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Article

Carsharing - Utopia or Real Gamechanger? - Conceptualising The Potential of Carsharing for Tackling Carbon Emissions

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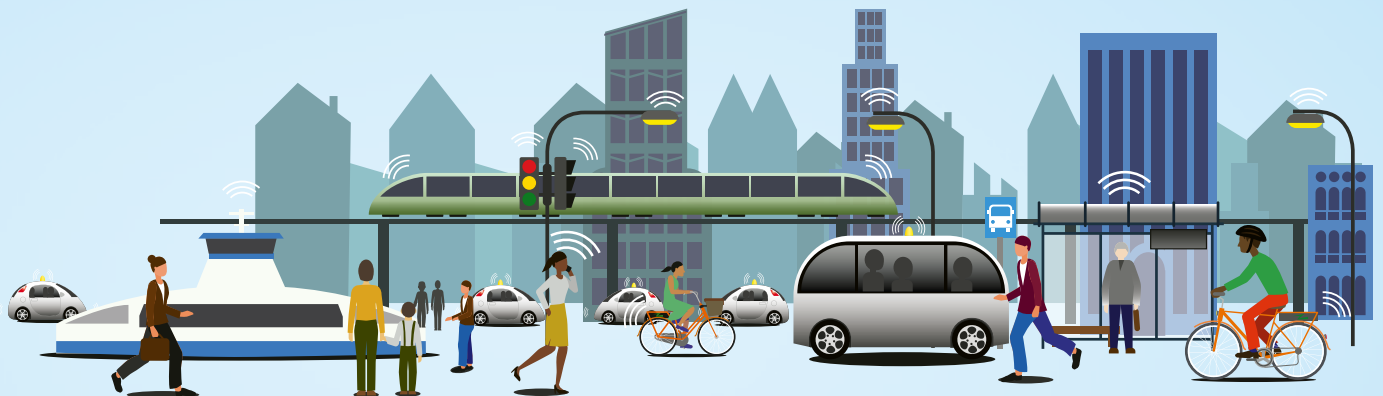
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Smart Mobility Marketing



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Carsharing – Utopia or Real Gamechanger?

Conceptualising The Potential of
Carsharing for Tackling Carbon Emissions

This conceptual paper addresses the different levers of both carsharing providers and their customers regarding the reduction of greenhouse gas emissions in the mobility sector. The various findings show that the main lever, besides the electrification of the vehicle fleet, is the integration of carsharing models into public transportation.

Andreas Collet, Dr. Philipp Scharfenberger

For quite some years now, carsharing concepts have been hailed as a possible driver of sustainable mobility. However, the breakthrough of these business models is still pending. The reasons vary, from unprofitable business models to higher perceived comfort levels of owning a car, resulting in a constant increase of private vehicle purchases (KBA, 2023; Kreimeier, 2022; MM, 2022). Simultaneously, in urban areas the demand for a new, less car-based and more sustainable transport policy and infrastructure is becoming stronger. Politicians and urban planners seek to address this demand by enforcing interventions that raise the usage costs of privately owned vehicles (Focus, 2022; SZ, 2019). This could, among other things, advance shared mobility concepts and thus enable carsharing concepts to achieve their breakthrough, especially in urban areas.

Public pressure to reduce greenhouse gas emissions (GHGE) of the transport sector and thus create a more sustainable mobility has grown constantly over the years, putting car-sharing solutions in the spotlight. While carsharing providers are themselves attempting to make their fleets more sustainable (Donath, 2022), they are partly also forced to do so by government regulations (NDR, 2022). In the last few years, there has been a broadening of perspective in science and politics regarding the calculation of “real” GHGE. GHGE are now increasingly calculated with a systematic lifetime approach including the relevant infrastructure to compare different modes of transport (Allekotte et al., 2020; Wild, 2021). This conceptual paper takes up this systemic view and closes the research gap mentioned by Shams Esfandabadi et al. (2022) regarding the establishment of a comprehensive long-term sustainability assessment framework. It develops an overarching framework to help both policymakers and corporate decision-makers to compare carsharing offers with privately owned cars in terms of ecological levers and distinguishes between *supply-oriented* and *behaviour-oriented* levers. Hence, our research aims to answer the following overarching question:

What are the main levers of carsharing business models to reduce their GHGE and the GHGE in the mobility sector in general?

A Systematic Perspective on Greenhouse Gas Emissions in the Mobility Sector

The pressure to reduce GHGE has increased dramatically in recent decades. The majority of society is now aware that climate change is a global problem requiring appropriate political and technological solutions (Sonnenberg, 2022). GHGE



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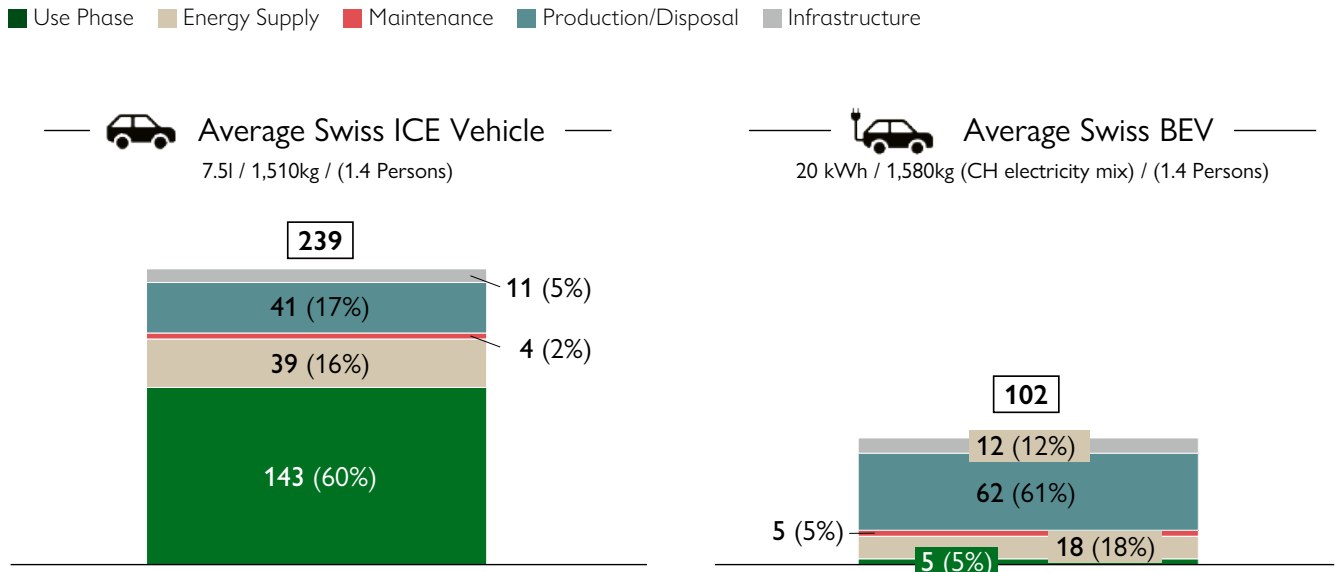
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are seen as the main driver of climate change (COM, n.d.) and therefore, as mentioned above, there is a search for possible mitigation options. However, the authors are aware that there are other factors to consider, such as biodiversity, air pollutants or resource scarcity, to avoid “carbon tunnel vision” (Konietzko, 2022). In order to compare the different types of GHGE with each other and to examine their potential to reduce GHGE, the factor CO₂ equivalent (CO₂-eq.) was introduced (Eurostat, 2016). Taking a closer look at the development of GHGE shows that in many industrialised countries, such as Germany and Switzerland, total GHGE have decreased significantly over the last decades. However, this occurred disproportionately across different sectors (BAFU, 2023; UBA, 2022b). Absolute GHGE in the mobility sector have remained unchanged (BAFU, 2022a; UBA, 2022b). Most technological efficiency gains that would have decreased mobility emissions have been offset by increased travel behaviour (BAFU, 2022b; UBA, 2022c), leading to a more or less unchanged total amount of GHGE in this sector (BAFU, 2022a; UBA, 2022c). The largest share of GHGE in the mobility sector results from motorised private transport, or more precisely, from the emissions accounted for by privately owned vehicles (UBA, 2022c).

Using a systematic perspective allows to consider the direct GHGE of the *use phase*, occurring due to vehicle operation with energy consumption and exhaust emissions. Moreover, the emissions of *energy supply* are taken into account, e.g., emissions produced during the transportation of fuel from its production site to the gas station. In addition, the

Figure 1: Comparison of ICE Vehicle vs. BEV regarding CO₂-eq. per PKM



Source: Own illustration.

indirect emissions caused by the *maintenance* of a vehicle, the emissions occurring during the *production and disposal* process and the emissions of the relevant *infrastructure*, like bridges, tunnels, or road construction, are added. Figure 1 shows the CO₂-eq. emissions per passenger kilometre (pkm) of an average Swiss vehicle with an internal combustion engine (ICE) and an average Swiss battery electric vehicle (BEV). For better comparability, the emissions are calculated as lifetime emissions and are standardised, following the usual scientific calculation parameters. However, the authors are aware that additional factors such as place of production and the specific energy mix and supply chains have a major influence on the ecological footprint. Emission data for German vehicles are in a comparable range (Allekotte et al., 2020; mobitool, 2022).

If one applies the systematic perspective to an ICE vehicle, most of the emissions occur during the *use phase* with 60% (143 g CO₂-eq.). The *energy supply* accounts for 16% (39 g CO₂-eq.), resulting in 76% of emissions (depending on the used ICE vehicle drive type). The remaining 24% are accounted by GHGE during *maintenance* with 2% (4 g CO₂-eq.), *production and disposal* with 17% (41 g CO₂-eq.), and *infrastructure* with 5% (11 g CO₂-eq.). These numbers result in total emissions per passenger kilometre of 239 g CO₂-eq. for the average Swiss ICE vehicle. In comparison, the total emissions

per passenger kilometre for a BEV are 102 g CO₂-eq. (which include 62 g CO₂-eq. generated during the *production and disposal* processes) (mobitool, 2022). The very low amount of emissions during the *use phase* (12 g CO₂-eq.) make BEVs very attractive for an urban context; however, the challenge of the high charging demand also needs to be considered (Adenaw & Lienkamp, 2021).

Defining Shared Mobility

With the success of companies like *AirBnb* or *Uber*, sharing economy business models have been established since the beginning of the 21st century and raised high media attention (Machado et al., 2018; Schor & Attwood-Charles, 2017). A key difference to existing business models is the platform that serves as a broker and allows peer-to-peer bookings (i.e., between users). This enables access to goods and services apart from actual ownership. One key advantage of sharing economies is the potential (re-)distribution and use of underutilised assets, leading to more sustainable consumption. From the beginning, sharing economy business models were seen as a potential driver of sustainable mobility, especially in urban areas (Machado et al., 2018). But the term *shared mobility* is not defined yet (Castellanos et al., 2021), and business models like carsharing, scootersharing, bikesharing, on-demand ride

services and ridesharing might be understood differently. Because this paper focuses on carsharing, the authors recommend the following papers for a more comprehensive view on the different definitions of shared mobility and different types of shared mobility concepts: Castellanos et al. (2021); Machado et al. (2018); McKenzie (2020); Santos (2018); Shaheen and Cohen (2018).

Current State of Research on Carsharing

Literature regarding carsharing is manifold. This paper uses the systematic literature review of Nansubuga and Kowalkowski (2021) as a basis. The authors classify the existing carsharing literature regarding *business models, drivers, and barriers, user behaviour* and *vehicle balancing*. Literature on *business models* has a very broad focus, ranging from strategic concepts to increase participation (e.g., Wilhelms et al., 2017) and the optimisation of relationships between carsharing providers and local governments (e.g., Cohen & Kietzmann, 2014) to pathways for local policymakers for the implementation of sustainable carsharing solutions (e.g., Bocken et al., 2020). The literature on *drivers* focuses on sociodemographic drivers (e.g., Magdolen et al., 2021; Prieto et al., 2017; Ramos & Bergstad, 2021; Ramos et al., 2020), geographic drivers (e.g., Münzel et al., 2019), socioeconomic drivers (e.g., Dill & McNeil, 2020; Hjortset & Böcker, 2020), and environmental benefits (e.g., Julsrud & Farstad, 2020), while literature on *barriers* mentions limited availability (e.g., Kim et al., 2019) and low public awareness (e.g., Burlando et al., 2019). *User behaviour* encompasses studies on trip purposes (e.g., Clark et al., 2015) and trip activities (e.g., Charoniti et al., 2020), frequency of carsharing use (e.g., Paundra et al., 2017), influence on car ownership (e.g., Chapman et al., 2020; Hausteine, 2021; Jochem et al., 2020; Kolleck, 2021; Miura & Yamamoto, 2022) and multimodal mobility (e.g., Münzel et al., 2019). The literature stream on *vehicle balancing* is technically driven, applying user-based (e.g., Brendel et al., 2020) and operator-based (e.g., Santos & de Almeida Correia, 2019) relocation models.

The literature on shared mobility and carsharing has led to the establishment of various frameworks: for instance, models on the impacts of shared mobility from the perspective of city authorities (Roukouni & Homem de Almeida Correia, 2020), models to compare GHGE before and after carsharing membership (Amatuni et al., 2020), discrete choice models to study the willingness to postpone car purchases due to carsharing offerings (Hui et al., 2019), frameworks to optimise the booking decisions of one-way carsharing users (Illgen & Höck, 2019; Nguyen et al., 2022), frameworks regarding shared mobility and the impacts on urban sustainability (Enochsson

et al., 2021), decision-support frameworks regarding critical decisions in a carsharing ecosystem (Golalikhani et al., 2021), or a comprehensive conceptual framework to systematize the interconnections between carsharing services and their environmental effects applying a system thinking approach (Shams Esfandabadi et al., 2020). However, these frameworks have in common that they do not provide an overview of the relevant levers regarding GHGE reduction. Our framework goes beyond the existing models and closes the research gap mentioned by Shams Esfandabadi et al. (2022) with regard to a comprehensive long-term sustainability assessment framework. It provides an overview of the different GHGE levers and distinguishes between *supply-oriented* and *behaviour-oriented* levers.

The Concept of Carsharing

Carsharing has been established for several decades now, first by private associations, later on by classic rental companies, public transport services, car manufacturers and others. In classic car renting, customers need to pick up and return the rented vehicle at a pre-defined station where the keys are handed over. The booking period is usually on a daily basis. The market for rental cars is very competitive (Kiani-Kreß, 2021). With carsharing, a new form of car rental was established. There are two types of operating carsharing models: *station-based* and *free-floating*. *Station-based* carsharing was established in the 1980s. Cars are picked up and brought back to pre-defined areas or parking spots. The rental process differs from classic car rental in that the pre-defined areas are not staffed and customers get access to the vehicle via an app, customer card or key card (BCS, 2023; Kolleck, 2021). In *free-floating* carsharing there is no predefined parking spot but rather a business area where customers pick up and park the car after usage. The interaction and booking process is handled via

Management Summary

Carsharing is supposed to offer various levers to reduce greenhouse gas emissions (GHGE), which can be either supply-oriented or behaviour-oriented. Among the supply-oriented levers, the electrification of the carsharing fleet is the major lever that providers themselves can use to cut their GHGE and should be further encouraged despite low customer demand. However, the mobility behaviour of carsharing users is the major lever and should be more deeply investigated to identify opportunities for extending existing business models.

an app. Payment options depend on the carsharing provider, varying from registration fees and pay per kilometre to pay per time (Balac et al., 2017). *Free-floating* carsharing started in Germany around 2011 (Heise Online, 2011) and by now outnumbers *station-based* carsharing regarding the number of vehicles (BCS, 2023).

Due to the fact that car rental and carsharing concepts vary mainly in the underlying business models, which are irrelevant for the ecological consideration, this paper summarizes *car rental*, *free-floating carsharing*, and *station-based carsharing* under the term *carsharing*.

GHGE Levers of Carsharing vs. Owning

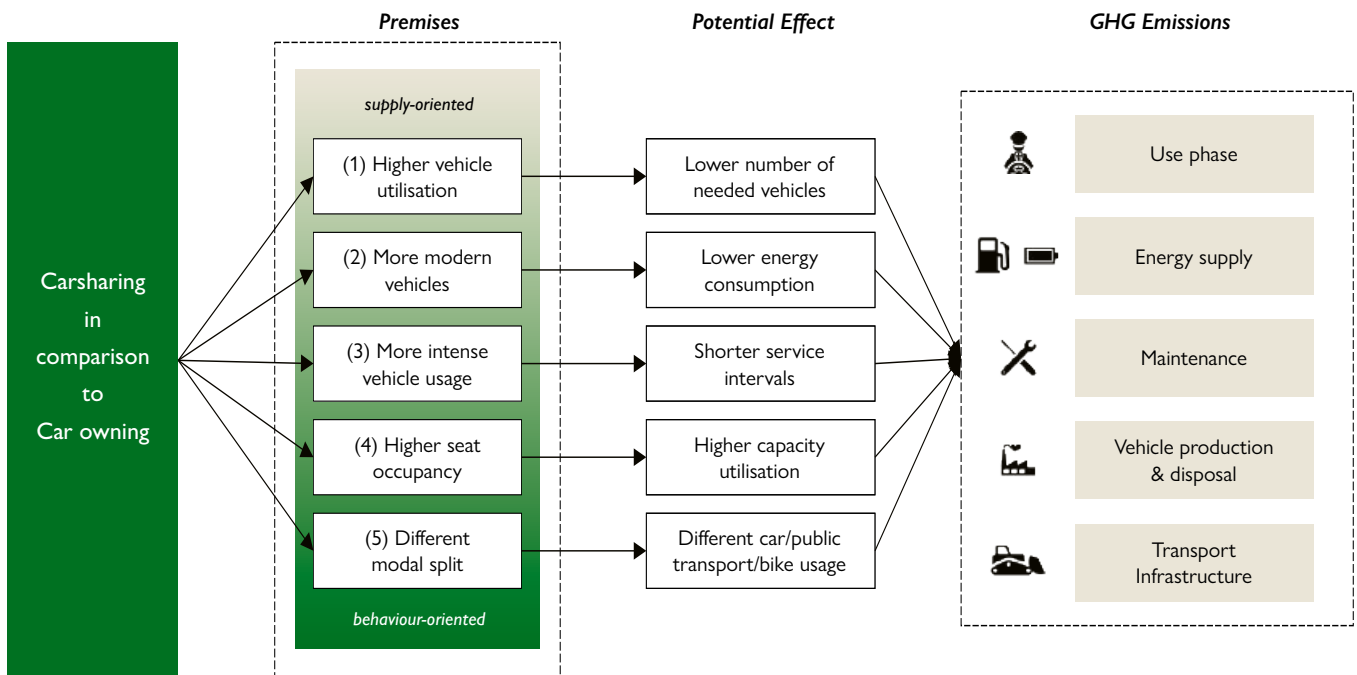
To highlight the differences between carsharing and privately owned vehicles regarding GHGE and to overcome the above-mentioned shortcomings, a conceptual framework was elaborated. It was derived in a two-step process: (1) a narrative literature review was conducted to identify research gaps and to derive the framework; (2) the derived model was challenged

by experts of a global rental and carsharing company (in the context of a project cooperation) as well as by scientific mobility experts and industry experts. The framework illustrates possible ecological levers of carsharing providers and distinguishes between supply-oriented and behaviour-oriented levers, showing the potential effects and the relevant levers to reduce GHGE (see figure 2).

(1) Higher Vehicle Utilisation

One of the main problems of privately owned cars, especially in urban areas, is their underutilisation. For example, an average vehicle in Germany covers 30 km per day and is used for 45 minutes, which is equivalent to a daily utilisation rate of 3% (Nobis & Kuhnimhof, 2018). The disproportionate space consumption by these cars has been addressed for years. The possible replacement rate of private vehicles by shared vehicles is estimated as ranging from 2 to 20. However, these figures must be considered with caution as these studies are based on different assumptions (e.g., Jochem et al., 2020; Magdolen et al., 2021). Regardless of the actual numbers, however, it is obvious that the number of underutilised

Figure 2: GHGE Levers of Carsharing in Comparison to Owning



Source: Own illustration.

private vehicles is far too high and thus valuable resources are literally “parked” unnecessarily (Chapman et al., 2020; Haustein, 2021; UBA, 2022a).

(2) More Modern Vehicles

On average, private vehicles in Germany are ten years old (KBA, 2022). Compared to new vehicles, the exhaust emissions are more harmful and fuel consumption is usually higher (mobitool, 2022). In the sharing context, vehicles are usually replaced after a certain amount of kilometres or at a certain age, which possibly leads to lower GHGE per passenger kilometre (caroobi, 2020; UBA, 2022a). In addition, the share of electric vehicles in the sharing pool is higher than among privately used vehicles (BCS, 2023). Furthermore, old, privately owned vehicles take up resources that would, after recycling, be available for newer and cleaner technology implemented in newer (shared) cars.

(3) Different Vehicle Usage

The different ways things are used that *do* or *do not* belong to a person have been widely researched in science. The use of one’s own belongings is distinctly different, which also applies to cars. Customer misbehaviour in the carsharing context has been researched extensively. However, it is not clear whether users of rental vehicles treat the vehicles better or worse in comparison to carsharing users; this has not been conclusively determined. The resulting costs for carsharing providers are high and the necessary replacements need to be considered when calculating GHGE (Bardhi & Eckhardt, 2012; Belk, 2010; Berliner Morgenpost, 2017; Fisk et al., 2010; Namazu et al., 2016; Schaefers et al., 2015).

(4) Higher Seat Occupancy

One of the most important parameters when comparing transport services is the passenger kilometre. Regarding GHGE, the emissions per passenger kilometre should be compared (Eurostat, 2021; UBA, 2023). Emissions per passenger kilometre can be reduced, inter alia, via higher passenger utilisation. Depending on the study, a privately owned vehicle is on average used by 1.3–1.5 people (Alle-kotte et al., 2020). These figures are lower than for shared vehicles, as these usually carry more people (Best & Hasenheit, 2018). However, seat occupancy strongly depends on the trip purpose, e.g., seat occupancy differs between leisure trips and commuting (Clark et al., 2015; Nobis & Kuhnimhof, 2018).

Main Propositions

- 1 Carsharing providers can reduce GHGE in the mobility sector directly through their own products and indirectly by changing the users’ mobility behaviour.
- 2 A major lever to reduce emissions is the electrification of carsharing fleets.
- 3 A change in the modal split of carsharing users represents the greatest lever to reduce emissions in the mobility sector.

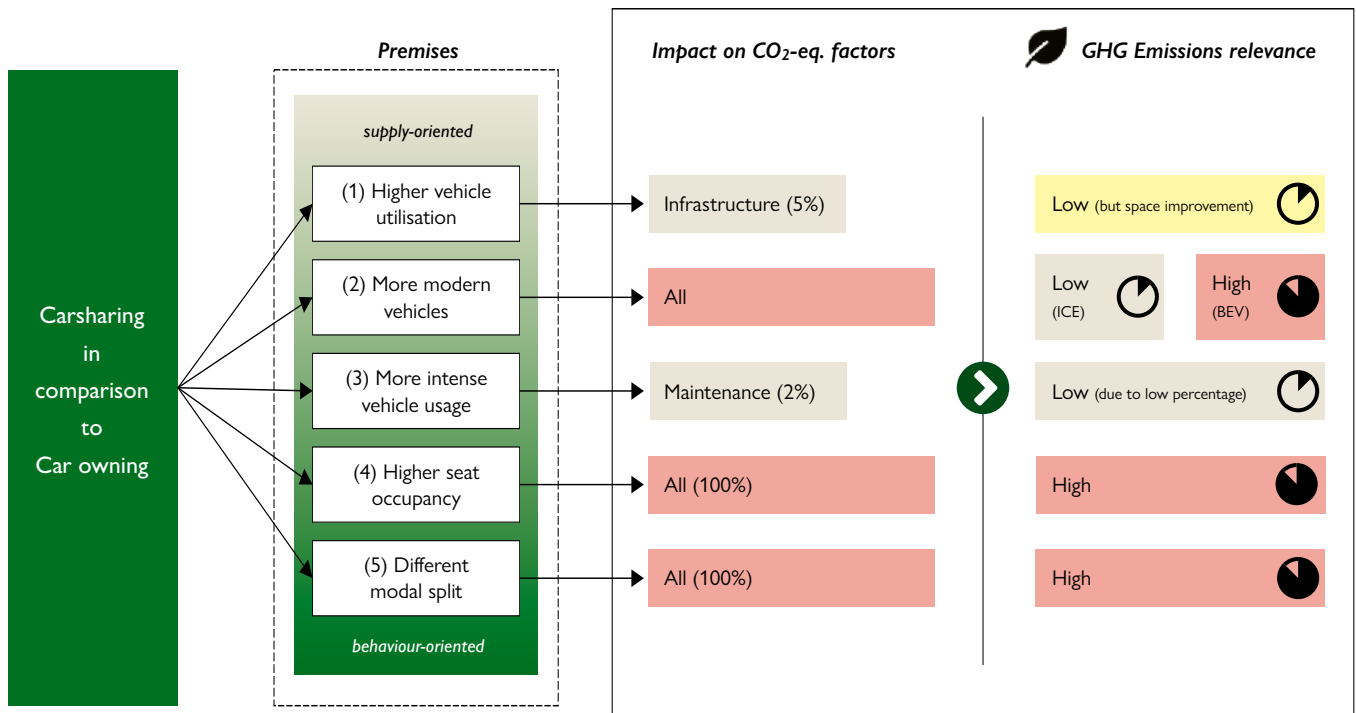
(5) Different Modal Split

The modal split indicates the distribution of the transport volume among different modes or means of transport (e.g., passenger cars, buses, trains) (Eurostat, 2019). Carsharing users might tend to take fewer trips with a car, using more environmentally friendly modes instead. However, studies are inconclusive as to whether the modal split of carsharing users differs from that of people using a privately owned car. Users of *station-based* carsharing tend to move differently and use more public transportation modes. However, there is also a risk that carsharing users will replace more sustainable transportation modes (like public transport) or walking trips, thus leading to a negative impact on GHGE. Furthermore, carsharing cars are often used instead of the privately owned car for certain purposes, which does not lead to a general reduction of vehicles or GHGE (Arbeláez Vélez & Plepys, 2021; Kopp et al., 2015; Magdolen et al., 2021; Nobis & Kuhnimhof, 2018).

Applying the Framework

Figure 3 takes up the previous discussion and extends the established framework of figure 2 by integrating the CO₂-eq. of the GHGE of an ICE vehicle, as shown in figure 1. This helps to distinguish between the main ecological levers of carsharing providers and their customers. The framework shows that the lever (1) *higher vehicle utilisation* of shared vehicles has an impact mainly on the factor infrastructure. Through the more efficient use of cars, journeys of several users can be bundled with fewer cars. However, no GHGE are avoided because the journeys still take place, and GHGE might even increase due to empty runs (Pantuso, 2022). Moreover, the cars need to be replaced at shorter intervals, because due to the higher utilisation rate the cars will reach the end of their lifetime earlier

Figure 3: Application of the Framework with Regard to GHGE



Source: Own illustration.

(assuming that these cars are solely used in a carsharing pool). The factor *infrastructure* is responsible for 5% of the CO₂-eq. of GHGE per pkm. This shows that the lower number of needed vehicles improves space utilisation and is an important benefit; however, it does not help to reduce GHGE significantly. The lever (2) *more modern vehicles* influences all CO₂-eq. factors cited above, has a positive influence on the exhaust emissions and might reduce fuel consumption. But this is highly dependent on the offered car types. By offering ICE vehicles, the impact on GHGE is relatively low, while offering more BEV has an impact on the reduction. The lever (3) *different vehicle usage* is represented in the maintenance factor, which is responsible for 2% of the CO₂-eq. of GHGE per pkm, showing that maintenance is important for sharing companies regarding operating costs, but does not have a high significance with regard to GHGE reduction. The lever (4) *higher seat occupancy* results in a higher capacity utilisation, influences all CO₂-eq. factors mentioned above and has therefore a high relevance for the reduction of GHGE. As shown above, seat occupancy has a high impact on lever (5) *different modal split*, resulting in a high importance of the modal split as well.

Implications

The framework shows that carsharing providers have two major levers to facilitate sustainable mobility and reduce GHGE: the electrification of the fleet and the modal split of their users. The electrification of the fleet is *supply-oriented*, and most of the providers are already electrifying their fleets (BCS, 2023; Donath, 2022). However, providers face a relatively low customer demand for BEV (Ecomento, 2022). The general scarcity of raw materials required for BEV, which are often mined and produced under critical conditions, further argues for a more efficient use of these vehicles in a sharing context. All in all, the electrification of the fleet is a one-off effect, and carsharing providers could use this as an argument to increase their fleet as it would not increase their overall fleet footprint.

Furthermore, carsharing providers can reduce GHGE by focusing more on the mobility behaviour of their customers. In combination with public transportation, shared mobility offers the possibility to avoid individual commuting trips

during the week and still provide the freedom a privately owned vehicle offers for the weekend. This means that car-sharing providers should see themselves more as mobility providers. They should operate as part of the public transportation system and not as car rentals, where merely the ownership differs compared to the model with privately owned vehicles. Furthermore, carsharing providers should more strongly emphasize the high costs of private vehicles for the owners and for society when communicating with their customers and with urban planners (Gössling et al., 2022; Nurhadi et al., 2017). However, the high number of privately owned vehicles in Switzerland shows that these are still in high demand, despite a public transportation system with a high standard and quality.

Future Research

Considering the above-mentioned implications, future research should focus on the following topics:

The drivers and barriers of users regarding BEVs. These have partly been analysed for privately owned vehicles, focusing on incentives, subsidies, or the charging infrastructure (e.g., Berkeley et al., 2017; Febransyah, 2021; Raux et al., 2021). However, the results cannot be fully transferred to the sharing context. Abouee-Mehrizi et al. (2020) showed that the main barriers in the carsharing context are charging speed, charging station availability, and battery range. However, a deeper understanding of the key drivers of BEV bookings in a sharing context is still missing.

The modal split of shared mobility users. Do these users really have a “greener” footprint? How can providers nudge them towards a “greener” modal split? By integrating their mobility apps into one overarching mobility app? Or is it not about booking infrastructure aspects but more about emotional or financial drivers? Is it possible to nudge customers to “greener” transportation modes outside of laboratory experiments (e.g., Schrills et al., 2020)? And how should shared mobility providers be integrated into the existing mobility landscape, especially the public transport system? Should they become part of the *Deutschlandticket* or the *Swiss Generalabonnement*, resulting in a partially updated business model?

Urban planning. Giving up the freedom offered by using a car is still not an option for many people. How should this aspect be considered in urban planning? Does it mean the implementation of *station-based* carsharing in certain areas in order to ensure a certain level of mobility in addition to public transport? Moreover, legislation needs to find solutions for dealing with shared mobility providers that increase their ecological footprint since this might reduce the footprint of the mobility sector in general (due to a changed mobility behaviour) and should therefore not be punished.

Calculation of each environmental lever. Future research should use this framework as a basis to calculate the concrete savings of shared mobility business models as compared to privately owned cars for specific countries, regions, or cities. Furthermore, this framework can be used as a basis for analysing other sustainable mobility factors such as biodiversity, air pollution or resource scarcity.

Lessons Learned

- 1 Carsharing should be considered as a part of public transport and be more fully integrated into public transportation systems.
- 2 Carsharing providers should be more deeply integrated into mobility booking apps to enable and support multimodal and intermodal travel choices.
- 3 Legislation needs to find a solution for companies that increase their own greenhouse gas emissions but at the same time reduce the total emissions of a sector.
- 4 The levers to increase the consumers' low demand for electric cars in the sharing context should be more deeply investigated.

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