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ShareDiMobiHub

In Search for Insights for Policymakers: The Impact of Shared Mobility Amid the Transition to e-Mobility in the Netherlands

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Summary sheet

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Management summary

Shared mobility has evolved significantly over the past decades, developing from a novel rare *ad hoc* local initiative to a specific branch in the mobility ecosystem. Meanwhile it is becoming a crucial part of the urban mobility market. Carsharing, along with other forms of shared mobility, is reducing the reliance on private car ownership and contributes to more sustainable urban environments. Hence, it is an attractive option for both policymakers and researchers to explore in-depth. With an increasing number of articles and reports presented in the literature – often differing in study set-up and mixed study results - the policymaker faces the difficulty to get an overview (the full-picture) of the actual body-of-knowledge and to develop effective strategies.

This market development of shared mobility coincides with the electrification of almost every type of road vehicle: from e-cars to e-micro mobility. The shift towards electrification in road vehicles is a significant development in reducing greenhouse gas (GHG) emissions. Together with vehicle sharing this may make a difference regarding the future quality of the global and local environment.

The objective of this report is to derive reference values from the literature. The report aims to provide policymakers a benchmark and a starting point from which they can undertake their own analysis and enable to support the development of effective future policymaking strategies. The focus in this document will be on the impact of shared cars and shared bikes into the direction of

- traffic intensity
- space utilization / occupation
- environmental impact
- additional mobility opportunities and benefits for the society.

Additionally, the impact of transitioning shared car mobility from petrol-powered vehicles to electric alternatives will also be considered.

Chapter 1 provides a brief historical overview and the development of the car and bikesharing market over time.

Chapter 2 delves into the car replacement ratio, offering practical estimates of the potential environmental impact of shared cars. This includes reductions in parking space requirements and changes in emission levels.

Chapter 3 focuses on bikesharing. Despite being used for short trips, bikesharing impacts the environment by affecting the mobility mix for origin-destination trips. Special attention is given to e-bikes and cargo bikes.

The final chapter reflects on shared mobility developments based on the findings of this report.

The appendices provide tables summarizing the most relevant estimates from current literature and open sources on the impacts of car and bikesharing.

This report is accompanied by an interactive Microsoft Excel tool that enables readers to explore the impact of shared mobility. In addition to basic scenario analysis, the tool provides decision-makers with the necessary information in a more accessible and user-friendly format. A tool manual is also available in an accompanying document.

The tool offers users reference values and the flexibility to integrate future studies into the analysis. Based on the car replacement ratio, it provides insights into the impact of carsharing on traffic intensity, public space usage for parking, and vehicle emissions, including changes associated with the transition to electric vehicle (EV) mobility. For Dutch policy makers, the tool also allows for the consideration of neighbourhood-level differences, enabling more tailored analyses. Additionally, the tool provides also quick overview of Dutch parking norms for various housing types, includes links to online calculators that assess the economic viability of carsharing, and offers a comparison of emissions between internal combustion engine vehicles and their electric counterparts. This makes it a practical resource for evaluating different mobility scenarios and supporting evidence-based decision-making.

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1. The Evolution of Car and Bikesharing: Historical Roots and Contemporary Trends

1.1 A Brief Introduction into the Car and Bikesharing Idea

In the Netherlands, the concept of vehicle sharing is not new. An early example is the Wittefietsenplan (White Bikes Plan) from the mid-1960s. In 1965, this bikesharing system was introduced in Amsterdam, offering free white bikes for public use to address the widespread issue of bike theft (O'Sullivan, 2022; Wikipedia, 2024a). Later, the idea of a small electric tricycle, the two-seater Witkar (see Figure 1), emerged (Nijland & van Meerkerk, 2017; Wikipedia, 2024b). However, none of the initiatives initially received support from the city council.

Figure 1: Figure 1: Witkars on the hub Amstelveld in Amsterdam in 1974. Source: Historiek (n.d.)

In 2000, a renewed bikesharing initiative gained backing from local government and a bank. Despite this support, technical problems led to the pilot's abandonment after several months. Over time, the concept evolved into the OV-fiets system (Mbugua et al., 2025). The OV-fiets started in 2003 and is a nationwide bikesharing program in the Netherlands. It allows users to rent bikes at train stations and other locations for convenient, last-mile transportation and is growing steadily (see Figure 2).

Figure 2: OV-fiets near metro station in Rotterdam. Source: De Ster (n.d).

In Germany and Switzerland, the first viable carsharing initiatives emerged in the 1980s, driven by environmentally conscious groups (e.g., Münzel et al., 2020; Shaheen, Sperling & Wagner, 1998; Truffer, 2003). These early schemes were organized in a business-to-consumer (B2C) format, typically operated by either for-profit or non-profit entities that owned and managed a fleet of vehicles. Notable examples include Stadtmobil in Germany and the Mobility Cooperative in Switzerland, both of which played pioneering roles in establishing structured car-sharing systems that remain influential today.

In Northern European countries, car- and bike-sharing programmes first appeared in the 1990s as modest, community-led initiatives aimed at sustainability. Since then, shared mobility has become a cornerstone of Nordic sustainability strategies, marrying innovation with environmental responsibility (e.g., EA Energianalyse, 2021; SimpleTransit, n.d.).

Also in the Southern part of Europe equivalent initiatives emerged (e.g., Beria et al., 2017; Ortega Hortelano et al, 2022). Italy was one of the first Southern European countries to experiment with carsharing, with Milan and Rome launching early programs in the late 1990s and early 2000s. The initial services were often cooperative or municipal initiatives, such as Car Sharing Italia (founded in 2001). Spain introduced carsharing in the mid-2000s, with Barcelona and Madrid leading the way. Avancar (2004) and Respiro (2009) were among the pioneers. In Portugal the city of Lisbon experimented with carsharing models in the late 2000s, often in collaboration with European mobility projects. These initiatives were part of broader efforts to reduce emissions and promote multi-modal transport. France, particularly southern cities like Lyon and Marseille, saw early adoption, influenced by successful models in Paris and other Northern European cities.

Early carsharing models were cooperative, station-based schemes, often supported by municipalities to alleviate urban congestion. Over time, these initiatives evolved into flexible, app-driven services that encompass peer-to-peer rentals and electric vehicle (EV) fleets, contributing meaningfully to regional carbon neutrality targets (Lebel & Lindberg, 2022; Nansubuga & Kowalkowski, 2021).

Public bike-sharing emerged in cities such as Copenhagen (in 1995) and Helsinki (in 2000), who introduced docked bike-sharing systems to encourage active transport and curb car dependence. These early networks were tightly integrated with public-transport timetables and fare structures and laid the groundwork for more modern docked bikesharing programs like in Paris (2007) and New York (2013) that used digital tracking, memberships and mobile apps.

More recently, bike-sharing has shifted toward dockless and e-bike formats, leveraging smart technologies, e.g. GPS, IoT-enabled locks, and real-time data platforms (Laine et al., 2018; SimpleTransit, n.d.). Municipalities are investing heavily in cycling infrastructure, adding protected lanes, intelligent parking stations, and multimodal hubs. These hubs are transportation nodes where multiple modes of transport - such as trains, buses, bicycles, trams, taxis, and even shared mobility service - are integrated to facilitate seamless travel for passengers. The focus now extends beyond daily commuting to tourism and cross-border cycling, reinforced by policies such as the "Right to Roam" to promote and regulate visiting nature (Berg & Hedenström, 2020; Johansson & Nilsson, 2018).

1.2 Modern Market Developments: The Carsharing Market

Carsharing is a flexible system that allows individuals to access locally available cars at any time and for any duration (Arias Molinares et al., 2024; Frenken, 2015). Unlike traditional car rentals and taxis, carsharing services provide user-operated vehicles that can be accessed more spontaneously and flexibly. The concept began gaining traction in Europe in the late 1980s, especially in Switzerland and Germany, through small, environmentally motivated initiatives (Shaheen et al., 1998; Truffer, 2003). Early carsharing models followed a business-to-consumer (B2C) roundtrip format, where organizations owned fleets and users returned cars to the same location. Later, one-way and free-floating models emerged, allowing users to drop off cars at different locations, increasing convenience (Shaheen et al., 2012). Around 2010, peer-to-peer (P2P) platforms were introduced, enabling private car owners to rent out their vehicles to others. P2P carsharing operates only in a round-trip format and is more geographically flexible but less frequently used than B2C models. Our report focuses on the B2C market. Smartphone technology has enhanced usability, especially for locating and unlocking vehicles. Carsharing has evolved into a diverse ecosystem with varying operational and economic models.

Notably, the carsharing market is estimated to be worth $4-6 billion globally, while peer-to-peer (P2P) carsharing is valued at approximately $3-4 billion. ABN AMRO (2022) estimates that the European carsharing market was valued at approximately €4 billion in 2022 and is projected to grow by about 8% annually, reaching €6 billion by 2026. The number of users of shared cars is expected to increase from 1.8% in 2022 to 2.3% in 2026. Regarding the carsharing market in the European Union, Bucsky & Juhasz (2022) identified 129 carsharing services operating in 81 cities across 26 EU countries. At that time, Greece was the only country without a carsharing system (see Figure 3).

As Figure 3 indicates, the Netherlands already has a high rate of carsharing vehicles per 100.000 inhabitants. Approximately 64.000 shared cars were available at the end of 2021 (Jorritsma et al., 2021).

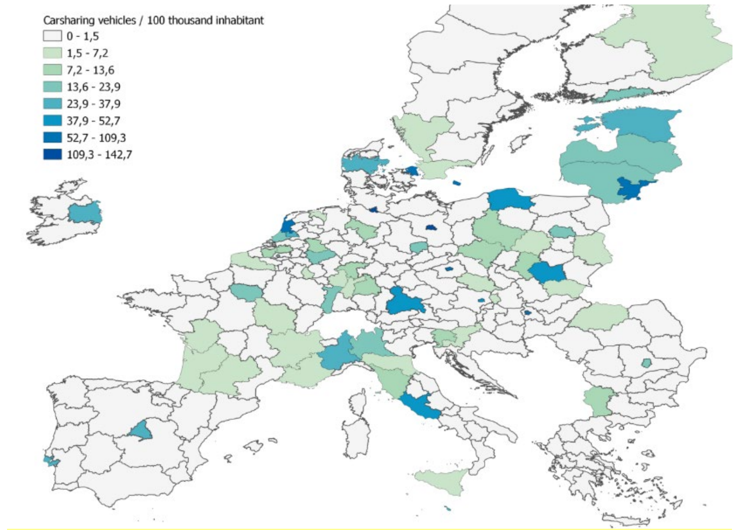

Figure 3: Carsharing penetration in NUTS2 regions of EU countries. Source: Bucsky & Juhasz (2022)

1.3 Modern Market Developments: the Bikesharing Market

According to the Netherlands Institute for Transport Policy Analysis (KiM), which operates under the Ministry of Infrastructure and Water Management, car travel in the Netherlands is expected to increase by approximately 6 to 12 percent by 2029, driven by economic growth and population expansion (KiM, 2024c). This rise will likely result in more traffic congestion and longer travel times (KiM, 2023a). Public transport is also anticipated to return to pre-COVID demand levels, raising concerns about whether the services can handle such growth. Shared mobility is likely to attract the interest of policymakers as a means to accommodate the ever-increasing demand for mobility and mitigate its negative side effects.

While cars are generally used for longer journeys, bicycles tend to serve local and “last-mile” trips, often in combination with public transport. According to Jorritsma et al. (2021), the Netherlands has roughly 27.500 shared bikes, the bulk of which are OV-fiets bikes, about 22.000 units stationed at 300 locations (Treinreiziger, 2025). These bikes are widely employed as a last-mile solution that complements rail and bus services, while free-floating bike-sharing schemes operate in many of the country’s larger cities.

In Belgium, for example, the Blue-Bike initiative strives to make cycling accessible to everyone by offering shared bicycles at more than 110 sites, primarily near train stations and other public-transport hubs (Blue-bike, n.d.). Through collaborations with local governments, transport operators, and private partners, Blue-Bike expands mobility options, curtails car dependence, and promotes healthy, eco-friendly “last-mile” travel. Also in less densely populated areas of the country (Departement Mobiliteit en Openbare Werken, 2024).

Another notable mode of transport is the e-moped (referred to as e-scooters in Dutch). As of 2022, there were approximately 12 500 shared e-mopeds (deelscooters) in operation across the Netherlands (Ministerie van Infrastructuur en Waterstaat, 2023). Similar to shared bicycles, these vehicles are predominantly found in urban areas. However, unlike the OV-fiets, e-mopeds typically operate as a free-floating mobility service, allowing users to pick up and drop off vehicles within a designated service area. To mitigate issues related to improper parking, some municipalities have introduced dedicated parking zones. A key challenge associated with free-floating systems is the logistical complexity and cost of vehicle redistribution, which can significantly impact operational efficiency (CROW, n.d.).

The city of Utrecht has recently expressed a preference for shared (e-)bikes over shared scooters ('deelscooters'), citing their more efficient use of space and easier parking. Beyond these logistical advantages, shared bikes also offer public health benefits. As noted by Kharaghani et al. (2023), bikesharing systems contribute to improved health outcomes by promoting higher levels of physical activity. With the growing availability and adoption of e-bikes, this mode of transport is poised to become a mainstream solution for sustainable urban mobility.

1.4 Objective of report

The markets for shared cars and bikes are the most prominent in terms of shared mobility in the Netherlands and Europe. In the following chapters, we will delve into the impact of car and bikesharing, using the existing body of literature as our starting point. Two main approaches can be employed to study this topic: qualitative and quantitative. To better understand the impact of shared mobility, we have developed a tool that measures its positive effects, drawing on both qualitative insights and quantitative data.

Through an extensive review of the literature and relevant open-source information, we aim to gather as many insights and estimates as possible regarding the impact of car and bikesharing on:

- Traffic intensity, assessed through changes in car ownership and kilometres travelled
- Space utilization, focusing on the occupation of public and urban space
- The environment with a special focus on CO_2, NO_x and PM pollutant emissions

Our objective is to present a comprehensive overview of relevant studies and their findings, with a focus on quantitative estimates. This synthesis aims to lay the groundwork for future qualitative and quantitative research. Additionally, we highlight the broader benefits of car and bikesharing, including their contributions to sustainability, urban efficiency and liveability, and public health.

The tool accompanying this paper is designed to enhance the accessibility of collected estimates and data, enabling policymakers to more easily navigate the extensive body of literature and online resources. It serves as a practical interface for exploring key findings and evidence related to mobility and emissions. A tool manual is available.

Further insights into the underlying principles and methodology of this tool can be found in *The Basics of the Micro Model for Calculating Emission Estimates of Modes of Mobility* in Appendix C.

2. The impacts of carsharing systems

Over time, various studies on shared mobility services have emerged, with most focusing on shared car and bike services. Comprehensive overviews of the merits and impacts of shared mobility services can be found in several literature reviews (e.g., Jorritsma et al., 2021; Reyes et al., 2020; Shaheen et al., 2019). We make use of the types of impacts identified and use study results as reference values.

2.1 Understanding the Car Replacement Ratio

Various studies indicate that the three forms of carsharing (as explained in 1.2) have different impacts on the car replacement ratio. According to Jorritsma et al. (2021), the ratio is higher among high-frequency

B2C roundtrip users, influenced by the availability of shared cars and the spatial context (such as parking policies, and the presence of public transport and bike facilities). The substitution effect may be significantly lower for free-floating and P2P shared cars (e.g., 6t, 2014; Loose & Nehrke, 2018; Martin & Shaheen, 2016; Nijland et al., 2015).

In the remainder of this paper, we will focus on the most common form of carsharing: the round trip. Table A1 in Appendix A gives an overview of estimates of the CRR found in literature. A wide range between the lowest and highest estimates can be identified (ranging from 1 to 16 cars being removed due to carsharing).

In the Netherlands, about a third of carsharing users either get rid of their car or avoid purchasing an additional one, often using a shared car to replace a second or third vehicle. The impact of carsharing on car ownership in the Netherlands varies with usage intensity; households using shared cars more than five times a year experience a significant reduction in car ownership, dropping to around 25-30%. Within the EU, one shared car can replace approximately 4 to 11 cars (Jorritsma et al., 2021). According to Jorritsma et al. (2021), this variation is due to differences in the spatial context (inner-city versus suburban or rural areas) and the study methods applied. CROW (2021) highlights the impact of the local quality of shared cars and alternatives such as public transport (PT) and bike services.

Estimates for free-floating and P2P carsharing found in literature are detailed in Appendix A, Tables A2 and A3 (ranging from 3 to 24 cars and 3 to 11 cars being replaced by one carsharing car respectively). A study by Witte & Kolkowski (2023) explores P2P carsharing from socio-demographic perspectives, offering valuable insights. The P2P carsharing market is substantial, comparable to the B2C shared car market in the Netherlands, but impact on car ownership needs to be studied more in detail in the future.

2.2 Calculating the Car Replacement Ratio

When seeking more accurate indications about the car replacement ratio, it is important to remember that the estimates are influenced by the context in which they are derived. The Rebel Group (2023) emphasizes that local developments may affect this ratio over time in specific city areas, for instance, due to changes in

- car dependency of the inhabitants
- the absence or availability of other mobility alternatives
- the parking situation
- socioeconomic factors
- policy measures.

Hence, city areas can differ significantly in mobility characteristics and are subject to changes over time. Therefore, the car replacement ratio should be considered a dynamic analysis model, calculated per area and iteratively over time. According to Rebel Group (2023), the car replacement ratio (CRR) can be estimated as shown in Figure 4. The basic CRR is the net change in car ownership per shared car user (number of cars sold and purchased per user, respectively, A_V, A_K) multiplied by the total number of shared car users (G_{DA}), which equals the net change in cars divided by the total number of shared cars (T_{DA}).

$$CRR = \frac{PrivatelyOwnedCarsdisplaced}{TotalnumberofSharedCars} = \frac{(A_v - A_k)G_{DA}}{T_{DA}}$$

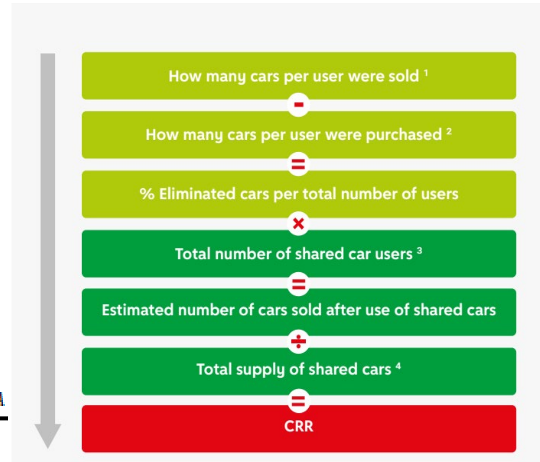

Figure 4: The car replacement ratio equation + visualisation. Source: Rebel Group (2023)

Policy measures influence the adoption curve (see Figure 5), providing policymakers with an indication of the growth potential and impact of introducing (or increasing) shared cars in an area (Rebel Group, 2023, p.5).

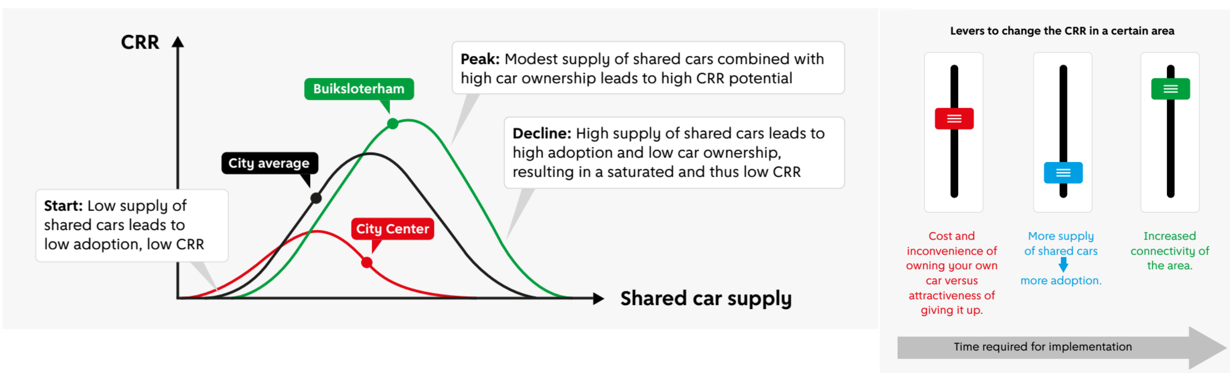

Figure 5: An example of the adoption curve for two areas, along with an estimated city average for Amsterdam, illustrates the policy levers that can influence the level of adoption. Source: Rebel Group (2023)

2.3 Insights into the Changes in Traffic Behaviour and Intensity due to Carsharing

The literature provides some indications of the environmental impact of changes in mobility behaviour due to shared mobility (e.g., Autodelen.info, 2023; CapGemini, 2020; Wu et al., 2019). According to Jorritsma et al. (2015), the mobility behaviour of individuals who do not own a car differs from those who do. Without a car readily available, people become more conscious of their mobility needs, and fulfilling these needs requires more effort. This necessitates more planning, altering the common habit of automatically using a car (Meijkamp & Aarts, 1997; Meijkamp, 2020).

According to the Federal Highway Administration (2024), Americans drive an average of approximately 14.263 miles (22.955 km) annually. Studies by Shaheen et al. (2009), Martin & Shaheen (2011), and Martin & Shaheen (2016) show that carsharing users reduce their mileage by 27-44%. In Sweden, carsharing users have seen a reduction of up to 43% (CapGemini, 2020). In the UK, individuals who switch to carsharing drive 793 miles (1,276 km) less annually compared to car owners (CoMoUK & Steer, 2018).

As presented in Table 1, in the Netherlands, three studies provide useful estimates on the reduction in travel:

Table 1: Dutch studies on the impact of carsharing in the Netherlands

Study	**Details**
Nijland et al. (2015)	Before carsharing: 1 car per household. After carsharing: 0.7 cars per household. Reduction in travel demand: 1750 km/year
CROW-KpVV (2016)	Before carsharing: 9100 km/year. After carsharing: 7500 km/year. Reduction: 1600 km/year.
Goudappel Coffeng (2019)	Reduction in travel: 1947 km/year due to deliberate mobility behavior.
Goudappel (2023)	Reduction in travel: 1250 km/year. GreenWheels users: 5000 km/year. Typical Dutch private car user: 10800 km/year.

Table B1 in Appendix B provides an overview of the indications from more literature sources regarding changes in traffic intensity due to carsharing services.

2.4 Understanding the Impact of Carsharing on Space Utilization

In Europe, several studies provide insights into the amount of space that can be saved through carsharing. It is important to note that a carsharing vehicle also requires parking space, so the net result is the car replacement ratio minus one.

In Sweden, each carsharing vehicle frees up 2.5 parking spaces in Malmö, compared to 3.6 in Gothenburg and Stockholm, indicating significant improvements in freeing up urban land from parking lots (Reyes et al., 2020). Rydén (2005) indicates that in the German city of Bremen and in Belgium, the need for parking space is reduced by 90-135 m² and 45-75 m², respectively.

In the Netherlands and many other European countries, there is a need to build houses, commercial, and public facilities to accommodate the steady population growth in urban areas. With limited space, existing urban areas are increasingly utilized more densely to make this possible. As activity within an area increases, finding room for additional vehicles becomes more challenging. In order to calculate space savings through carsharing information on car parking lots is needed. Table 2 presents an overview of the parking characteristics in the Netherlands.

Table 2: Overview of the parking characteristics

Statistic	Details
Cars Registered	Nearly 9.1 million (CBS, n.d.)
Unused Time	About 96% of the time (KiM, 2022)
Parking Lots	Approximately 19 million (KiM, 2022)
Area Covered	225 km² (Zijlstra et al., 2022)
Parking lots /1000 households	860 (Meijkamp, 2000)
Minimum Requirements	Yes (Overheid.nl, n.d.)
Average Size of Parking Lot	10-12.5 m² (Goudappel, n.d. (b); Rijkswaterstaat, n.d. (b))
Parking Lots per Car	Approximately 1.8-2 (Goudappel, n.d. (b); Rijkswaterstaat, n.d. (b))

With the known number and size of parking lots, multiplying this number by the car replacement ratio provides an estimate of the potential public space savings due to carsharing. For instance, based on an average replacement ratio of 4-11 cars (see Section 2.2), this would range between 36-120 m² per shared car. Due to their slightly higher car replacement ratio, Goudappel (n.d. (a)) estimates that a shared car frees up 270 m² of public space.

However, CROW (2016) notes that the effect of carsharing on public space usage may vary by location. In Amsterdam, for example, the impact is less pronounced due to the low level of car ownership. A shared car, which occupies a parking lot itself but replaces multiple ones, saves about 2.14 parking spaces, equating to approximately 21.4-26.8 m² of public space (Nijland et al., 2015).

Alternative modes of transport that reduce the number of cars would occupy less public space (e.g., Vleugel & Bal, 2017). With high-quality public transport and carsharing opportunities, the number of parking lots could be reduced by 20% below the standard requirement for a period of 10 years (Goudappel, n.d. (b)). However, achieving this may require a number of carsharing vehicles that is commercially unrealistic in the current market (e.g., CROW, 2022b; Goudappel, n.d. (b)).

2.5 Understanding the Environmental Impact of Carsharing

Mobility significantly impacts the environment. Besides occupying space and causing traffic jams, it also generates other negative externalities such as noise and emissions. Climate change is driven by the emission of greenhouse gases (GHGs) through the interaction of natural processes and human activities. Given its role as a GHG, it is no surprise that the focus on the negative environmental impact of mobility often centers on CO_2 emissions. However, other pollutants are also important in relation to mobility. While CO_2 emissions have a global impact, NO_x and PM_{xx} affect local air quality. In the Netherlands, high NO_x levels particularly deteriorate nature, severely restricting agricultural, road infrastructure, and real estate development. The volume and composition of emissions vary depending on trip data, routing, fuel efficiency, emission factors, and engine-fuel configuration.

The composition of the car fleet and the presence of shared car mobility significantly influence emission levels (e.g., Baptista et al., 2014). According to ACEA (2021), the average car age in the Netherlands is 11.2 years and is increasing (AutoWeek, n.d.). The literature indicates that, in general, the shared round-trip car fleet is more modern and consists of smaller, more economical cars than those commonly found on Dutch roads (van Mensch & Münzel, 2021). The proportion of electric cars in this fleet is substantially higher with 48%, than the 7.1% average for the Dutch car fleet (CROW, 2024).

With the trend towards electrifying car mobility, it remains to be seen whether this will continue, as plug-in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEVs) are significantly bigger, belonging to the C, D, and E car type categories (Automobiledimension.com, n.d.). This difference in the composition of the car fleet in terms of car segments is shown in Figure 8. This increase in size is partly due to the space required for onboard safety systems and the battery packs needed to power them and provide sufficient range. Consequently, this may lead to changes in the minimum parking lot requirements (in terms of m² per car) on streets and in parking garages in the future. Additionally, it remains to be seen how quickly smaller B and A category electric cars will enter the market in substantial numbers.

The composition of the fleet of shared cars in operation differs in several ways:

1. The average age of shared cars is lower than the EU average and the Netherlands average (ACEA, 2021).
2. There is a higher number of small cars in the A-B segment (CROW, 2022c; see Figure 6).
3. The percentage of electric vehicles (EVs) is higher compared to the average car fleet (RVO, 2024).

All these factors should result in lower emissions for shared cars compared to the average private car used under the same circumstances.

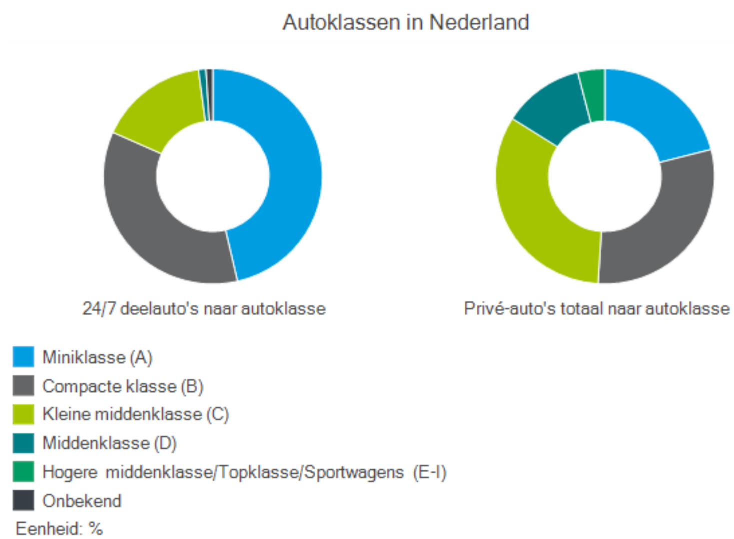

Figure 6: Composition of the car fleet of shared respectively privately owned cars. Source: CROW (2022c)

According to Goudappel (n.d. (a)), carsharing users emit 10% less CO2 compared to private car owners due to lower car ownership and fewer kilometers driven. As mentioned in Section 2.4, Rijkswaterstaat (n.d. (a)) states that a reduction of 1,600 kilometers driven per year, resulting from decreased car ownership, equates to a saving of 175-265 kg CO2 per year per carsharing household. However, this type of mobility partly replaces more environmentally friendly transport modes (e.g., bike rides, public transport), resulting in a net emission reduction of 90 kg CO2 per carsharing user per year (Nijland et al., 2015).

In addition to car size, transitioning from traditional combustion engine technology to (plug-in) hybrid and battery power trains can further reduce emission levels (Schelte et al., 2021; Zhang et al., 2021). For example, Chen & Kockelman (2016) demonstrated that the improved fuel efficiency of the shared car fleet and changes in travel behavior could reduce emissions from 244.7 to between 80.0 and 163.7 g CO2eq per passenger kilometer.

As indicated in section 2.2, carsharing can lead to changes in travel behavior. According to Arbeláez Vélez (2023), the availability of shared cars led to a 14.2% increase in train use, a 1.4% increase in bus use, and a 1% increase in bike use, resulting in a reduction of 823 kg CO2eq per person-year (Amatuni et al., 2020). Regarding the type of shared car market, Arbeláez Vélez & Plepys (2021) note that B2C and P2P carsharing produce similar emissions during the use phase.

However, carsharing can also have negative environmental side effects. The servicing and reallocation of free-floating vehicles generates emissions (Ding et al., 2019). Additionally, carsharing may attract travelers who previously used more sustainable alternatives. According to Arbeláez Vélez & Plepys (2021), users shifting from public transit and active transportation to carsharing increase emissions by 23.4–25.7 kg CO2eq per person-year for B2C and P2P, respectively. But over all user groups, positive effects can be identified (Nijland et al., 2015).

2.6 Insights into the Environmental Impact of Electrifying Shared Cars

Due to the Green Deal initiative (EC, n.d.), the transition to more sustainable mobility involves introducing zero-emission (ZE) vehicles on the roads, which will reshape car fleets in the near future. Although limited studies exist, some indications can be found regarding the impact of carsharing and estimates of the introduction of ZE shared cars. According to CROW (2024), 48% of the Dutch shared car fleet is electric (see Table 3).

Table 3: Energy source per category of shared car. Source: CROW (2022c)

Energy Source	Community-based	Free-floating	Peer-to-peer (keyless)	Roundtrip	Total Shared Cars	Total Private Cars
Petrol	0%	0%	58.5%	68.9%	59.5%	84%
Diesel	0%	0%	33.1%	0%	2.6%	10.7%
Electric	100%	100%	3.7%	29.8%	36.5%	3.4%
Green Gas	0%	0%	-0.2%	-0.02%	–	–
Hybrid	–	–	-4.5%	-1.3%	-1.4%	-1.9%
Total	100%	100%	–	–	–	–

In Amsterdam, the carsharing fleet is the largest in the Netherlands. According to van Mensch & Münzel (2021), all 960 free-floating vehicles were zero-emission (ZE) in 2020. The round-trip fleet, consisting of 1,016 vehicles, is still partly petrol-fuelled but is more modern and smaller in size compared to the average car fleet on Dutch roads, resulting in an overall emission reduction. The impact of these changes is detailed in Table 4 (van Mensch & Münzel, 2021).

Table 4: Estimated emission reduction in the inner-city of Amsterdam due to increased carsharing and a growing number of zero-emission (ZE) cars in the carsharing fleet, based on the total vehicle kilometres for the base year 2020.(van Mensch & Münzel, 2021)

Reference year	CO_2 level (kton)	NO_x level (ton)	$PM_{2,5}$ level (ton)
2020	-2.8 (-1.0%)	-2.8 (-1.0%)	-0.04 (-0.05%)
2022	-4.9	-4.3	-0.06
2025 (all shared cars are ZE)	-9.9 (-4.0%)	-7.1 (-3.0%)	-0.11 (-1.4%)

It is important to note that, in the literature, cars classified as electric vehicles may include a mix of hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), and battery electric vehicles (BEVs), making it challenging to isolate their individual environmental impacts.

To understand the environmental impact of changes in demand for (shared) car mobility, the total amount of vehicle kilometres is commonly used (e.g., Lorig et al., 2023; van Mensch & Münzel, 2021; Vleugel & Bal, 2018). In the Netherlands, a significant number of petrol-burning vehicles are still operational in round-trip carsharing fleets. However, a transition towards zero-emission (ZE) mobility is expected in the next decades. As demonstrated by MyWheels and WeDriveSolar (WDS), shared car mobility providers are likely to lead this transition by rapidly converting their entire B2C round-trip fleets to electric vehicles of various types and sizes (WDS, n.d.). An indication of the impact of a shift to 100% ZE shared cars can be obtained using a simple calculation tool (see Appendix C).

The introduction of zero-emission (ZE) shared cars leads to a decline in direct emissions of the three pollutants in Tank-to-Wheel (TTW) calculations. However, these tailpipe estimates may not fully represent the environmental impact. The type of vehicle and the method of energy production play crucial roles in determining the overall environmental benefits of this transition. A more comprehensive understanding of the environmental impact of car mobility can be achieved through Life Cycle Analysis (LCA), which offers a holistic perspective by accounting for emissions and resource use across a vehicle's entire lifespan. For example, Messagie et al. (2014) employed a range-based modelling approach to assess the environmental performance of various vehicle technologies, enabling a more nuanced comparison of vehicle categories from an LCA standpoint. Building on such work, Dolganova et al. (2020) conducted a literature review of over 100 LCA studies, providing a broader synthesis of findings related to electric vehicles, particularly in terms of environmental impacts and resource depletion.

Based on the current body of literature, the impact of new policy measures for greener mobility may be too abstract and limited in practical application for policymakers. Although emission estimates are becoming outdated due to rapid advancements in car powertrain technologies, the study by Messagie et al. (2014) provides a useful framework for future research by focusing on the various phases of a Life Cycle Analysis (LCA) for mobility. Their emission estimates remain valuable for historical scenario analyses.

As shown in Figure 7, for new technologies like battery and fuel-cell powered vehicles, the environmental greenhouse gas (GHG) impact primarily stems from the production and distribution of energy (Well-to-Tank, or WTT). In contrast, for conventional combustion engines, Tank-to-Wheel (TTW) emissions, including tailpipe and tire and brake abrasion, contribute the largest share of negative externalities. Interestingly, the authors indicate that the positive environmental impact of battery-powered cars depends significantly on the level of battery pack recycling and the production of green electricity.

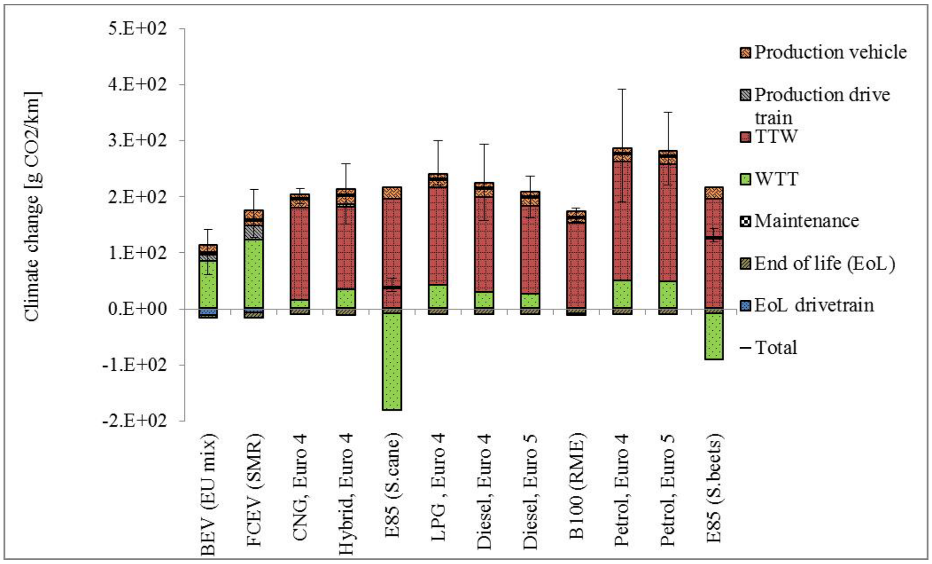

Figure 7: The visual representation of the effect of various vehicle technologies on climate change presented by Messagie et al (2014) on pp. 1474.

With the influx of large numbers of electric cars, most of these vehicles are likely to be charged via the grid. In the interconnected European energy market, the grid mix is highly dynamic. Platforms such as Nowtricity (n.d.) provide useful indications of the CO2 emissions associated with electricity production, offering insights into the Well-to-Tank (WTT) emissions of electric cars. Unfortunately, information regarding NOx and PMx levels associated with this process is generally lacking.

With the current fleet of vehicles on European roads, Tank-to-Wheel (TTW) emissions are a decisive factor in their environmental impact. For policymakers, gaining more insights is crucial for establishing benchmarks and developing new mobility policy measures. The COPERT software from the European CORINAIR project (see: https://copert.emisia.com/) can be useful in this respect (Migliore et al., 2020). Additionally, quick scans of car magazines and simple tools can also provide valuable information. Vleugel & Bal (2018) developed a model that offers viable indications of changes in the three emission levels from a TTW perspective. The basics of their model we have used to create our tool for policymakers, providing quick scan indications of the impact of the zero-emission (ZE) transition and energy provided by national grids (see Appendix C).

2.7 Additional Benefits of carsharing

Over the past decades, the negative side effects of various modes of transport have garnered significant attention, particularly tailpipe emissions that contribute to climate change and deteriorating local air quality (e.g., Liao et al., 2024; Vleugel & Bal, 2017; Vleugel & Bal, 2018), as well as competition on using public space in ever growing cities. Shared mobility aims to mitigate these issues. Shared cars, in particular, add to the range of options available to meet mobility demands. As the market for shared mobility grows, the positive side effects of this mode of transport become clearer. This section highlights several of these benefits.

Mobility Poverty

Carsharing provides affordable mobility for ad hoc needs, such as unexpected cargo transport, and for car trips by low-income groups. On average, for distances below 10 000 km a year, these services are cheaper than owning a private car (ING, 2018). For low-income households, shared car services can enhance flexibility in mobility options. These groups, who often travel longer distances by public transport, may benefit from the opportunity to use a shared car, especially for destinations that are difficult or inaccessible by public transport due to location (e.g., remote facilities) or specific times of the day (e.g., during night hours). Shared car services can bridge this mobility gap (e.g., Reyes et al., 2020).

In the Netherlands, the cost of mobility has increased by approximately 30 percent over the past eight years (PBL, 2019; Nibud, 2024). This rise has created significant financial challenges not only for low-income individuals but also for those earning up to €44.000. People living in rural areas, who often travel longer distances, are particularly affected by these financial burdens.

Various online calculators (e.g., https://www.deelautovergelijker.nl) indicate that, compared to public transport and privately owned second-hand cars, shared cars are often not an affordable alternative when used frequently and for longer distances. Generally, a shared car is expected to be a cheaper option compared to owning a private car when driving less than 10,000 km per year (e.g., Goudappel, n.d. (a)).

Unfortunately, according to TNO (2024), between 113.000 and 270.000 low-income families tend to travel significantly more - up to 20.000 kilometres per year - making it difficult for them to reduce their travel demand and switch to greener alternatives such as newer and shared cars.

Liveability

Car-oriented infrastructure often limits pedestrians' and bikers ability to enjoy peaceful surroundings, vibrant street life, and safe spaces for walking and children's activities (Stefánsdóttir et al., 2024). In response, many Latin American capitals have implemented Open Streets programs, which temporarily close roads to motorized traffic to promote community well-being and enhance urban quality of life (World Economic Forum, n.d.). Similar initiatives can also be found in Belgium (e.g. the Speelstraten in Ghent, Stad Gent, n.d.) and the Netherlands. For example, the city of Utrecht runs a program known as the Leefstraat, where streets are temporarily transformed into shared community spaces (Gemeente Utrecht, n.d.). Initiatives to re-purpose public (street) space can lead to:

- Reduced car traffic and parking pressure
- Increased social interaction among neighbours
- Safer play areas for children
- Improved quality of life through creative and green use of public space

From the perspective of decision-makers, effective shared car services offer the opportunity to further limit or deny access to specific inner-city zones by private cars in favour of shared cars.

In Spain, the city of Pontevedra (Fastcompany.com, 2023) restricted car access, removed on-street parking, widened sidewalks, and allowed only essential traffic about two decades ago. They have observed:

- An improved inner-city ambiance, which is attractive to tourists and stimulates local restaurants and retail activity.
- Urban revitalization due to increased air quality and road safety, attracting new residents, especially young families, to the city center.

The revitalization of historic inner cities can significantly influence the real estate market. In the Netherlands, the rise of remote work and online shopping has led to an increase in vacant office buildings and retail spaces. A more liveable inner-city environment may encourage the transformation of these spaces into attractive housing options (BBC, 2019).

Unfortunately, there is no clear evidence yet on how such initiatives have affected mobility demand in Spain. However, as more urban areas implement traffic restrictions and pursue sustainability goals, understanding their impact on mobility patterns becomes increasingly important. A social-economic approach (e.g., Rebel Group, 2023; Sustrans, 2024; Úbeda Cartañá et al., 2023; Witte et al., 2024) offers a valuable starting point for analysing and guiding these transitions.

Heat and Rain Adaption

Several Dutch cities are experimenting with replacing parking spots with green spaces (e.g., Den Haag, 2021). A key element of this policy is the transition from privately owned cars to shared car use. In addition to improving the street ambiance, the increased presence of trees can help mitigate the impact of rising temperatures by providing shade and cooling the urban environment during summertime. Furthermore, greening the remaining parking spots can reduce heat buildup and improve rainwater drainage, as shown in Figure 8 (De Groen Parkeerwijzer, n.d.; RTL Nieuws, 2024).

Figure 8: Green parking spots. Source: RTL Nieuws (2024), Nanda Sluijsmans

In practice, realizing this ambition in the foreseeable future seems the be challenging, especially financially (Rekenkamer Utrecht, 2024)

How Shared e-Cars May Ease Net Congestion

The electrification of households presents major challenges for existing electricity grid infrastructure. Technologies such as heat pumps and various types of electric vehicles (EVs) require substantial amounts of electricity - often daily leading to peak demand and grid congestion during certain hours. According to Hammerschmitt et al. (2024), the current composition of EVs, particularly battery electric cars, contributes to baseline grid loading. However, they also have the potential to alleviate grid congestion through smart charging strategies (SSCH, n.d.; Robust project, n.d.).

While the technical components for smart charging are largely in place, the use of battery electric vehicles (BEVs) in this context is still in its early stages. Legal barriers and proprietary, closed charging systems dominating the market currently prevent BEVs from being widely used as flexible energy assets. As a result, this service is not yet available at scale. However, various theoretical studies show that shared electric cars might be an effective solution to counter net congestion in the low-voltage grid, which feeds e-car chargers and households in residential areas (Brinkel et al., 2020; Brinkel et al., 2021). Due to the different user mobility profiles compared to privately owned e-cars, shared e-cars shift a significant share of the charging demand towards weekends. Based on simulated charging transactions for shared and private e-cars, Brinkel et al. (2020) estimated that the average overall charging demand of shared e-cars on weekend days is 51% higher compared to weekdays. This delay in charging demand to the weekends, combined with longer stationary times at the hub or charging station throughout the week, adds flexibility for distribution system operators (DSOs) to meet user demands.

The number of shared electric cars needed to maintain power flows below the threshold level and avoid peak loads 24/7, while still meeting user demand, depends on the local transformer load capacity. This can contribute to lower charging costs for end users. According to Brinkel et al. (2021), *"the potential of shared e-cars to fully mitigate transformer congestion problems is lower in grids with a 250 kVA transformer. In such grids, shared e-car adoption rates of 60 to 90% are required to bring the transformer peak load below its capacity, depending on the specific scenario."*

Controlled discharging via V2G-capable e-cars paves the way for the flow of redundant energy stored in car battery packs back into the grid. However, the infrastructure and e-car onboard systems currently need further development to make this exchange (charging and discharging) possible, which is likely to occur within the next five years. In June 2025, in the city of Utrecht a pilot project is launched involving Vehicle-to-Grid (V2G) shared electric cars. This initiative has started successfully and is expected to generate valuable insights into the integration of shared mobility with smart energy systems (WDS, n.d.(b)).

3. Shared Bike Systems: Their Impact on Traffic Intensity, Space Occupation, and the Environment

Besides providing local stand-alone origin-destination mobility over short distances, bikes are often used in combination with other transportation modes (e.g., Vlaamse Overheid, 2025). In both cases, they impact traffic intensity and space usage. This chapter delves into the impact of bikesharing. It begins with a description of bikesharing systems in Section 3.1. Insights into the bike replacement ratio are presented in Section 3.2. The impact of bikesharing on traffic intensity is discussed in Section 3.3, while Section 3.4 focuses on its impact on space usage. The environmental impact of biking is discussed in Section 3.5. Positive externalities resulting from bikesharing are explored in Section 3.6.

3.1 The Lay Out of Modern Bikesharing Systems

As mentioned in section 1.1, bikesharing in the Netherlands began with the Witte Fietsenplan. Since then, new initiatives have emerged over time. Ma et al. (2020) categorized them as follows:

- *1st generation*: Unlocked and free-for-public-use bikes (Shaheen et al., 2011; Wikipedia, 2024a).

- *2nd generation*: A "Coin Deposit System" with a refundable deposit to unlock and use a bicycle (Demaio, 2009).
- *3rd generation*: Improved bicycle designs, sophisticated docking stations, and automated smart cards (or magnetic stripe cards) with electronic bicycle locking and payment systems (Shaheen et al., 2010).
- *4th generation*: A highly flexible dock-less system using GPS and smartphones, easier installation, and power assistance (Fishman & Christopher, 2016; Gu et al., 2019; Parkes et al., 2013).

According to Liu et al. (2018), worldwide bikesharing systems can be divided into two types:

- Docked bikesharing: Users rent bicycles from designated docking stations and return them to available lockers at these stations. This setup can be either a 'back-to-one' or 'back-to-many' dock arrangement (Rijkswaterstaat, n.d. (c)).
- Dockless bikesharing: Riders are free to leave bicycles in designated parking areas, which can be either physical or geo-fenced, provided in public spaces with or without bicycle racks.

3.2 Insights into the Bike Modal Shift Potential

The Netherlands has a strong biking tradition, with most inhabitants owning at least one bicycle (DutchNews, n.d.; Euronews.com, n.d.). In 2022, the average Dutch resident cycled for 102 hours and covered 1108 kilometres, accounting for approximately 10% of all kilometres travelled (CBS, 2022b).

On average, a single bike trip covers 4.22 kilometres, which is roughly twice the distance of an average walking trip in the Netherlands (CBS, 2022a). Moreover, about 50% of all passenger car trips (around 3.6 billion annually) are shorter than 7.5 kilometres, and 33% (approximately 2.5 billion trips) are shorter than 5 kilometres. These distances are well within the range of a typical bike ride, especially with the widespread adoption of e-bikes.

With almost 23 million bikes and 6.4 million households, each household owns on average more than three bikes (RAI, n.d.). Despite this, there is still a market for bikesharing. Generally, shared bikes often replace a second bike, for example in another city. A survey among users of a bikesharing system in Antwerp revealed that 70% of the users also own their own bicycle (RWS, n.d. (c)). They observed that around 40% continue to cycle on their own bike as often as they did before, while a shared bike replaces another mode of transport (e.g., public transport or car).

Clearly, using shared bicycles affects more than just car-traffic volumes. Jianhong et al. (2024) provide an overview of the substitution rates for various travel modes across different city areas in Asia, North America, and Europe (see Table 5). Relevant data for Europe are also available (e.g., Cycling Industries Europe, 2023).

Table 5: The proportion of bikesharing users in various studies who substituted other travel modes with bikesharing during their recent trips (Jianhong et al., 2024).

Serial number	Walking (%)	Private bike	Bus	Rail	Private car (%)	Taxi	New trips	Other modes	Sample size	City
1	49	0.23	0.17	0.03	3	0.02	—	0.03	117	Beijing
2	27	0.26	0.22	0.08	6	0.1	—	0.01	167	Beijing
3	47	0.09	0.19	0.08	7	0.07	0.02	0.01	670	Shanghai
4	47	0.15	0.19		15	0.04	—	—	168	Nanjing
5	19	0.1	0.58		8	0.05	—	—	275	Hangzhou
6	31	0.06	0.45		7	0.06	0.04	0.02	5287	2011 Washington D.C.
7	38	0.05	0.44		4	0.06	0.03	0.01	2809	2013 Washington D.C.
8	37	0.05	0.4		6	0.06	0.03	0.03	4287	2014 Washington D.C.
9	39	0.03	0.14	0.21	5	0.16	0.02	—	5832	2016 Washington D.C.
10	31	0.05	0.15	0.34	3	0.04	0.04	0.04	191	Boston
11	38	0.08	0.2		19	0.03	0.09	0.03	N	Minnesota
12	7	0.14	0.14	—	21	0	0.36	0.07	14	San Antonio
13	18	0.24	0.5		8	0	—	—	2502	2009 Montreal
14	21	0.22	0.41		10	0.06	—	—	2509	2010 Montreal
15	25	0.28	0.34		2	0.08	0.03	—	1432	2010 Montreal
16	38	0.06	0.18	0.07	6	0.03	0.18	0.05	4533	Vancouver
17	29	0.05	0.23	0.38	1	0.04	0.01	0.01	1199	London
18	45	—	0.26	0.09	20	—	—	—	360	Dublin
19	54	0.12	0.31		3	—	—	—	237	Dublin
20	20	—	0.65		8	0.05	—	0.02	N	Paris
21	37	0.04	0.5		7	—	0.02	—	N	Lyon
22	27	0.09	0.41		19	0.02	0.01	0.01	N	Melbourne
23	23	0.08	0.43		21	0.03	0.01	0.01	N	Brisbane
24	26	0.06	0.51		10	—	—	0.07	N	Barcelona

The substitution effect of shared bikes on private car use is significant but limited compared to other travel modes. This is due to the different travel demand requirements of users over longer distances.

3.3 Shared Bikes and their Impact on Traffic Intensity

Policymakers advocate for the use of public transport to reduce the negative side effects of private car use. Bikes play an important role as first- and last-mile connectors with public transport. They serve as both a substitute and a supporter of the public transport system for short and medium travel distances, with the added benefit of making the system more robust (Jianhong et al., 2024; LDA Consulting, 2012; McKenzie, 2020).

In their study of the Boston area, Basu & Ferreira (2021) indicate that a new bikeshare station reduces:

- Vehicle ownership per household by 2.2%
- Vehicle miles travelled per person by 3.3%
- Per-capita vehicular GHG emissions by 2.9%
- Auto-dependence by about 10% where bikeshare connections to transit stations are less than one kilometre long

They also found that the reduction in vehicle ownership is almost immediate and lasts up to a year, while reductions in vehicle use and emissions are observed over 1.5 years.

Regarding the metropolitan Washington, D.C., area, Hamilton & Wichman (2018) found that the presence of bikeshare stations results in approximately a 4% reduction in traffic congestion.

According to Rijkswaterstaat (no date (c)), in the Netherlands four out of ten professional-traveling drivers have reduced their car use thanks to the availability of bike-sharing. The study indicates that, on average, about 0.1–0.6 rush-hour trips per day are avoided because of bike-sharing. More specific details are presented in Table 6.

Table 6: Nature and possible effects of bikesharing systems. Source: Rijkswaterstaat. (n.d. (c))

Function of the bike	Target group	Potential effect per shared bike in terms of instances of rush-hour avoidance per day		Examples
Public transport related system	Public transport users (especially business and commuters)	0.2	0.8 users per day, 80% in 1.8 hours of the rush-hour period, 5% otherwise uses the car	NS OV-fiets Nextbike Arriva Keobike Syntus
Urban/tourist sharing system	Visitors (especially for recreational and business purposes)	0.1	1.2 users per day, 10% avoid main journey by car in one hour of the rush-hour period thanks to shared bike on site	Gobike Rotterdam Nextbike Maastricht Hopperpoint Eindhoven
Park+Bike system	P+R users (all)	0.7	0.6 users per day, 80% would otherwise use the car	Park+Bike Leeuwarden Nextbike Maastricht
Commercial location system	Local employees (especially for business use)	0.3	0.5 users per day, 0% in the rush-hour, 33% avoid commuting in 1.8 hours of the rush-hour period by using a shared bike on site	Hopperpoint Eindhoven Shared bikes at business/ commercial sites

3.4 Shared Bikes and Space Utilization

According to Rijkswaterstaat (n.d. (c)), one possible disadvantage of bikesharing is that 'floating' bikes may cause environmental nuisances due to the difficulty of government control. Additionally, it can be challenging for users to find a free bicycle nearby in their neighbourhood.

Shared bikes are considered a solution to crowding at important spaces, such as large train stations in city centres. However, Goeverden & Correia (2018) suggest that their effect may be limited due to factors like the actual willingness to share bikes and the buffer times between demand and supply.

A transition from two- and four-stroke mopeds to electric mopeds appears to benefit public health due to lower pollutant emissions (RIVM, 2011). However, the city of Utrecht has a preference to shift from e-mopeds to e-bikes to provide the same mobility service while reducing the space needed per vehicle. E-bikes fit into the regular indoor and outdoor bike parking facilities throughout the city (Nu.nl, n.d. (a)).

3.5 Bikesharing and its Environmental Impact

According to RWS (n.d. (c)), as a rule of thumb, bikesharing results in a reduction of 3.7 kg of CO_2 per instance of rush hour in the Netherlands. The estimates of avoided emissions for CO_2, NO_x, and PM_{10} are presented in Table 7.

Table 7: Emission reduction in KG/instance of rush-hour avoidance. Source: Rijkswaterstaat (n.d.(c)).

CO_2	NO_X	PM_{10}
3.7	0	0

In addition to car usage, shared bikes serve as a partial substitute for the city's public transport network, privately owned bikes, and walking (Jorritsma et al., 2021). They also mitigate some disadvantages of public transport by providing a complementary element to the modern origin-destination mobility chain, specifically as a first and last mile solution. Shared biking reduces waiting and transfer times compared to public transport and is faster than walking. These time savings make the bike-PT travel combination more competitive with cars, potentially shifting up to 3.4% of all car trips to bike-PT trips (KiM, 2024a).

The average train trip in the Netherlands is 43 km long (CBS, 2022c). With appropriate policy measures, it is expected that 60-70% of car trips between 33-41 km can be shifted to bike-PT (train) trips during peak hours (KiM, 2024a). According to Rijkswaterstaat (n.d. (d)):

A bike-PT multi-modal trip is expected to replace a 43 km car drive. A shared bike used as a first and last mile solution is expected to replace or reduce a car trip by 5 km, leading to a reduction in emission levels as shown in Table 8

Table 8: The estimated reduction of emission levels in kg due to avoiding car use based on the KEV report (KEV, 2022)

	CO_2	NO_x	PM_{10}
multi-modal trip by PT+shared bike	3.5	0.0044	0.00048
multi-modal trip by car+shared bike	0.6	0.00091	0.0001

3.6 Additional Benefits of bikesharing

Similar to carsharing, bikesharing provides numerous positive side effects that contribute to societal well-being. This section will explore the various benefits associated with conventional bikes, e-bikes, and cargo bikes.

Bikesharing and Public Transport: Synergy Effects

As a last-mile mobility solution, bikesharing supports multi-modal travel by complementing public transport. It enables seamless transitions between transport modes, especially for short distances that are less efficiently served by buses or trains. Moreover, bikesharing often fills service gaps in public transport, particularly during off-peak hours, at night, and on weekends, when traditional transit options

– especially in rural areas - may be limited or unavailable (Woodson et al., 2024). This complementary role is well-documented in recent research (e.g., Cheng et al., 2024; Wei & Zhu, 2023).

Active Transport and Health Conditions

Switching from car usage to walking and biking, known as active transport, can significantly reduce the carbon footprint. Asiamah et al. (2024) indicate that climate change awareness and sustainability knowledge may shift consumer behaviour towards greener choices, including transport modes. This shift tends to favour biking over walking due to the distances city inhabitants need to cover for work, shopping, and medical facilities.

According to Brand et al. (2021), "those who switch just one trip per day from car driving to cycling reduce their carbon footprint by about 0.5 tonnes over a year, representing a substantial share of average per capita CO_2 emissions." They claim that if just 10% of the population were to adopt active travel behaviour, the corresponding CO_2 life-cycle savings would be around 4% of all car travel emissions.

Based on the Integrated Transport and Health Impacts Model (ITHIM), Woodcock et al. (2024) showed that bike-sharing delivers net health benefits even in a densely populated city such as London, despite the associated risks of injuries and exposure to $PM_{2.5}$ from vehicle emissions. Using the same model, Shaw et al. (2018) demonstrated that reductions in local air pollution combined with increased physical activity lead to improved health outcomes for urban residents. Moreover, a long-term social-cost-benefit analysis spanning two decades conducted by Mbugua et al. (year missing) indicates that integrating bike-sharing with public transport enhances environmental quality, promotes public health, and can be an economically viable mobility solution at the same time.

Biking appears to have a significant positive impact on perceived health and active travel: the longer distances people cycle, the more their perceived health increases (KiM, 2021a). In the same study, KiM (2021a) did not find a significant impact on perceived health from e-bikes and walking. According to Rijksoverheid.nl (n.d.), employees who bike are sick for 7.4 days per year compared to 8.7 days for those who do not cycle, a reduction of 1.3 days per year. The Dutch online platform for entrepreneurs and SME businesses, MKB Servicedesk (n.d.), estimates that a sick employee costs between €150 and €400 per day, depending on whether the employer can manage without them or needs a replacement.

Rijkswaterstaat (n.d. (e)) presents a comparison of the costs and benefits of biking in cities. Biking generates a health benefit of €0.39 per km, which translates to a social benefit of €0.68 per km in a social cost-benefit analysis. In contrast, cars and buses incur social costs of €0.37 and €0.29 per km, respectively. However, the provision of shared bikes involves investment costs of approximately €1200,- to €1800,- per bike and operational costs of around €1200,- per year (Rijkswaterstaat, n.d. (c)), which must be considered.

e-Bikes extend cycling use cases and user groups

Similar to regular bikes, shared e-bike services can be either docked or dockless systems. The common trip distance range for dockless shared e-bike systems is 1-3.5 km (Guidon et al., 2019; Reck et al., 2020), while the average distance for docked systems is 4.2 km (Bielinski et al., 2021) or even around 7.5 km or longer (He et al., 2019).

Campbell et al. (2016) found that travelers who previously used sheltered travel modes (such as cars, buses, and other modes providing shelter from wind and rain) and those who traveled longer distances tended to shift to shared e-bikes compared to shared bikes. According to Liao et al. (2024), there is a positive relationship between the share of cyclists choosing shared e-bikes and the increase in trip distance: the benefits of e-bikes (higher speed and less effort) are more pronounced on longer trips. Furthermore, reducing the usage fee of shared e-bikes seems to be the most effective measure to encourage shared e-bike use and reduce car use, although it may reduce the use of shared e-cars due to the substitution effect between shared e-bikes and e-cars (Liao et al., 2024).

Due to their physically easier ride, e-bikes can extend the range of bikers in terms of trip kilometres travelled, as well as provide special target groups, such as elderly and disabled people, the ability to travel more easily (McCurdy et al., 2024). In the Netherlands, e-bike usage is expected to grow by 40% by 2029, whereas normal bike use is expected to decline by 7% in the same period (KiM, 2024c).

E-bikes shouldn't be confused with smart bikes. The latter refer to bicycles equipped with advanced sensors, microprocessors, connectivity features, self-diagnostic systems, and data exchange and navigation features to provide enhanced functionalities to the (longer-distance) bike rider and the environment (Wolniak and Grebski, 2023). For example, smart bikes can adapt the rider's en-route assistance uphill or optimize battery use in different weather or road conditions. Clearly, this requires a properly functioning smart infrastructure and more extensive urban planning to achieve the full potential of smart biking (Boichuk, 2020).

For bikesharing services, smart bikes provide essential components such as keyless use and automated docking stations. However, in the Netherlands, the majority of shared bikes (totalling 27,500 in 2020, with a market share of 0.2-0.3%) are regular bikes, of which 75% are utilized via the OV Fiets as a substitute for public transport, privately owned bikes, and walking (CBS, 2024; KiM, 2021b).

Shared cargo bikes extend cycling user groups

Cargo bikes, positioned between cars and bicycles in the mobility spectrum, offer a promising alternative to car use and ownership due to their ability to transport people and goods (Börjesson Rivera & Henriksson, 2014; Pearce, 2016; Riggs, 2016). Marincek et al. (2024) identify three main motivations for using cargo bikes: transporting children, staying active, and reducing car use. The benefits of cargo bikes over cars extend beyond environmental advantages to include convenience factors such as less stress, freedom from searching for parking spots, bypassing traffic, faster travel, more predictable trip durations, and the ability to make unplanned trips (Anable & Gatersleben, 2005; Daley & Rissel, 2010; Masterson, 2017; Thomas, 2021).

Owned and shared cargo bikes are complementary and have the potential to attract new audiences to cycling and reduce car use (Riggs, 2016). Furthermore, depending on factors such as built-environment conditions, quality of the cargo bike, and road safety, cargo bikes can become the primary vehicle for home and child-related activities for both men and women (Bissel & Becker, 2024; Riggs & Schwartz, 2018).

The literature suggests that higher socioeconomic class households tend to buy their own cargo bikes, whereas shared cargo bikes primarily target middle-class households (Hess & Schubert, 2019; Riggs, 2016). Cargo bikesharing is in demand among potential users who did not purchase one due to high purchase prices, lack of parking space, or irregular travel demand (Dorner & Berger, 2020; Ghebrezgiabiher & Poscher-Mika, 2018).

According to Bissel & Becker (2014), cargo bikes have substantial potential to reduce car ownership, ranging from 7.4% to 18.1%, with the largest share relating to users deciding against purchasing a car.

Shared cargo bikes impact urban logistics

Cargo bikes are increasingly being used for last-mile delivery in e-commerce logistics. To foster a more sustainable distribution network, many providers are promoting the use of joint pick-up points, such as parcel lockers and post offices, instead of traditional home delivery (Nu.nl, n.d. (b)).

In this context, shared cargo bikes offer a wide range of social, environmental, and practical benefits, particularly in urban areas. Households may be encouraged to use these bikes to travel to pick-up points, reducing reliance on cars for short trips. This shift not only frees up parking space near collection hubs but also promotes eco-friendly travel behaviour.

As a form of active mobility, cargo bikes help users save time, avoid congestion, reduce emissions, and gain independence from public transport schedules, while also contributing to physical and mental well-being (Cavill & Davis, 2007; Daley & Rissel, 2010). Using a QGIS-based model, Duran-Rodas et al. (2022) demonstrated the potential of promoting cargo bike use through a combination of round-trip and free-floating shared services across both the inner city and the wider metropolitan region of Munich, Germany.

4. Retrospects and Prospects

The story of shared mobility is one of a changing urban landscape. In cities around the world, the way people move is undergoing a quiet revolution. This report dives into that transformation, focusing on the growing role of shared mobility, particularly carsharing and bikesharing, and the ripple effects these services are having on our streets, our environment, and our daily lives.

The focus is commonly on reducing car use. Carsharing is doing more than offering a convenient ride: it is reshaping how people think about car ownership. A shift from ownership to use leads to fewer cars on the road, which in turn means fewer kilometres driven, lower emissions, and less space needed for parking. Our report shows that with a car replacement ratio available, the impact of carsharing can be estimated for these factors.

But the benefits do not stop there. With fewer cars cluttering the streets, cities can reclaim space for parks, bike lanes, and pedestrian zones—making neighbourhoods more liveable and climate-adaptive. Shared cars, often newer and cleaner, also contribute to better air local quality. And thanks to smart charging and vehicle-to-grid (V2G) technologies, they can even help stabilize the energy grid.

Importantly, shared mobility is also more inclusive. It offers access to car travel for people who might not afford a private vehicle, making mobility more equitable.

Based on the available literature, insights can be obtained about the impact of shared bikes may bring to the society. While carsharing tackles longer trips, bikesharing is revolutionizing short-distance travel. Shared bikes, especially e-bikes and cargo bikes, are replacing car trips, cutting emissions, and freeing up space. They also bring health benefits and make cycling more accessible to a broader group of people. In a world of growing online shopping and local deliveries, shared cargo bikes are emerging as a sustainable solution for transporting goods in urban areas.

A Market in Motion

Shared mobility is still evolving. New services are emerging, blending with traditional transport systems and responding to modern needs. This report offers a snapshot of this fast-moving field, summarizing findings from a wide range of studies.

In such a dynamic setting, policymaking can be a challenging endeavour because many variables interact, and their interrelationships must be considered to develop effective and efficient measures. The tool accompanying this report provides users with reference values and the flexibility to incorporate future studies into the analysis over time. Based on the car-replacement ratio, it offers insights into the impact of carsharing on traffic intensity, public-space usage for parking, and vehicle emissions—including changes associated with the shift toward electric-vehicle (EV) mobility. For Dutch policymakers, the tool also allows for the consideration of neighbourhood-level differences, enabling more tailored analyses.

Consequently, the tool serves as a practical resource for evaluating various mobility scenarios and supporting evidence-based decision-making. At the heart of the analysis is the Car Replacement Ratio (CRR), a measure of how many private cars are replaced by each shared vehicle. While estimates vary, the trend is clear: shared mobility is reducing the need for private car ownership. And as more data becomes available our understanding of these impacts will deepen.

With the focus increasingly on sustainable development of our society, the future of mobility is electric, data-driven, and shared. As technology advances, we’ll see more personalized, multimodal travel options that are cleaner, smarter, and more efficient. While we can’t predict every twist in the road ahead, one thing is certain: the way we move is changing and shared mobility will influence this way.

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Appendix A

Car replacement ratio: Round-trip carsharing estimates

Table A1: Indications about the impact of carsharing round trip in various countries and places, based on Shaheen et al. (2019) and Bucsky & Juhasz (2022) with additional recently published estimates.

Operator + Location	Source	Nr. Vehicles removed p/carsharing vehicle	Members selling personal vehicle	Member avoiding vehicle purchase
USA+Canada (General indication)	Martin & Shaheen (2011)	9-13	0.33	0.25
Denmark (General indication)				
France (General indication)	6t (2014)	7	0.67	
Germany (General indication)	Kolleck (2021)	1-2 (35 cities; free floating)		
Berlin & Munchen	Giesel & Nobis (2016)		0.15	
Bremen	Moses Project (Rydėn & Morin, 2005)	4-10	21-34%	14-17%
Bremen	Rydėn (2005)	7-10		
Bremen	Team Red (2018)	16 (7 sold, 9 not purchased)	± 32%	± 40%
Frankfurt/Main	Lichtenberg & Hanel (2007)		0.14	0.27
Italy				
Palermo	Migliore et al. (2020)	4		
Norway				
Bergen	TOI (2022)	10-15	0.5	0.25
Sweden				
Malmö	Trivector (2014)	3.9		
Stockholm	CapGemini (2020)	8		
Belgium (General indication) Brussels + Wallonie: Namur, Liege, Louvain la Neuve, Dinant)	Moses Project (Rydėn & Morin, 2005)	4-10	21-34%	14-17%
Belgium (General indication)	Rydėn (2005)	4-6		
Belgium (General indication)	Autodelen.net (2022)	3.1-9.5	6.6	2.9
Belgium + the	Goudappel (n.d. (c))	10-14[1]	30%	0.27

[1] According to Goudappel (n.d.) in their combined Belgium and Dutch market research the replacement ratio consist of the real replacement ratio (6-7 cars possessed sold) and a hypothetical one (in which cars are not purchased to fulfill the mobility need)

Netherlands (General indication)	Maak van autodelen een succes in uw gemeente.	(6-7 sold, ... not purchased)	(60% 1st car / 40% 2nd-3th car)	
The Netherlands (General indication)	CROW-KpVV (2016)	9-13 (4-6 sold, 5-7 not purchased)	0.34	
	Nijland et al. (2015)			0.37
	Rijkswaterstaat (n.d. (a))	4-8		
	CROW (2021)		18-60% 37% on average (Depending on quality of PT)	
	Jorritsma et al. (2015)		0.3	
	Jorritsma et al. (2021)	4-11		
	Liao et al. (2020)		20% (based on Stated Choice)	
Amsterdam	van Mensch & Münzel (2021)		59% 1st car / 41% 2nd car	
UK ((General indication)				
London	Steer Davies Gleave (2017)	10.5	0.16	0.34
London	Wu, Le Vine, Clark, Gifford, & Polak (2020)			23% less car ownership

Car replacement ratio: Free-floating carsharing estimates

Table A2: Estimates of the car replacement ratio in case of one-way (P2P) carsharing based on Shaheen et al. (2019) and Bucsky & Juhasz (2022) with additional recently published estimates.

Operator + Location	Source	Nr Vehicles removed p/carsharing vehicle	Members selling personal vehicle	Member avoiding vehicle purchase
Global (General indication)	Mounce & Nelson (2019)	15 (1:15 replacement rate)		
USA+Canada (General indication)				
San Francisco	Cervero, Golub, & Nee (2007)		0.24	
Philadelphia	Lane (2005)	23		43 % less car ownership
Austria (General indication)				
Vienna	Jochem et al (2020)	7.7		
Belgium (General indication)	Moses Project (Rydėn & Morin, 2005)	4-10	21-34%	14-17%
	Autodelen.net (2022)	3.6	0.9	2.7
	Invers (2023)	3 (Just 3% response rate)		
Brussels	Jochem et al (2020)	8.6		
Denmark (General indication)				
Copenhagen	Haustein (2021)			9.7% less car ownership
Copenhagen	Jochem et al. (2020)	18.6		
Finland (General indication)				
Helsinki	Jochem et al. (2020)	9.0		
France (General indication)				
Paris (Autolib)	6t (2014)	3	0.23	
Germany (General indication)	Schmidt (2018)	2-4.5		
Berlin	Jochem et al. (2020)	11.3		
Hamburg	Jochem et al. (2020)	13.4		
Ulm	Firnkorn & Müller (2011)		0.14	

Italy (General indication)				
Rome	Jochem et al. (2020)	14.4		
Turin	Ceccato, Chicco & Diana (2021)			20%-36 % less car trips
Portugal (General indication)				
Lisbon	Jochem et al. (2020)	10.4		
Spain (General indication)				
Madrid	Jochem et al. (2020)	8.4		
Switzerland (General indication)				
Basel	Becker, Ciari, & Axhausen (2018)			6 % less car ownership
The Netherlands (General indication)	Jorritsma et al. (2021)	3-11		
Amsterdam	Jochem et al. (2020)	10.3		
UK (General indication)				
London	Le Vine & Polak (2019)			36% less car ownership
London	CoMoUK (2021)	24 (1:24 replacement rate)		
London	Jochem et al. (2020)	13.3		
London	Steer Davies Gleave (2017)	11	0.19	0.27

Car replacement ratio: P2P carsharing estimates

Table A3: Estimates of the car replacement ratio in case of one-way (P2P) carsharing

Operator + Location	Source	Nr Vehicles removed p/carsharing vehicle	Members selling personal vehicle	Member avoiding vehicle purchase
Germany				
(General Indication)	Schmidt (2020)	3		
Italy (General indication)				
The Netherlands (General indication)	Witte & Kolkowski (2023)			30% less car ownership (varies among target groups)

Appendix B

Traffic intensity estimates

Table B1: Indications about the change in traffic intensity en CO2 emissions due to carsharing in the Netherlands

Operator + Location	Source	Kilometers traveled before carsharing	Kilometers traveled after carsharing	Change in kilometers traveled by car	CO_2 reduction
USA	Shaheen et al. 2009			-44% (vehicle miles round trip)	
	Martin & Shaheen (2011)			-27% (vehicle miles round trip)	
	Martin & Shaheen (2016)			-6-16% (vehicle miles free floating)	
UK	CoMoUK & Steer (2018)			-1.276 (-793 mi) 998 (round trip) -460 (free floating)	
The Netherlands	Jorritsma et al. (2015) Nijland et al. (2015)	9.1	7.5	-1.600 (-17.6%)	175-265 kg 8-13%
	Goudappel Coffeng (2019)			-1.947	
	Goudappel (2023)			-1.250	
	Suiker & van den Elshout (2013)			-230.000 (overall)	
Amsterdam					
	Suiker & van den Elshout (2013)			0	
Sweden					
Stockholm	Capgemini (2020)			-0.43	

Appendix C

Environmental impact estimates

Table C1: Summary of environmental impacts for carsharing from Arbeláez Vélez (2023), Table 4.

Environmental Impact category	Indicators	Results	Level of Analysis	Reference
Air pollution	NO_x emissions	Private driving: 0.077	City	Migliore et al. (2020)
		Carsharing: 0.0892 t	City	“
	PM_{10} emissions	Private driving: 0.028 t	City	“
		Carsharing: 0.021 t	City	“
Climate impacts	CO_2 emissions	15% reduction	Neighborhood	Lausselet et al. (2021)
		Private driving: 334.5 t	City	“
		Carsharing: 208.93 t	City	“
		35-65% reduction	City	Baptista et al. (2014)
	GHG emissions	Before carsharing: 0.00024 t CO2eq	Per kilometer	Chen & Kockelman (2016)
		After low-use scenario: 0.00016 t CO_2eq	Per kilometer	“
		After medium-use scenario: 0.00012 t CO_2eq	Per kilometer	“
		After high-use scenario: 0.00007 t CO_2eq	Per kilometer	“
		Carsharing (free-floating): 0.00024–0.00028 t CO_2eq	Per kilometer	Sun & Ertz (2021)
		Carsharing (stationary): 0.00017–0.00019 t CO_2eq	Per kilometer	“
		Private car: 0.00025 t CO_2eq	Per kilometer	“
		Carpooling: 0.00020–0.00022 t CO_2eq	Per kilometer	“
		Netherlands: 0.15–0.29 t CO_2eq reduction	Per person annual transportation	Amatuni et al. (2020)
		San Francisco: 0.44–0.50 t CO_2eq reduction	Per person annual transportation	“
		Calgary: 0.084 reduction	Per person annual transportation	“
		Increase of 0.025–0.023 t CO2eq or reduction of 0.92–0.94 t CO2eq	Per person annual transportation	Arbeláez Vélez & Plepys (2021)
		Best-case reduction: 0.31 t CO_2eq Worse-case reduction: 0.15 t CO_2eq	Per personal annual transportation	Firnkorn & Müller (2011)
		Increase of 0–0.25 t CO_2eq or decrease of 0.50–0.65 t CO_2eq	Per household annual transportation	Martin & Shaheen (2011)
		Decrease of 48%–55%	Per household annual transportation	Namazu & Dowlatabadi (2015)
		Savings of 136000 t CO_2eq	Country	Te & Lianghua (2020)
	GWP	Private car: 3.60 t CO_2eq per year Two nodes1: 2.24 t CO_2eq per year Free-floating: 4.00 t CO_2eq per year AB mode1: 4.54 t CO_2eq per year Carpooling: 3.58 t CO_2eq per year	Per vehicle lifetime	Ding et al. (2019)

	CH_4	Private driving: 0.0258 t Carsharing: 0.0688 t	City	Migliore et al. (2020)
	CO	Private driving: 0.7309 t Carsharing: 0.7309 t	City	“
Land use	Land use	4.68 × 109 m^2 reduction	Country	Te & Lianghua (2020)
Ozone depletion	Ozone depletion	Private driving: 0.1751 t Carsharing: 0.0291 t		Migliore et al. (2020)
Resource depletion	Energy use	Current shared system: No reduction Scenario with 3000 cars: 1853 t fuel savings	City	Zhang et al. (2021)
		Current shared system: No savings Scenario with 3000 cars: 3.36 GWh increase in energy consumption	Per kilometer	Chen & Kockelman (2016)
		Before carsharing: 3.21 MJ After low-use scenario: 2.15 MJ After medium-use scenario: 1.55 MJ After high-use scenario: 0.98 MJ		
		35%–47% reduction	City	Baptista et al. (2014)
		1.67 × 109 MJ reduction	Country	Te & Lianghua (2020)

Appendix D

The basics of the micro model for calculating emission estimates of modes of mobility

Even a simple MS Excel model can be used to estimate the impact of changes in mobility behaviour. Vleugel & Bal (2018) utilized an MS Excel model to estimate the energy consumption and emissions of a fleet of private cars with different engine-fuel types, based on an average model that serves as a reference vehicle. The model consists of several modules:

A module to enter data and estimate fuel consumption and emissions, taking as input kilometres driven per year, emission factors, and average fuel consumption per kilometre, and then calculating total fuel consumption and emissions.

- A solver module where policy scenarios are entered as constraints in a linear programming exercise.
- Tables with fuel consumption, emission factors (EF), and TTW-WTW conversion.
- Tables with the electricity mix to charge EV batteries, with emission factors based on the current grey-green mix of energy sources or only green energy sources.
- A module that adds dynamics, such as growth of the car fleet and changes in the electricity mix.

They emphasize the necessity of combining data from many sources, both academic and professional, as data from car manufacturers turned out to be too biased. The estimates found are on a tank-to-wheel (TTW) basis. However, well-to-wheel (WTW) values were multiplied with a 'WTW-factor' (Verbeek et al., 2014). Unfortunately, no multipliers were found for NO_x and PM_{10} in the literature, so CO_2 multipliers were used to adapt all WTW values.

With carsharing companies and policymakers gradually aiming for a transition toward zero-emission mobility, the future environmental impact of electric mobility becomes increasingly important.

In general, the emission level EL of using a fuel can be specified as

$EL = G(E,ef,t) = \text{Energy used} \times \text{emission factor with } EL, E, ef, t \in R^+$ **(1)**

where E is the amount and t is the time energy of type E is used. ef denotes the emission factor corresponding to this type of energy and EL is the emission level which is the result of this activity.

Due to its linear character, the magnitude of a change in NO_x and PM_{10} emissions is about the same as the change in the emission level of CO_2.

Obviously, the introduction of zero-emission (ZE) shared cars results in declining emission figures for these three pollutants when considering TTW (tank-to-wheel) calculations. However, these tailpipe emissions may not be fully representative. The vehicle and energy production processes will determine how green this transition really is. An indication in this direction can be obtained via a Life Cycle Analysis (LCA).

The ShareDiMobiHub Consortium

The consortium of ShareDiMobiHub consists of 13 partners and 4 subpartners with multidisciplinary and complementary competencies. This includes European cities and regions, universities, network partners and transport operators.

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