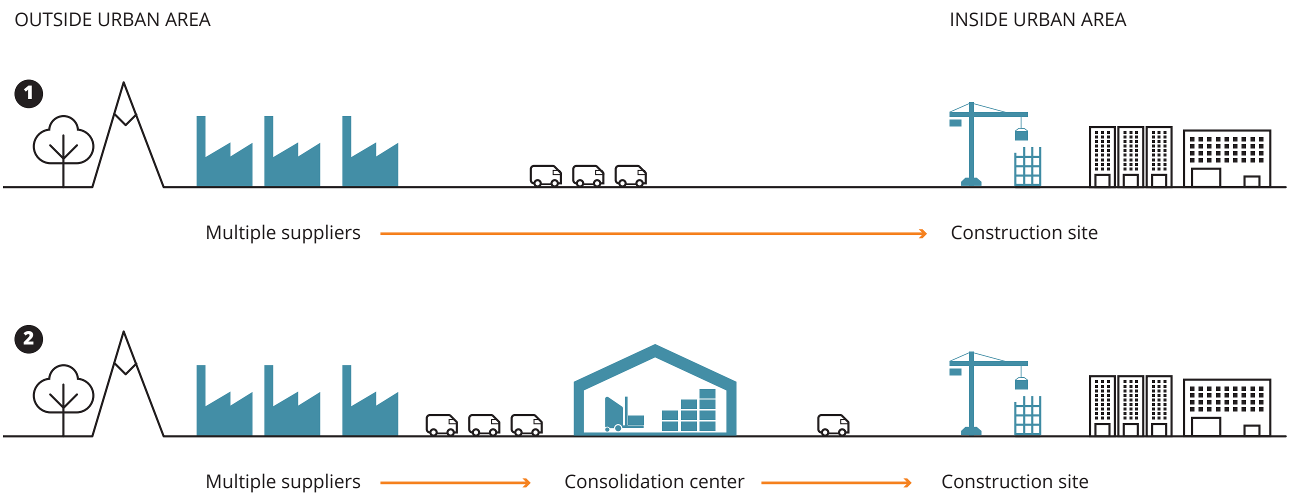
Urban consolidation centres (UCCs) are the conventional form of consolidation centre and correspond to the definition provided above. The consolidation centre is situated outside the city or urban area, and from there a neutral carrier conducts the last leg of the deliveries (Holguin-Veras et al., 2018). The initial carrier delivers the goods to the consolidation centre and pays a fee for the last mile.

The principle is illustrated in Figure 5.6 where a construction site is the destination. Without a consolidation centre, different providers send goods separately to a destination in an urban area (upper part of Figure 5.6). With a consolidation centre, all providers send goods to the consolidation centre outside the city. From there only one regular delivery takes place at regular times (lower part of Figure 5.6). The transport burden in the urban area is in that way significantly reduced.

Urban consolidation centres inside the urban area

The principle of these centres is exactly the same as that of centres outside the urban area. These are often smaller and can even be very small. Parcel lockers or proximity delivery points are examples of very small consolidation centres that make it unnecessary for the courier to make final deliveries. This means that the courier can significantly rationalise the trip. The recipient can/has to pick up their parcel at these

Figure 5.6 Illustration of urban consolidation centres



Source: VCF et al. (2018).

locations. Shops where clients go to pick up their parcels are examples of delivery points. These are a type of micro-consolidation centre.

Consolidation linked to a modal shift terminal

A modal shift terminal in or close to the city will nearly always imply an F/L/O option. If goods are shifted from road to ship or train, to arrive in or close to the city, these goods will most probably be unloaded in a consolidation centre, from where a last mile mode will take the goods to the receiver. Although appealing to many, such initiatives face major obstacles in urban areas. These consolidation centres may be inside or outside the urban area, depending on the situation of the railway (or inland waterway) terminal.

Consolidation centres can work in different modalities. Some of those provide incentives for using them. This contributes to their success. The following are examples.

Changes in the destination of deliveries to a consolidation centre

The key to these programmes is that the receivers change the destination of the deliveries. Parcels are then sent to delivery lockers, delivery points or consolidation centres. However, normally receivers do not choose to change destination. They generally choose a place that is most convenient for themselves; in most cases this is delivery to their shop, business or house at a normal price (or even for free) instead of using a consolidation centre, which sometimes has a longer waiting time and/or an extra cost. Serious efforts to convince receivers to participate are necessary. This is well illustrated in the example of the Dutch 'Binnenstadservice' that operates consolidation centres in the Netherlands and provides appreciated services and value added for its users (see Box 6.1).

Receiver-led delivery consolidation programmes

This kind of delivery consolidation does not require the use of separate terminals outside the city as a UCC does. Consolidation happens at one of the shippers' facilities, rather than at a consolidation centre. Often the receiver requires suppliers to organise themselves to reduce the delivery frequency for the receiver's convenience. In that way, one supplier delivers its goods to another supplier, and the latter makes the final delivery of all the goods to their common customer. Instead of separate shipments and deliveries, shipments are consolidated and deliveries combined. Holguin-Vera et al (2018) give the example of Transport for London, where delivery servicing plans were introduced. In these plans, receivers assess their delivery patterns, with the aim of mitigating negative impacts. Organising combined and consolidated deliveries can be one of the measures in these plans. For the receiver, a lower number of deliveries results in a more productive business as long as the new organisation avoids any interruption in the supply chain.

5.5.3 Role of new technologies and innovations

Technology, and its challenges and constraints, play an important role in triggering innovation. The development of information technology that offers, for example, possibilities for localisation, tracking and tracing, digital coding (adaptable at a distance) and fast data treatment has enabled, is enabling and will be enabling innovation in (urban) logistics. The rapid growth of e-commerce is one example of that.

Some potential innovations linked to (urban) logistics are described below. These include the use of drones and delivery robots that can make journeys from and to the consolidation centre, and the use of 3D printing, in which the printing office can also be a consolidation centre.

Delivery drones

Drones with automated navigation systems can be used to deliver small parcels directly to the consumer. Retailers and logistics companies are currently trialling the commercial use of such delivery drones. Delivery by drone could prove faster and more efficient than ground delivery. It could also be more environmentally friendly if congestion and emissions are avoided. The challenges of making drones competitive for parcel delivery are, however, important. The societal benefits, for example in reducing traffic congestion, of drones can therefore be expected to be marginal in the near-term. The European drones outlook study (SESAR Joint Undertaking, 2016) estimates that drones would be able to make approximately 1 % of total parcel deliveries today. This estimate takes into account aspects of costs, weight and distance. Drones will be most useful for more expensive same-day deliveries, urgent deliveries (e.g. in the medical sector), and where the parcel's weight does not exceed 2.5 kg and the delivery distance is short.

But before drones will be able to capture that market, further challenges remain (McKinnon, 2017):

- Delivery by drone requires inventory dispersal and local dispatch, which increases costs.
- Drones will need landing space, which will not always be guaranteed. In urban areas, they will compete for limited space. There is also a risk of accident, theft or vandalism during and after landing. Large numbers

of drones landing could also cause noise and visual pollution. 'Drop solutions' may need to be envisaged. Such solutions will of course involve other challenges.

- For safety reasons there is the need to establish strict rules for the operations of delivery drones to avoid any interference with aviation, which will reduce delivery speed.

Delivery robots or droids

These are small autonomous vehicles that deliver parcels. Some tests are being undertaken (Espinoza, 2018). Further challenges remain, however. Delivery robots are much more conspicuous than drones, which implies a higher risk of interaction with the public and of more conflict with other pavement users, which could threaten public acceptance. San Francisco passed a law in 2017 to limit the use of delivery robots (Brinklow, 2019). It should be noted that the productive use of delivery robots requires inventory dispersal and local dispatch, as is the case for drones.

Three-dimensional printing: an example of a proximity station

Another future development that could influence the logistics challenge is 3D printing. Boon and van Wee (2017) organised an experts' judgement-based conceptual model on the impact of 3D printing for the transport sector. Although there is a high level of uncertainty, the experts came up with the following conclusions:

- 3D printers will probably be situated in city-level hubs. Those hubs can then facilitate the coordination of material flows.

- 3D printers will locally produce goods in those city-level hubs, avoiding transport of the finished goods. Distribution of goods will become more efficient and fewer vehicles may circulate. Vehicles would only be used to transport the raw materials.

- Mass individualisation and personalisation dictates the needs for 3D printers, and they will not be competitive for mass production and mass consumption goods. However, with a tendency towards personalisation and mass individualisation, 3D printers could supplement existing retail goods.

The general impact of 3D printing on transport volumes and environmental impacts, however, remains uncertain. Experts' opinions diverged on this topic. The question is whether total consumption will increase and become individualised in such a way that it compensates for the potential gains of 3D printing.

6 The potential environmental and health effects of first/last/only mile options

Summary

- First/last/only mile (F/L/O mile) options make public transport more attractive. In that way, they can contribute to less car use in urban areas as long as the generalised cost of public transport becomes low enough compared with car use.
- On short distances, F/L/O mile options can compete with public transport. This is not necessarily bad, as long as F/L/O mile options are sustainable, as they can free up some capacity on overcrowded public transport during rush hours. It can, however, also undermine the economic viability of public transport services that are used less.
- Active modes as F/L/O mile options will provide the highest societal benefits, as they help people to achieve the World Health Organization (WHO) recommendations on physical activity and make the urban mobility system more sustainable.
- Shared autonomous vehicles can improve the urban mobility system as long as there is an appropriate regulatory framework for their development. If not, shared autonomous vehicles could take market share away from mass public transport and make the mobility situation worse.
- The current experience with ride hailing or transport network companies illustrates that the absence of an appropriate regulatory framework can have negative impacts on the mobility situation in cities.
- Mobility-as-a-service can make public transport more attractive. However, expectations should not be exaggerated. Good physical services (infrastructure and vehicles) remain the basis for a good public transport system.
- F/L/O mile options in freight transport have the potential to reduce the burden on the urban environment and the urban mobility system.
- The economic viability of these options is often challenging. Today, consolidation centres are only viable in niche markets and in areas with a high density of delivery points for small parcels.
- Changes in the regulatory framework, such as the introduction of access regulation, can make last mile urban logistics more attractive.

6.1 Introduction

This chapter explores the impacts of F/L/O mile options. It investigates whether they deliver what they promise, namely more sustainable mobility in urban areas. The chapter starts by investigating the potential health impacts of F/L/O mile options, in particular the active modes of walking and cycling. It investigates whether these can help reach the WHO standards for physical activity and whether electric bicycles can also provide positive health impacts.

The next section looks at a wide variety of F/L/O mile options and assesses their effects on sustainability. For a number of options, observations and modelling exercises are analysed, whereas for others a more qualitative approach is taken. The final section investigates the impacts of F/L/O mile options in freight transport.

6.2 Assessment of potential environmental and health effects — passenger transport

This section assesses whether F/L/O mile options for passenger transport provide positive environmental and health effects and other societal benefits. To assess F/L/O mile options, it is important to be aware of the beneficial (health) impacts of active modes. Therefore, this section starts by explaining these health benefits. It then continues by assessing the impact on car use and some further qualitative assessment of F/L/O mile options.

6.2.1 Positive health effects of active transport

Apart from being a source of societal costs (see DG MOVE, 2019, for a quantification of their magnitude), transport can also be an important source of health benefits for society when active modes are used, of which cycling and walking are the main ones. Each kilometre that is cycled or walked provides health benefits to the individual and to society. The latter includes reduced costs for the healthcare system and reduced absence from work due to illness.

The reason behind the benefits of active transport is that people need physical exercise and that modern lifestyles often do not provide many opportunities for that. The WHO recommendation for a healthy lifestyle prescribes 150 minutes of moderate-intensity physical activity per week for those over 18 years old (60 minutes for those between 5 and 17 years old) and 300 minutes of moderate-intensity physical activity for additional health benefits. Activity periods should be at least 10 minutes long. This recommendation can be translated into 30 minutes of this kind of activity 5 days a week. This type of physical exercise can typically by achieved by some walking or cycling every day (WHO, 2010).

As a consequence, each extra kilometre that is travelled by active modes provides societal benefits, independently of whether this kilometre was previously travelled by bus or car or is a new kilometre. This needs to be qualified by the fact that there are diminishing rates of return on health benefits. The health benefits are most important for people who start walking or cycling from a point of relative inactivity, not for athletes who commute by bicycle as well as doing their daily physical training.

Apart from the direct health benefits to the user, switching to active modes of transport can also reduce emissions and noise.

The electric bicycle can be considered an active mode

With electric bicycles (e-bikes) becoming more popular, the question of their health impact should be raised. Various studies suggest that electric bicycles also have beneficial health impacts. Dutch research suggests that while riding electric bikes is less intense than conventional cycling, it requires moderate effort that could increase physical health (Schepers and Wijnen, 2015).

A Norwegian study found that e-bike users increase their amount of physical activity compared with non-users. Furthermore, they found that people with little interest in physical activity are most attracted to/interested by e-bikes (Sundfør and Fyhri, 2017). Peterman et al. (2016) found that volunteers who started using an e-bike for commuting improved their physical performance within only 4 weeks. As a consequence, they concluded that active transport can improve some cardiometabolic risk factors within 4 weeks.

Other researchers (Castro et al., 2019) took a more general look at e-bike users. They observed that e-bike users and conventional bike users have similar physical activity levels. The reason is that e-bike users generally use the bicycle over longer distances. Concerning mode switchers, e-bike users who switch from conventional cycling reduce their weekly activity levels (a reduction of 200 metabolic equivalent task (MET) minutes in a weekly total of around 4 000 MET minutes). The limited reduction is due to an increase in the distance travelled. E-bike users who switch from car or public transport, however, increase their physical activity by between 550 and 800 MET minutes/week.

The benefits of physical exercise are greater than the negative effects of pollution and accidents

Several studies looked at the impact of pollution on people using active modes of transport, in particular cycling. A WHO literature review investigating 10 studies found that the negative pollution effect is generally marginal compared with the positive physical activity effect. The change in the relative risks for all-cause mortality ([20]) related to $PM_{2.5}$ (particulate matter with a diameter of 2.5 μm or less) during the physical activity reported by each exposure group was less than 5 % in all the studies included (WHO, 2017; de Hartog et al., 2010; Tainio et al., 2016). The positive health effects were also bigger than the mortality risk due to accidents. It remains, however, a challenge to compare the impacts of cycling accidents with the health benefits, because of the under-reporting of cycling accidents (WHO, 2017).

Several studies conclude that the health benefits outweigh the risks of pollution and accidents: Otero et al. (2018) found that in an analysis of 12 European bicycle sharing systems in all scenarios and cities, the health benefits of physical activity outweighed the

([20]) This is the number of deaths, independent of the cause.

health risk of traffic fatalities and air pollution. Mueller et al. (2015) concluded that active transport can provide substantial net health benefits, irrespective of the geographical context.

Indirect health benefits of public transport

Using public transport could also have an indirect positive health impact. Liu et al. (2018) reported that public transport users walk more than non-public transport users — 8.3 minutes on average per day. This translates into better health, a better body mass index ratio and medical savings of USD 5 500 (approximately EUR 4 950) per user and an additional USD 10 000 (approximately EUR 9 000) in reduced costs related to obesity. However, other studies indicate that the health impacts of public transport require further investigation (Shaw et al., 2017).

6.2.2 Do first/last/only mile options help to reduce car use and its externalities? A quantitative assessment

Different kinds of potential F/L/O mile options exist and impacts often vary according to the context and type of F/L/O option. Based on the literature, a quantitative assessment of different options is presented here. First, a modelling exercise for Chicago is discussed that has the advantage of creating a virtual situation that can be perfectly monitored but the disadvantage that it will be never be 100 % similar to reality. Then, various examples with real observations are presented. These concern investments in bicycle infrastructure combined with a reduction in the space attributed to cars (Seville), the implementation of an urban bicycle sharing system (various cities), car sharing systems (various cities) and ride hailing services (San Francisco and New York). The section ends with results from a simulation exercise on autonomous vehicles.

A cost increasing measure for car use is more effective than F/L/O mile options (Chicago simulation exercise)

A simulation exercise for commuters in the city of Chicago illustrates the potential impacts of F/L/O mile options (Zellner et al., 2016). It compares the effectiveness in reducing car use of various policy options in four neighbourhoods, each of them having different characteristics in terms of income and land use. It concerns a simulation exercise, which has the advantage of making comparison easier but the disadvantage of not being directly empirical, although model hypotheses are based on (a simplified) reality.

Three basic options and a combination of those options were tested:

- 'Ideal improvements' make physical improvements for cycling and walking by changing the streetscape.
- 'Shuttles' in this exercise are future autonomous driverless shuttles, or an example of an ideal F/L/O mile option. Psychological factors of autonomous vehicles (AVs) are not taken into account.
- In 'cost scenarios', car use is made less attractive by changes in parking and fuel costs.

The results presented in Figure 6.1 show that the cost scenarios are the most effective, with F/L/O mile options coming in second place. Furthermore, combinations of policies are more effective than single policies. The impacts are, however, different. In high-density mixed use neighbourhoods, F/L/O mile options seem less effective, whereas in lower density single use neighbourhoods, they seem more effective. The reason is probably that high-density, mixed use areas favour walking, making other F/L/O mile options less attractive and less useful. Car use is probably already relatively low. The density of transit stops is probably also higher, making F/L/O mile distances shorter.

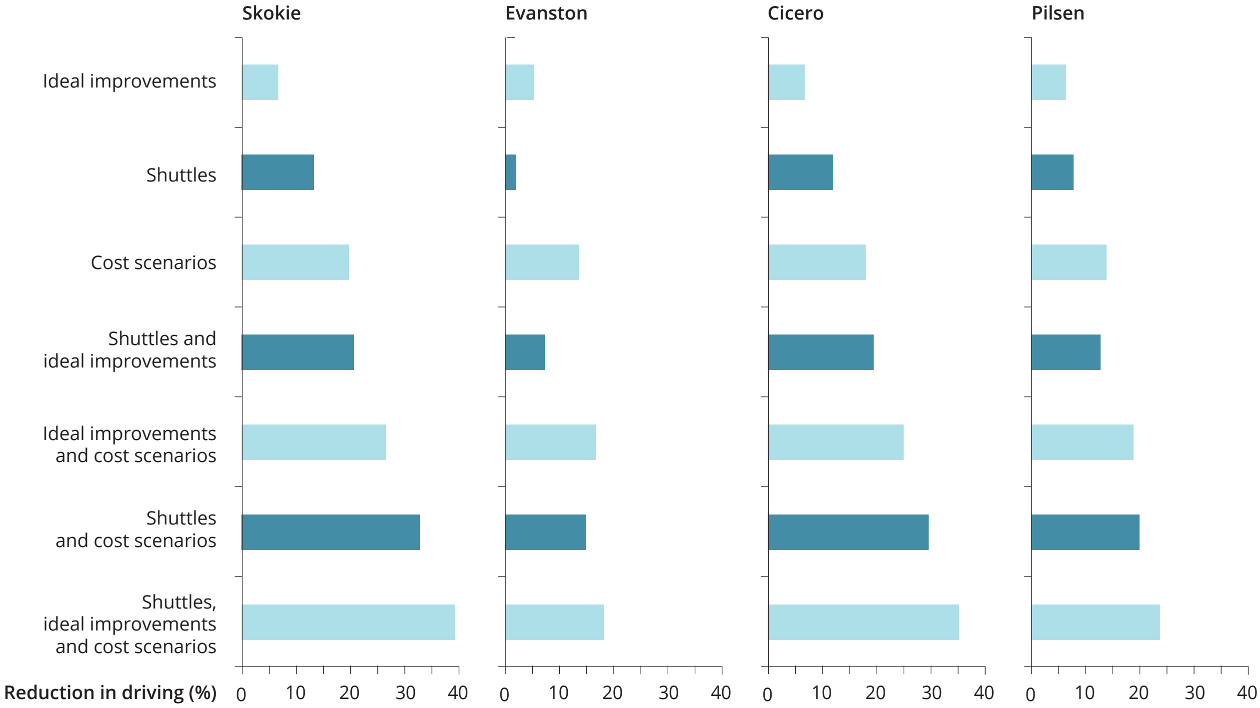
Cycle lanes replace car space in Seville: cycle share increases from 1 to 9 %

Between 2006 and 2011, Seville invested heavily in building a continuous and homogeneous network of segregated cycle paths. This resulted in an impressive increase in the modal share of cycling, from 1 or 2 % before the policy to 9 % of mechanical trips in 2011. Surveys showed that around 30 % of the new bicycle users were previous car users, around 40 % were previous public transport users and between 25 and 30 % were previous pedestrians.

However, the 2008 economic crisis could have also played a role, as car use became less affordable. This might have prompted parts of the population to switch to cycling. Furthermore, there were also car drivers who switched to public transport following the creation of the new public transport infrastructure. It is important to mention that the cycle network was made up of 2.5 m wide bidirectional cycle ways that replaced parking lanes. Alternatively, traffic lanes were narrowed

([21]) Evanston: higher income, higher density mixed use, at the Davis station. Skokie: higher income, lower density single use, at the Dempster-Skokie station. Cicero: lower income, lower density single use, at the Cermak station. Pilsen: lower income, higher density mixed use, at the Damen station.

Figure 6.1 Reductions in driving share under various improvement scenarios in towns in Illinois, United States: Skokie, Evanston, Cicero and Pilsen ([21])



Source: Zellner et al. (2016).

or eliminated (Marqués et al., 2014). The observed changes in travel choices are therefore the result of a combination of investments in cycling and public transport, making the car less attractive because of the reduction in the space attributed to cars and possibly also the economic situation.

Other quantitative information can be drawn from cities that have implemented bicycle sharing schemes.

Bicycle sharing schemes modestly reduce car use (various cities)

The number of bicycle sharing schemes has been growing rapidly over the last decade. Between 2010 and 2017, their number multiplied by three, while the number of bicycles in sharing schemes multiplied by 30 over the same period.

The impact on car use of these systems is, however, rather limited. Users of public bicycle schemes are predominantly previous pedestrians or public transport users. This is confirmed by, for example, the user survey of Brussels bicycle sharing users. Only 7 % of the users of the scheme were previously car users (Timenco, 2012).

Round trip-based car sharing systems: more sustainability thanks to the intention of users (various cities)

An analysis of the different types of car and ride sharing schemes shows that the environmental impact varies.

Round trip station-based car sharing systems have a positive environmental impact. Several studies (Brimont et al., 2016; Franckx and Mayeres, 2015; KIM Kennisinstituut voor Mobiliteit, 2015; Nijland et al., 2015) show that members of round trip-based car sharing systems sell one or more cars (25-30 %) or postpone buying a car (25-60 %). This has a positive effect on use of space and raw materials. Round trip-based car sharing users also reduce the number of kilometres driven, by between 18 and 80 %, depending on the study. Even if station-based car sharing can lead to an increase in the kilometres driven by some people who did not have a car before, this is compensated for by the reduction in kilometres driven by other users. The latter make a more considered use of the car. Use of round trip-based car sharing systems is often associated with an increase in cycling and walking. However, it is difficult to predict how future car sharing users will behave, because, as the number of car sharing users increases, their profile and intentions could change.

Current free-floating systems seem to have a limited impact on the number of kilometres covered, but they do reduce the impact on public space. It is, however, hard to draw firm conclusions in this case, as study results vary widely. A study on free-floating systems in five North American cities (Calgary, San Diego, Seattle, Vancouver and Washington, DC) concludes that one 'car2go' vehicle replaces 7 to 11 cars and that the kilometres driven are reduced by 6 to 16 % (Martin and Shaheen, 2016). Another study for Ulm (Germany) finds that car2go members who did not have a car previously walk and cycle less and use public transport less (Firnkorn, 2012). Another study reports that members of free-floating systems make more variable mode choices than the average transport user (Kopp et al., 2015). In addition, a study of the Paris free-floating system 'Autolib' shows that free-floating car sharing has no or a limited positive societal impact (ADEME-6t-bureau de recherche, 2015). Based on research in Cologne and Frankfurt, Hülsmann et al. (2018) found that 'car2go' had no impact on car possession, public transport use and greenhouse gas emissions.

Free-floating car sharing systems could, however, attract new target groups for whom it is probably a first step to a life without a private car (Matthijs, 2018).

Ride hailing competes with public transport and increases car-km and congestion (New York and San Francisco)

Two American studies provide some insights into the impacts of ride hailing services such as Uber and Lyft at the city level. A study for the city of New York shows that the majority of ride hailing trips would have been made by public transport in the absence of the ride hailing service. To the question 'How would you make this trip if not by ride hailing' the answers were 50 % public transport, which increased to nearly 70 % in the centre of the city; 43 % taxi or car service; 13 % walk; 12 % car. Note that multiple answers were possible. The study suggests that for each ride-hail-km, at least 500 m are additional car-km, compared with the situation without ride hailing. The study also reports that people with a disability are more likely to use ride hailing services (NYC Department of Transportation, 2018).

A study from the San Francisco County Transport Authority analysed the impact on congestion. This analysis seems to confirm the above hypothesis that ride hailing services (provided by transport network companies, TNCs) such as Uber and Lyft increase the kilometres driven collectively and worsen road congestion. According to the study, they were responsible for 51 % of the increase in the daily vehicle hours of delay between 2010 and 2016 and 47 % of the increase in vehicle miles travelled. 25 % of congestion, and as much as 36 % in downtown San Francisco, is due to TNCs. At the same time, the report found that street configuration changes (such as the introduction of bus lanes) contributed only 5 % of the increase in congestion (SFCTA, 2018).

These results are confirmed by another study of nine US metropolises by Schaller (2018) that account for 70 % of the US Uber and Lyft trips. TNCs caused a 160 % increase in car-km in these areas.

The majority of TNC users would previously have used public transport. Furthermore, TNCs seem also to be an alternative for own car use if parking is expensive or difficult to find.

Autonomous vehicles may provide gains if operated in a framework aligned with sustainable mobility goals

The literature points to shared AVs as a potentially interesting mode of travel to make the mobility system more sustainable. Especially as an F/L/O mode for public transport, it could make public transport more attractive (see Zellner et al. (2016)). They could also reduce pollution and significantly increase road safety. However, some caution is needed, as they should not replace high-capacity public transport. Furthermore, it is probable that car-km will increase, as AVs could replace buses (Schaller, 2018). In scenarios in which traditional private and shared AVs are used, total vehicle travel could increase by 30 to 90 % (ITF, 2015).

A Swiss study points in the same direction, finding an increase in traffic volumes of 25 to 40 % due to the cheaper transport offer of autonomous vehicles. Autonomous taxis would become even cheaper than private cars and the cost of autonomous public transport would also halve (Hörl, S. et al., 2019).

A simulation for Singapore that preserved high-demand bus routes (90 %) while repurposing low-demand bus routes and using shared AVs (10 %) as an alternative shows that the integrated system has the potential to enhance service quality, use fewer road resources, be financially sustainable, and utilise bus services more efficiently (Shen et al., 2018).

However, in other scenarios, where all or part of first mile bus services are replaced by AVs, the system performance worsens, i.e. there are far more private car-km in the system to maintain the same level of service quality as in the benchmark case.

Another report (ITF, 2015) also adds that:

> shared vehicle fleets free up a significant amount of space both on and off-street. However, prior experience indicates that this space must be pro-actively managed in order to lock-in benefits. Management strategies could include restricting access to this space by allocating it to commercial or recreational uses, delivery bays, bicycle tracks or enlarging sidewalks. Freed-up space in off-street parking could be used for logistics distribution centres.

AVs can therefore increase the vehicle kilometres travelled and reduce public transport and the share of walking and cycling. This particularly applies to private AVs, which are also leading to a more dispersed urban growth pattern. These risks are well illustrated by the assessment of ride hailing services above. The actual ride hailing services could be considered as an AV with a driver and a bit more expensive. Unregulated AVs could perform in the same way as ride hailing services at a lower price. As a consequence, kilometres driven and congestion could increase even more.

Shared AV fleets in a regulated framework, conversely, could have positive impacts, including reducing the overall number of vehicles and parking spaces. Moreover, if it is assumed that automation would make the public transport system more efficient, AVs could favour urbanisation. However, the results are very sensitive to model assumptions that are still very uncertain (e.g. the perception of time in AVs), and more research is warranted, along with development of the models and their further adaptation to AVs (Soteropoulos et al., 2019).

All of this makes clear that shared AVs are not a miracle solution in themselves. They can be part of a solution within a clear public policy framework to ensure that technology and innovation bring the desired environmental improvements.

6.2.3 Further assessment of first/last/only mile options for passenger transport

The previous section showed that F/L/O mile options may contribute to a reduction in car use. Below some further considerations are provided on the different types of F/L/O mile options that have been presented.

Larger environmental benefits with F/L/O mile options for long-distance than for short-distance travel on public transport

The environmental gains of F/L/O mile options are potentially larger for longer than for shorter distance travel by public transport. If a person shifts from car to train for a 30 km commute, thanks to an appropriate F/L/O mile option, the gains will be larger than for a person shifting from car to metro for a 3 km commute.

Moreover, there is no competition between the F/L/O mode and longer distance public transport travel. The F/L/O mode provided in combination with longer distance public transport travel will only increase train transport, partly due to a shift from car users to train and the F/L/O option. The F/L/O mode will not be an alternative for a 30 km train trip, while it could be an alternative for a 3 km metro trip. Campbell and Brakewood (2017) point out that there can be competition between, for example, public transport and urban bicycle sharing systems. A shift from public transport to bicycle sharing can be relevant for decongesting public transport, but this is another discussion topic.

More benefits with active mobility modes

As mentioned in Section 6.1, the health benefits of active modes of transport are important. Even without a reduction in car driving, societal gains will be obtained. The main barriers to increasing active mobility shares are cultural and infrastructural. People are not used to using bicycles, and public space is not adapted for cycling and walking. By making space more attractive for cycling and walking, authorities could achieve the double win of increasing cycling and walking shares while reducing the share of car use, as space that was attributed to cars could be attributed to cycling and walking.

Other sharing systems such as electric kick scooters could have a negative environmental impact

Apart from bicycles, other sharing systems pop up in cities, such as systems with shared electric kick scooters. Only few detailed studies of their environmental impacts have been published so far. A life cycle analysis by Hollingsworth et al. (2019) found that the environmental impacts directly linked to the use of shared electric kick scooters are relatively small and lower than for most other motorised modes of transport. However, the negative impacts linked to materials and manufacturing are substantial. Especially if the lifetime of the shared scooter is less than two years. The emissions from collecting the scooters for recharging during the night are the second most important factor as this task is typically carried out with diesel vans. Another publication concluded that shared electric kick scooters are more likely to result in an emissions increase rather than decrease (Chester, 2019). A recent survey in France found that three out of four users would have chosen to walk or use public transport otherwise (ADEME 6-t bureau de recherche, 2019).

There are some further considerations:

- Regulation of how the providers of electric kick scooters (and other shared vehicles) can provide them might be needed to avoid hindering other public space users. Some cities, Paris and Brussels among others, have put in place a framework for such shared vehicles (Dumon, 2019).
- Accidents could be an issue. Electric kick scooters are relatively fast and have small wheels. Because of this, a little unevenness or roughness or a small obstacle can cause a fall. The issue could be bigger for electric kick scooters than for bicycles, as the scooter wheels are smaller and more sensitive to small obstacles.
- Electric kick scooters do not provide positive health effects in the way that active modes of transport do. To the extent that electric kick scooters replace walking (and cycling), they will cause a loss of societal welfare in this respect.

Park and ride — F/L/O mile options for cars

Providing park and ride facilities can be seen as proposing F/L/O mile options for cars and making car use more attractive. Studies show that car-km often increase with such systems. In other cases, car-km can decrease, especially with the provision of park and ride systems in more peripheral areas. It can also be the case that car-km increase but total societal costs decrease because congestion decreases (Mills and White, 2018; Mingardo, 2013; Parkhurst and Meek, 2014).

Mobility-as-a-service

Although mobility-as-a-service (MaaS) provides extra assets for public transport and may improve its competitive position compared with cars, the scientific literature also warns of exaggerated expectations. In particular, researchers report the following:

- MaaS is an evolutionary continuation in terms of transport integration, using the technological means at its disposal. At first, travel information was only available in a scattered way on paper; then it became digital but was still unimodal; then integrated multimodal travel information was available. MaaS adds seamless booking, payment and ticketing to this further integrated offer (Lyons et al., 2019).
- Tailored solutions mean a better match with the demand for travel. They could also lead to more vehicles on the road if they are not accompanied by a culture more motivated to share (Mulley, 2017) or measures to decrease car use.
- Hensher (2017) reports that the MaaS model could be very dependent on a revised role for the car, with services such as ride hailing and AVs that add convenience for the users.

The MaaS model will probably not be the silver bullet for mobility challenges. It will improve the customer experience of alternatives to individual car use. However, MaaS and integrated tariffs and bookings are irrelevant if the physical transport assets underpinning these services are insufficient. 'Limited capabilities in the conventional public transport space are still worth looking at, particularly given the likely increase in improved choice for customers' (Hensher, 2017). The importance of the conventional public transport space remains crucial. To be able to satisfy user needs, the first assets needed are infrastructure and vehicles, next are mobility services, information services and transaction services. Only when all these elements are available, can the mobility intermediary (MaaS) provide further added value.

6.3 Assessment of potential environmental and health effects — freight transport

6.3.1 General assessment of urban consolidation centres

Consolidation centres are an interesting option from environmental and mobility perspectives. They reduce negative impacts when electric vehicles or cargo bikes replace conventional delivery vans or lorries. Cargo bikes also provide important health benefits for their drivers. Negative environmental and mobility impacts are also reduced by reducing the number of kilometres travelled for urban logistics.

The local impacts can be significant. At the project level, a bicycle fleet can replace delivery vans and drastically reduce emissions. However, as the number of urban consolidation centres (UCCs) is still very limited the impact of last mile urban logistics is small on a European scale. The reason for the low number of UCCs and other last mile urban logistics initiatives is that their economic viability is often challenging and far from guaranteed. The UCCs that are operational today are exceptional in this respect. The Civitas policy note on urban logistics (Civitas Wiki, 2015) comes to a similar conclusion, stating that 'historically, the success rate of such measures is lower than hoped for'. Also the Cyclelogistics project (Wrighton, 2017) states, 'According to the city administrations in the Cyclelogistics project, a shopping or home delivery platform can rarely survive without the support from the city'. The reason is that a consolidation centre needs an extra transfer of goods (from vehicle to consolidation centre and to another vehicle), which costs time and money. The transfer will only be beneficial for the economic stakeholders if its gains are bigger than its costs.

There are, however, some factors that can contribute to viable sustainable urban logistics and UCCs, which will be discussed in Section 6.3.3.

6.3.2 Assessments of some particular types of consolidation centres and means of last mile delivery

Some specific types of urban logistics are assessed below, based on the work of Holguin-Vera et al. (2018).

Receiver-led delivery consolidation programme

These are programmes in which a receiver requires suppliers themselves to organise common deliveries. A pilot test in London led to a reduction of 20 % in the total number of deliveries made to a building site. Further benefits are time gains (less interruption of business) for the receivers and increased load factors and a reduced number of trips for the supplier.

Changes in the destination of deliveries

In general, environmental and mobility impacts are positive in most cases in which UCCs are used. The economic viability is, however, often problematic. One of the few that has succeeded is Binnenstadservice, thanks to the value added for the receivers (Box 6.1).

Mode shift programmes

Modal shifts seem to be possible in niche markets. Good examples of this are the micro-hubs put in place, where goods are distributed by cargo bike by PostNL in the city of Amsterdam (Box 6.2). A cargo bike is affordable, flexible and manoeuvrable and therefore a good option for use in dense urban areas. However, it is less suited to longer round trips because of the limited storage space and weight restrictions.

Drones

Although not widespread today, some studies already started exploring the environmental impacts of delivery drones. Park et al. (2018) found that greenhouse gas emissions of drone delivery were one-sixth of those of motorcycle delivery. For particulates, drones only emitted half those of motorcycles. Figliozzi (2017), and Goodchild and Toy (2018) found positive effects for the greenhouse gas emissions of drones compared with vans, as long as the shipments are small and close to

Box 6.1 Binnenstadservice, an economically viable urban consolidation centre

Binnenstadservice Nederland, a network of UCCs in the Netherlands, has been financially viable for several years, which is unusual in the world of UCCs (Holguin-Veras et al., 2018). It developed a concept in which goods are delivered to a consolidation centre on the edge of the city centre. This means that the delivery address is changed to the UCC. From there, goods are bundled and the last mile to the retailers is performed with a high load factor, a high density of delivery points and, where possible, with clean vehicles (bicycle, (e-)cargo bike, electric vehicles). The service was launched in 2010 in Nijmegen as a non-profit initiative, mainly motivated by environmental goals. After 5 years, 15 cities in the Netherlands and abroad were being served by it (Bestfact, 2013).

Most interesting in this case is that the promotors realised that the receivers were the key stakeholders. Receivers were approached and value-added services were proposed to them. The receivers were convinced and asked their suppliers to send deliveries to the UCC. Suppliers were willing to do so, even if they had to pay a fee to bring the goods from the UCC to the receiver. The reason is that the fee was still lower than their cost for a similar trip.

Since its inception, the Binnenstadservice has expanded to other cities. Receivers' participation is key to counteracting market pressures. Substantial efforts were needed to achieve sufficient participation of receivers and throughput of goods.

Today, more attention is paid to economic viability than during the service's initial years. For this reason, the number of delivery addresses in Nijmegen has been reduced from 160 to 55. The profitability rate today is 2.5 % (Björklund et al., 2017).

Box 6.2 New concept of urban freight logistics tested by Post NL

In the framework of the EU CITYLAB project, PostNL, the Dutch mail, parcel and e-commerce company, developed a new concept of urban freight logistics (Ørving et al., 2018). An important concern that led to this development was the high levels of congestion in Amsterdam's centre. On average, additional travel time is around 22 to 27 %, but in the morning and evening peak times it can reach up to 65 %.

The initial project idea was to bring mail and parcels into the city centre by ship, and to distribute these by (electric) van in the city centre. The ship would have acted as a small or micro-consolidation centre. However, on closer analysis, it became clear that it was not sustainable from a business point of view.

Therefore, the project was rethought and became based on city micro-hubs in combination with e-freight bikes. The micro-hubs are located in the centre of Amsterdam. As the price per square metre of space is very high there, it was decided to share the use of the micro-hubs. From there, special e-freight bikes (2 200 orders/day) and vans (1 300 orders/day) do the distribution in the city centre. Trucks supply the micro-hubs twice a day.

Thanks to this project, the productivity of delivery increased. Bicycles can handle 5 % more orders during a trip than vans, which saves about five trips per day, mainly because of parking issues and detours for vans. Over 90 trips per day are now being done by bicycle, which is over 60 % of the total. Bicycle drivers are satisfied with the additional exercise they gain by cycling and experience less stress because congestion and parking issues affect them less. Also, there has been a positive reaction from the public with tourists taking pictures and clients being enthusiastic.

the consolidation centre. However, if delivery addresses can be grouped, cargo bikes or electric vehicles become better than drones. If emissions from materials and manufacture are taken into account, the situation worsens for the drones. It needs to be added that all of the quoted studies see environmental benefits only for a narrow segment of the market (i.e. last mile delivery to a single or few recipients with low payload).

6.3.3 What stakeholders can do to increase the economic viability of sustainable last mile logistics

Section 6.3.1 made clear that building a business case for sustainable F/L/O mile options in freight transport is difficult. The challenge is always to find ways to cover the extra cost, for example for the trans-shipment at the UCC or micro-hub. Some ways can be proposed to make it easier to cover the extra cost and time necessary for the trans-shipment:

- The cost for the last mile can be cut if there are sufficient economies of scale. A high concentration of delivery points in which different carriers make many small deliveries is a situation where large economies of scale can be achieved by using a consolidation centre, which is likely to be profitable. Further potential for an increase in deliveries adds to the chances of success. The case study on the Gothenburg shopping centre illustrates this (Section 6.6).
- Increasing the engagement and motivation of all stakeholders may also help to find solutions to cover the extra costs. Establishing close links between the stakeholders in all parts of the logistics chain increases the likelihood of their engagement and their collaboration in the project. One way is to be able to charge for (part of) the extra trans-shipment by creating added value for clients, receivers in the first instance, but also senders/operators. This added value can be in the form of improved return logistics, inventory control, changes in delivery frequencies to meet receiver's needs or an attractive fee charged to the senders for transporting the last mile. One of the few successful examples of a larger UCC in Europe, 'Binnenstadservice', succeeded in providing and selling added value to its clients (Box 6.1).
- The socio-economic framework can be changed so that it takes better account of societal costs and value creation (authorities):
  - Public authorities can provide a subsidy to encourage the use of the UCC, based on the reduction in external costs of delivering goods in cities. It is, however, more logical to internalise external costs and to let carriers pay for the external costs they cause.
  - Public authorities can levy a fee on transport that does not use the UCC. This is done, for example, in Lucca in Italy.

- Congestion charges or road user charges can be used: these are fees/charges to access a specific area, usually a city centre. A number of cities have introduced this fee, typically for relieving congestion and traffic. These can incentivise using UCCs, as using a UCC will enable carriers to write off the congestion charge on a larger amount of goods.

- Time-based access restrictions/time windows can be used, which set out periods of the day during which delivery vehicles are not allowed to enter certain areas of a city. Time windows are a policy that is commonly applied by local authorities in order to better organise urban traffic flows by banning freight vehicles during specific hours. Off-peak deliveries are an example of this.

- Access rules can be put in place. Many authorities have introduced urban traffic regulations on the type of vehicles that can enter certain areas. Regulation is based on characteristics (such as weight, load factor, height or emission standard). Low-emission zones, limited traffic zones and restricted driving zones are all examples of access rules.

6.3.4 E-commerce

When e-commerce was starting up, it was often assumed that it would reduce the environmental and mobility impact of freight transport by combining various individual purchases into a single round trip by a van. There is no clear-cut view yet on the environmental impact of e-commerce; however, the reality could well be different from this initial assumption. According to van Loon et al. (2014), e-commerce has three different environmental effects:

- Impacts of the information and communications technology equipment used for ordering and processing orders: there are negative environmental impacts from the production, the use (energy) and the disposal of this equipment.

- Impacts on the supply chain: the replacement of energy-intensive shops by warehouses and delivery by van can reduce carbon intensity if the drop density (i.e. the number of delivery addresses in a specific area) is high enough. Choices for the fastest and most convenient delivery option contribute, however, to the fragmentation of parcel flows, thus causing urban challenges and increasing the environmental burden.

- The degree to which physical shopping is substituted with online shopping: this seems to be overestimated. Before ordering something on the internet, people often go to shops to see different options in real life, to ask for information, etc. Taking into account these complementary shopping and browsing trips, only few trips are avoided. Furthermore, online shopping does not necessarily replace complete physical shopping trips, as physical shopping trips are often combined trips (trip chains). Products bought on the internet would have been bought during a normal shopping trip to a store or in a store close to the normal 'shopping route'.

Another element not mentioned by van Loon et al. (2014) is that online shopping can also lead to extra shopping. This means that without the possibility of online shopping, no purchase would have taken place. In his 'business of fashion blog' Jiang (2016) summarises it as follows:

> Scarce literature points to the fact that normally a pure digital customer with the same consumption pattern as a pure offline customer reduces its environmental impacts. However, pure digital customers are nearly inexistent. Customers often go to brick and mortar shops to check and test objects, they go to shops just for fun and entertainment, they also send objects bought online back, customers often choose for the fastest delivery possible which reduces the possibility for the sender the optimise the sending.

Kalevi Dieke et al. (2019) point to a particular regulatory issue that adds to the fragmentation of e-commerce and as a consequence its negative burden. An ever-increasing part of e-commerce concerns international trade, with an important share coming from China. At present no value added tax is payable on low-value parcels imported by post. Legislation will change in 2021 and abolish this 'de minimis' rule. After that it is expected that fewer individual parcels will be sent by post, and that European distribution centres will be created. These will be supplied by containers from China under normal customs procedures, and fewer parcels are expected to be exchanged under the Universal Postal Union system with its terminal dues that are currently below local delivery costs. At present, with relatively low terminal dues for air importation, a major part of this e-commerce is shipped by air freight which has a considerable negative environmental impact. Apart from the environmental burden from air freight transport, there is also the burden of land transport, especially in cities and towns, where, for example, air pollution and traffic noise affects proportionally most people.

Kalevi Dieke et al. (2019) also include in their analysis observations from the labour market. Growing business means more jobs, although the quality of these jobs can be at stake. They mention among other issues that not all delivery workforces are covered by collective labour agreements, that subcontractor payments are often oriented towards minimum wages and that there are indications of precarious working conditions in some Member States.

Strategies to relieve the environmental burden of e-commerce are similar to the general freight F/L/O mile options:

- a modal shift towards environmentally friendly delivery modes such as cargo bikes in combination with micro-hubs;
- increasing delivery efficiency with particular software and planning procedures;
- avoiding misloads and improving compliance with (extended) delivery times, given that the second delivery attempt can increase emissions by 9 to 75 %;
- eco-driving courses for delivery drivers.

6.4 Case study 1: BiTiBi (bike-train-bike)

6.4.1 The BiTiBi logic: combining the most energy-efficient modes into a mode that can compete with a car

BiTiBi stands for a seamless bike-train-bike combination for moving from A to B. BiTiBi combines the most energy-efficient transport modes with the bicycle; the latter is ideal for short distances and the train for longer distances. The combination of both modes is a win for each of the separate modes. In that way, the competitive positions of the bicycle and the train are improved compared with the car. The BiTiBi project is therefore also a good illustration of what is meant by F/L/O mile options. This project was sponsored by the European Commission within the framework of the STEER programme, today integrated in the Horizon 2020 programme.

The project first looked at the successful implementation of the BiTiBi model in the Netherlands and then replicated it in other regions and cities.

6.4.2 How to build a seamless intermodal transport service — the BiTiBi building blocks

Convenience and seamlessness are crucial to making an intermodal transport journey (or a journey with a transfer) attractive. To get a good bike-train-bike service, the project focussed on the barriers to using the service that potential users (could) experience. A real user perspective was therefore adopted. A user perspective means looking at how to make a journey from origin to destination and not from station to station or public transport stop to public transport stop. Table 6.1 illustrates the main barriers to setting up such a service and the solutions to cope with them, also called the BiTiBi building blocks. Some seem rather obvious, but reality shows that these barriers are not always effectively dealt with.

Four of those building blocks, safe bicycle parking (first mile), shared bicycle (last mile), integration of services, and integration of payment are inherent factors of the service. However, further explanation of the shared bicycles is in order. The system that is linked to railways is slightly different from the more widely spread urban bicycle sharing systems. Shared bicycles are rented for 24 hours and must be brought back to the station from where they were taken (round-trip station-based system). This significantly reduces the costs for the operator. It allows the Dutch railways to run the service at a break-even cost, which is impossible for the other urban bicycle systems, whose bicycles are for occasional use. For daily use, one's own bicycle at the railway station is a more rational option.

The availability of an attractive bicycle infrastructure could also be considered as an inherent factor of a BiTiBi service. It is even a very important factor. However, the railway transport operator has only limited power and influence on the presence or building of attractive cycling infrastructure.

The basic features of an attractive bicycle infrastructure are safety and directness. Also, the comfort of the cycle route will help people to use bicycles. This will, however, not be of any value if the need for safety is not fulfilled. Of course, there can be nuances of the importance of these criteria depending on target groups and motives (Mann, 2013).

6.4.3 Impacts of a BiTiBi service

The project was able to provide estimates on the impacts of bicycle parking and last mile bicycle sharing.

Table 6.1 Overview of barriers and solutions for a seamless bike-train-bike service

Barriers for a seamless bike-train-bike service	Solutions for a seamless bike-train-bike service
Lack of safe and bicycle friendly railway access (first mile and last mile)	Bicycle routes to train station provided with the involvement of local authorities
Lack of secure bicycle parking (first mile)	Secure sheltered bicycle parking for rail users' bicycles
No way of reaching a destination that is further than walking distance — lack of shared bicycle systems (last mile)	Provision of a specific type of shared bicycle where tariffs allow the bicycle to be kept for 24 hours without a financial penalty. This allows the user to go to the final destination and come back to the railway station with the same bicycle
Bicycle parking and or shared bicycles are hidden somewhere, or information is not available from railway employees, etc. — lack of coherence between bike and train services	Bicycle and train organisation are well integrated. Bicycle parking and shared bicycles are clearly signposted, all kinds of information is available at the railway office, etc.
Different tariff and payment systems are used for bicycle and train services	One integrated tariff and payment system, for example one card or app enables the payment of all services via one invoice
Users do not know the service	Creative ways to communicate about the service. Creation of partnerships with cities and towns in order to make them ambassadors of the service, creation of small local events with local press coverage, etc.
Lack of attractiveness of the service — cultural barrier	Play to the emotions of potential users. Do not use too many rational arguments about the environment, but appeal to notions like fast, easy and cool.

Source: Based on Van Zeebroeck et al. (2017).

Bicycle parking at railway stations

Around 10 % of users of bicycle parking at railway stations were previously car users for the whole distance. A further 15 to 20 % stopped driving to the railway station (Cabré et al, 2016; Goria, 2016). The investment in bicycle parking is relatively cheap as long as the land value is not too high.

An example of the Belgian BiTiBi pilot, the railway station in Ghent, makes the potential impacts clearer. If for that station nearly 10 000 daily BiTiBi users are assumed, 60 000 car-km are avoided daily. This figure is based on the assumptions that 10 % of bicycle parking users would have used the car for the whole journey and 20 % would have used the car to reach the station. To reach an annual estimate, the following assumptions were made: an average car distance of respectively 50 km (whole trip) and 5 km (trip to railway station), 4 days/week, 45 weeks/year. This leads to nearly 11 million car-km and 1 620 tonnes of CO_2 emissions avoided, assuming 150 g CO_2/km.

Last mile shared bicycle at railway station

In the Belgian BiTiBi pilot for Ghent, 22 % of shared bicycle users at railway stations would have used the car for the whole (intercity) trip and another 7 % would have been picked up by car. If one assumes 50 nearly daily BiTiBi users, the avoided kilometres will be approximately 100 000 car-km/year, leading to a reduction of 15 tonnes of CO_2/year.

The comparison of the impact of the shared bicycle and the bicycle parking in Ghent is interesting. It illustrates very well the much larger impact of bicycle parking compared with shared bicycles, although bicycle sharing is very popular among politicians. Furthermore, the operation of a shared bicycle service is more expensive than the operation of a bicycle parking facility.

An EU-wide roll out of the BiTiBi approach for 2030

The project also calculated the possible impact of the implementation of the BiTiBi approach all over Europe. It was assumed that 20 % of railway users would ride a bicycle to the railway station in 2030. This is less than half of the actual Dutch share but five times more than the estimated 4 % for all EU railway users. This implies that:

- There will be 250 million more railway users in the EU.
- There will be a reduction of 800 kilotonnes of CO_2, 55 tonnes of particulate matter and 250 tonnes of nitrogen oxides emitted.
- There will be a reduction in energy use of 200 000 tonnes of oil equivalent or 2 500 MWh.
- 1 200 premature deaths will be avoided each year because of the increase in physical activity. This is equivalent to EUR 3 billion in savings in health

expenses when a train passenger rides to the station at least three times a week (according to the WHO's HEAT tool).

- There will be a 400 % social rate of return on investments in bicycle parking (not taking into account the opportunity cost of land). This means that for each EUR 1 invested in bicycle parking, EUR 4 of societal benefits are generated. This ratio does not take into account the opportunity cost of the land use. Very often, bicycle parking space could be used for other commercial objectives. These will often generate a higher purely financial return than bicycle parking, albeit not a societal return (BiTiBi, 2017).

6.5 Case study 2: Deutsche Post DHL StreetScooter

Deutsche Post DHL uses electric vans to deliver parcels and mail in towns and small cities. These electric vehicles have an advantage over their diesel counterparts from an environmental point of view and are also more convenient to use. Today, nearly 10 000 electric vans are used for mail and parcel delivery in Germany.

The unique feature of the electric vans is that they are the result of an innovation outside the traditional vehicle industry through a collaboration between Aachen University and Deutsche Post DHL, with specific attention being paid to the needs of the company.

The StreetScooter e-vehicles were developed for use by the postal services and were co-conceived and tested by employees of the postal services. The vehicles' battery range is limited to 80 km, the maximum speed is 85 km/hour, the battery output is 48 kW and its electric traction is ideal for frequent start-stop traffic. Each vehicle makes 300 stops every day, 300 days a year.

The Deutsche Post DHL workforce's satisfaction with these vehicles is generally better than their satisfaction with diesel vehicles. Deutsche Post DHL as a company also seems to be very satisfied. It has gradually increased its fleet to 9 000 StreetScooters and this is expected to increase further. The vehicles are sustainable from a business perspective. Gero Kahlen from Deutsche Post DHL states:

> We can confirm that StreetScooter offers significant cost savings compared to an internal combustion engine powered vehicle in the short and particularly the long-run. Such lower costs generally apply to repair and maintenance costs, energy costs as well as insurance and vehicle tax. However, the exact savings depend very much on the specific use case, location of deployment and fleet cost structure (e.g. agreed electricity costs). It is safe to assume that on aggregate such savings amount to at least some hundred euros per year but can also be as high as more than 2 000 euros per year (Kahlen, 2019).

The 9 000 StreetScooters replace 9 000 diesel vans. According to the company, each vehicle saves between 3 and 4 tonnes of CO_2 and between 1 100 and 1 500 litres of diesel per year, depending on the vehicle type. Direct CO_2 savings amount to 32 000 tonnes/year. As regards the emissions from power generation, these fall under the EU Emissions Trading System, which sets a cap on CO_2 emissions in the sectors covered by it (i.e. higher emissions from power generation must be compensated for by lower emissions elsewhere), a cap which is reduced gradually over time.

The main success factors for the development of the StreetScooters were:

- the presence of the innovation cluster at, and the innovation expertise of, Aachen University, which focused on the technique of production rather than on the innovation of the engine;
- the innovative idea of a low-cost, low-emission and highly ergonomic vehicle;
- higher management's active participation in developing and financing the concept;
- the funding by the German Environmental Ministry to further develop and test the vehicles between early 2016 and the end of 2019.

Note: this case study is based on the following sources: Kommission 'Wachstum, Strukturwandel und Beschäftigung' (2019), Clausen (2017), Moro and Lonza (2018), and Kahlen (2019).

6.6 Case study 3: Gothenburg consolidation centre

6.6.1 Description of the objective

Gothenburg has a population of approximately 530 000. As a result of its rapid growth and the impact of that on demand, the city has a long tradition of implementing various measures in the field of city logistics. It also has a large amount of infrastructure and a large number of building projects and is intent on creating an attractive, clean and safe city centre, where pedestrians and cyclists are separated from motorised transport.

Within the framework of the EU Novelog project, Gothenburg is setting up a consolidation service for deliveries to the Nordstan shopping centre (located in the centre of Gothenburg). The main aim of the service is the consolidation of small shipments. Small shipments generate the most traffic in relation to the volume of total goods. The service will be launched in autumn 2019. All the preparatory work has been done.

6.6.2 Process of installation

The project started with verifying the viability of the project in 2016-2017. Delivery data of all shops in the shopping centre were analysed. Making all shop and office tenants provide data was very challenging. Tenants registered their deliveries and shipments for a 2-week period (a total of three data collection periods was required to gather data from a sufficiently large share of the tenants). Both experts from the project management in Gothenburg and the University of Gothenburg studied the potential for a last mile shuttle, based on the data collected. The analysis made clear that smaller shipments make up a large part of the total number of shipments, which confirmed the usefulness of a consolidation centre. Consolidation centres are of most interest when many small deliveries are concentrated in a small area.

The UCC will start in autumn 2019 on a small scale, with about 50 out of 200 businesses in the shopping centre participating. The last mile delivery of goods to those businesses will be replaced by a shuttle between the UCC and the shopping centre. The shuttle will initially make one or two delivery trips per day, while each shop will get only one delivery each per day, which reduces the delivery burden to the shops. A procurement procedure was held to decide on the operator of the service. A small local haulier won the contract.

6.6.3 Expected impacts

The expected impacts of the project are positive. With the project fully implemented, CO_2 emissions are expected to be reduced by 50 %, traffic throughput (last mile kilometres) will decrease by 97 % for the consolidated goods volumes, and fewer vehicles will enter the shopping centre (300 compared with 600), which means that the consolidation centre is well situated. The service is, furthermore, expected to avoid 140 000 km, based on rough estimates. That is around 50 % of the total kilometres driven to deliver goods to the Nordstan shopping centre today.

For the first phase starting in autumn 2019, the impacts are expected to be at most half of those described above. Only half of the potentially participating shops will take part in this first phase.

6.6.4 Sustainability from a business perspective

The sustainability of the project from a business perspective is challenging. In this pilot project, the extra cost is paid by the shopping centre owners, not the shop tenants. It is a relatively small amount compared with the total overhead cost of the shopping centre. The shuttles are paid on a per hour basis (around EUR 60/hour), while the consolidation centre/warehouse that is used by the operator costs around EUR 40/day.

Setting up such a service brings the benefits of a better image and creates goodwill for the shopping centre.

6.6.5 Key success factors

- The good collaboration of the different stakeholders, especially the municipality, the real estate owners and the logistics players was important for the project to go ahead. Getting all the relevant stakeholders on board was the result of good 'selling' of the project. There is often an extra cost for these kinds of services. It is therefore crucial to sell the project in the right way and make people enthusiastic about it. For this project, the shopping centre owner was interested, as well as some of the shopkeepers. It was sufficient that only some shopkeepers participated.

- EU funding in the framework of the Novelog project was an important factor. Without that funding, the city or another stakeholder would have had to take the initiative to study the feasibility of such a service.

6.6.6 Most important barrier

The most important barrier was clearly the cost element. Last mile logistics using a consolidation centre nearly always incur an extra cost. This was not different for this service. The challenge was to see how the cost might be accepted.

6.6.7 Potential for further extension of the service

The city of Gothenburg intends to support the set-up of other consolidation centres. However, the operation of the services will not be financially supported by the city. In the past, the city has already supported two other last mile logistics services that are operational in Gothenburg but that are based on different business models. One service operates in the inner city. Freight forwarders subcontract small hauliers to take care of the deliveries in the inner city. Another service operates on the university campus, combining parcel delivery and waste collection. The variation in business models illustrates the importance of being creative in setting up last mile logistics services.

This case study is based on Widegren (2019).

7 Lessons learnt: leveraging first/last/only mile options for systemic change

This chapter summarises the main lessons learnt in order to leverage first/last/only mile (F/L/O mile) options to achieve systemic change. The first section focuses on passenger transport, and freight transport is the topic of the second section.

7.1 Passenger transport

7.1.1 Make explicit the impacts of mobility choices and provide alternatives

Confront transport users with the costs created by their mobility choices

Today our urban mobility system is struggling with congestion, excessive emissions of air pollutants and greenhouse gases, too-high noise levels, habitat fragmentation and problems with the quality of the living environment in some areas. The most effective way to cope with these challenges is to confront the transport users with the costs that they incur for society that are not yet reflected in their personal costs. This means internalising the external costs of each transport mode. Internalising external costs helps users to realise the societal cost of their mobility behaviour. In that way they can make a more balanced choice between mobility alternatives. Estimates for the external costs of emissions, accidents, congestion, noise and habitat fragmentation are available (DG MOVE, 2019). For other external costs, such as the impacts on the quality of the living environment, quantified estimates are unfortunately more difficult to obtain. Measures such as reducing street parking spaces, increasing parking tariffs, road charging, or more generally 'getting the price right' can help to reduce the societal burden of the mobility system and to internalise part of the external costs. These are the very first steps towards a sustainable mobility system.

Provide sufficient and comfortable alternatives

Sustainable urban mobility also means providing sufficient and comfortable alternatives if the use of unsustainable modes needs to be reduced. It is therefore important that sustainable alternatives are available. Public transport with good F/L/O mile options can provide such attractive sustainable alternatives. It is however important to realise that only providing alternatives is not necessarily effective in reaching a more sustainable mobility system. The generalised costs of unsustainable (often the car) and sustainable modes (often public transport) are often similar. When making the sustainable mode (often public transport) more attractive under these circumstances, by providing F/L/O mile options, for example, the likelihood that a modal shift will take place is high. Increasing the generalised cost of the unsustainable alternatives will also contribute to a shift towards a more sustainable mobility system.

The generalised cost is composed of the monetised journey time costs and the financial costs. For public transport the financial costs are, most of the time, not the part that makes it uncompetitive compared with the car. The time costs are often more important. The perceived time costs are higher for unpleasant parts of the journey such as transfers, delays and the need to hurry to make a transfer. These incur an extra penalty when determining the generalised cost.

F/L/O mile options can play an important role in reducing the most unpleasant part of the journey. 'Good' F/L/O mile options try to make the whole transport chain as seamless, fast and comfortable as possible. This means avoiding, as much as possible, delays, waiting time and transfers, or if they cannot be avoided, making them as comfortable as possible and providing real-time, integrated and accurate travel information.

7.1.2 Promote active modes as first/last/only mile options

As stated above, F/L/O mile options make public transport more attractive and contribute to a modal shift. From a societal point of view, active modes are very attractive F/L/O mile options:

- Active modes provide considerable health benefits for their users, thanks to the physical activity that they provide. Active modes are the only modes with (nearly) no external costs and with substantial external benefits. Each kilometre walked or cycled provides benefits to society. As a consequence, the promotion of active modes is a no regret option.

- Cycling can also be successfully introduced into cities that do not already have a cycling culture. Political will is however necessary. The city of Seville succeeded in increasing the modal share of cycling from 1 to 9 % in 5 years. The key to this success was a massive investment in cycling infrastructure and a reduction in road space for cars. Other factors such as the relative price increase of car use due to the 2008 financial crisis could also have played a role (Marqués, et al., 2014). This case illustrates that measures that make cities and streets more attractive places also enable F/L/O mile options.

7.1.3 Align technology with sustainable mobility goals

Thanks to technology, many new mobility solutions are available. Technology enables various types of sharing systems: sharing of cars, bicycles, electric kick scooters, etc., and free-floating systems, station-based systems, etc. It also enables the creation of apps and platforms that can better integrate different mobility services into a more convenient service, and/or provide ride hailing services. This creates several opportunities for a more sustainable mobility system.

A positive mobility impact is, however, not guaranteed, as was illustrated in Section 6.2. The key findings were:

- The effectiveness of new shared modes in making the mobility system more sustainable is variable. Based on current studies, the best performing sharing systems from a sustainability point of view are station-based systems. Station-based car sharing reduces vehicle-km by 18 to 80 % for current users (who, however, do not necessarily have the same profile as the general public). Bicycle sharing systems realise a shift away from car use for between 5 and 20 % of the rides. Most users of bicycle sharing systems use the shared bicycle instead of public transport. This may, however, relieve some capacity for public transport.

- Ride hailing services appear to have a negative impact on the urban mobility system. Several studies indicate that a majority of ride hailing trips replace a public transport trip. These studies also indicate that vehicle-km increase by 50 % in certain parts of the city, which contributes to congestion. In San Francisco, 25 % of congestion can be attributed to ride hailing.

- A good public transport network that offers trustworthy services with limited delays, a minimum number of transfers, comfortable transfers, and easy and integrated payment possibilities needs to be the priority. In addition, mobility-as-a-service can increase the positive user experience. It cannot, however, compensate for bad physical transport services or unpleasant transfers.

- Shared autonomous vehicles can improve the urban mobility system as long as there is a regulatory framework that seeks to maximise their environmental benefits. In the absence of an appropriate regulatory framework, simulations indicate that congestion could get worse, as these vehicles might replace public transport. Therefore, public policy should make sure that:

  – space that is freed up thanks to a reduced need for vehicles is proactively managed in order to lock in benefits;

  – the public transport system remains the backbone of the urban transport system.

7.2 Freight transport: create conditions to make last mile logistics profitable

7.2.1 An extra trans-shipment makes a sustainable business case for first/last/only mile options in freight transport challenging

Last mile logistics and the urban consolidation centres (UCCs) necessary to enable last mile logistics are an interesting option from an environmental and mobility perspective. They reduce environmental impacts by reducing the kilometres driven for urban logistics and in some cases by using environmentally friendly vehicles.

The number of UCCs in Europe is, however, low. The main reason is that the economic viability of these initiatives is very often challenging and not guaranteed. The UCCs that are operational today are exceptions that confirm the rule. The main reason for this challenging economic outcome is that a consolidation centre needs an extra transfer of goods (from vehicle to consolidation centre and from there to another vehicle). This costs time and money.

This makes it fundamentally different from F/L/O mile options in passenger transport. In passenger transport, F/L/O mile options improve, by definition, public transport services, whereas in the case of freight transport, they add a transfer and time to the initial journey. In other words, F/L/O mile options decrease the generalised cost of public transport services and usually increase the generalised cost of logistics services.

7.2.2 Policies and circumstances that favour economic sustainability of first/last/only mile options in freight transport

In spite of the societal advantages of F/L/O options and UCCs, economic logic makes it difficult to set up sustainable business cases. The challenge is always to find ways to cover the extra cost for the trans-shipment at the UCC or micro-hub. Certain circumstances or policies do, however, contribute to the economic sustainability of UCCs:

- A high concentration of delivery points in combination with many small deliveries made by different carriers. A profitable consolidation centre can emerge, especially if a further increase in deliveries is anticipated. The case study on Gothenburg's shopping centre illustrates this.

- A strong engagement of all the stakeholders and close cooperation between senders, receivers, carriers, logistics providers, etc., increases the likelihood of finding solutions to the challenges.

- Providing added value for the clients and making clients pay for it can make a UCC viable. This added value can consist, for example, of improved return logistics, inventory control, changes in delivery frequencies to meet receiver's needs or an attractive fee charged to the senders for transporting the last mile. One of the only larger successful examples of a UCC in Europe, 'Binnenstadservice', succeeded in providing and selling added value to its clients.

- Authorities can change the socio-economic framework so that it takes better account of societal costs and value creation. If external costs can be internalised, F/L/O mile freight options will become relatively cheap compared with classic delivery.

- It is difficult to internalise external costs completely and some of the most effective measures for doing so, such as taxation, are not usually controlled by cities. However, other measures can have a similar effect as long as they give a competitive advantage to environmentally friendly delivery vehicles and methods. These can take different forms, such as congestion charges, road user charges, time-based access restrictions and access rules. Alternatively, the provision of a subsidy may encourage the use of a UCC based on the reduction in external costs.

Abbreviations, symbols and units

3D	Three-dimensional
µm	Micrometre(s)
AV	Autonomous vehicle
B2C	Business-to-consumer
CO	Carbon monoxide
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
dB	Decibels
E-bike	Electric bike
E-cycling	Riding an electric bike
EEA	European Environment Agency
EMTA	European Metropolitan Transport Authorities
EQLS	European Quality of Life Survey
EU	European Union
F/L/O mile	First/last/only mile
g	Gram(s)
GDP	Gross domestic product
GHG	Greenhouse gas
ITS	Intelligent transport system
kg	Kilogram(s)
km	Kilometre(s)
L_{den}	Day-evening-night level
MaaS	Mobility-as-a-service
MWh	Megawatt hour

NH_3	Ammonia
MET	Metabolic equivalent task
NEC	National Emissions Ceiling
NMVOC	Non-methane volatile organic compound
NO_2	Nitrogen dioxide
NO_x	Nitrogen oxides
O_3	Ozone
$PM_{2.5}$	Particulate matter with a diameter of 2.5 μm or less
PM_{10}	Particulate matter with a diameter of 10 μm or less
SDG	Sustainable Development Goal
SO_x	Sulphur oxides
SUMP	Sustainable urban mobility plan
THE PEP	Transport, Health and Environment Pan-European Programme
UCC	Urban consolidation centre
UMP2013	Urban mobility package 2013
TNC	Transport network company
WHO	World Health Organization
WTW	Well-to-wheel

Glossary

Avoidance cost approach: an approach used to value external costs by determining the cost to achieve a particular policy target (DG MOVE, 2019).

Damage cost approach: an approach to valuing external costs that values all damage experienced by individuals because of the existence of an externality. When market prices are unavailable for the damage experienced, as is often the case, the willingness to pay of individuals to (partly) avoid the damage or the willingness to accept the damage is used as an indicator of individual preferences (DG MOVE, 2019).

Electric bike: also known as e-bike is a bicycle with an electric propulsion motor powered by a battery. Contrary to an electric motorcycle or electric scooter, an e-bike can be pedalled. The electric component is meant to augment human power.

Electric kick scooter: vehicle with a platform called a deck, a handlebar for steering and usually two small wheels propelled by an electric motor. Electric kick scooter are intended to be ridden while standing on the deck. They are now widely used as part of dockless sharing systems.

Electric motorcycle/scooter: usually two-wheeled electric vehicle with one or more seats and an electric propulsion motor powered by a battery. Contrary to an electric bike, an electric motorcycle or scooter is exclusively propelled by the motor. Electric scooters are distinguished from electric motorcycles by their step-through frame.

External cost: external costs, also known as externalities, arise when the social or economic activities of a person or a group of people has an impact on another person or group of people and when that impact is not fully accounted for, or compensated for, by the first person or group of people. In other words, the external costs of transport are generally not borne by the transport user and hence not taken into account when they make a transport decision (DG MOVE, 2019).

Generalised cost: the combined monetary and non-monetary costs of a journey. Monetary costs typically include the fare for using public transport, or the cost for fuel, parking, vehicle maintenance etc. of a car journey. Non-monetary costs refer to the time spent undertaking the journey, which is converted into a money value. Transfers, delays and the need to hurry to make a transfer are also taken into account when determining the generalised cost. This provides an idea of the competitive position of different modes and thus the potential of a modal shift.

MaaS: mobility-as-a-service brings all transport options together in a convenient way. In that way, consumers can, via a one-stop shop, have access to the transport option that fits them best. To realise MaaS, a mobility broker or integrator is added to the mobility system.

Metabolic equivalent task: a way of describing the energy expended by a person for a physical activity by expressing it as a multiple of the equivalent energy expended when sitting quietly.

Park and ride: a system in which people drive to a place where they can leave their car and get on a bus or train to complete their journey.

Passenger-km: a unit of measurement representing one passenger travelling a distance of one kilometre.

Tank-to-wheel emissions: includes emissions from the combustion of fuel in a vehicle.

Tonne-km: a unit of measurement representing the movement of one tonne over a distance of one kilometre.

Transport network company: a company that matches passengers with vehicles through an online-enabled platform (e.g. mobile app). TNCs for cars are often referred to as ride hailing services. Well-known examples are Grab, Lyft and Uber.

Vehicle-km: a unit of measurement representing the movement of a vehicle over a distance of one kilometre.

Well-to-tank emissions: includes emissions and impacts up to and including delivery of a fuel (e.g. electricity or petrol) to a vehicle. This includes resource extraction and fuel production.

Well-to-wheel emissions: a type of assessment for vehicles that focuses on the energy carrier used to drive the vehicle, e.g. electricity. This can be subdivided into categories such as well-to-tank and tank-to-wheel.

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