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A pathway for parking in line with the Paris Agreement

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ABSTRACT

Current European parking policies do not seem to steer towards a future where urban transport meets the climate goals. Prominent in current housing and parking policies are the so-called *minimum parking standards*. Recent research has shown that they contribute to increased car use and consequently to higher CO_2 emissions. This is because they contribute to urban sprawl, extensive land use, increased housing and infrastructure construction costs, and that they restrict the number of flats per urban land unit. Other recent research shows that the construction of underground garages causes considerable CO_2 emissions. This paper is based on previous research on the development of the transport sector to be in line with climate targets (i.e., the Paris Agreement). It intends to fill a research gap regarding how parking management can be designed to be consistent with these targets. Through a future study approach with Stockholm as a case example, this paper illustrates a policy shift in parking policies considered to be in line with national climate targets. The article presents concrete indicators to quantify the scope of change needed (e.g., removing 60,000 residential parking spaces and providing vehicle sharing with 7,500 cars and at least 7,500 bikes). The focus shift goes from providing physical parking spaces to providing satisfactory mobility and accessibility. We outline a pathway towards a future scenario of parking and mobility in Stockholm, with a combination of mobility services, parking restrictions (e.g., cap on parking spaces, removal of minimum parking standards), and citizen participation. The pathway is also analysed regarding equity, feasibility, and acceptance.

1. Introduction

1.1. Background and state of the art

How cities plan for car parking has a considerable impact on the cities we live in. The traditional planning approach has been to use so-called minimum parking standards, which means that the city requires a minimum number of car parking spaces in order to issue the mandatory building permit for new buildings. The parking spaces required are typically provided on-site; in Stockholm, which is the case in this article, predominantly in new underground facilities. These standards were developed at a time when private cars gained market shares, and where a purpose of planning was to adapt cities to cars (Lundin, 2008). Today, many cities have other policy objectives, including aims to reduce car traffic and limit CO_2 emissions in order to be in line with the Paris Agreement. For instance, Stockholm has set an objective to reduce CO_2 emissions by 70 % between 2010 and 2030 (City of Stockholm, 2016). Several studies (e.g., Hickman and Banister, 2007; Höjer and Åkerman, 2006; Persson et al., 2019; Swedish Transport Administration, 2020b) highlight that new technology is not considered to be enough to reach the aims of the Paris agreement. According to these studies, car ownership and car use should also decrease if the climate objectives are to be met. Plans for encouraging walking, cycling, and public transport while lowering car use is also beneficial in order to meet a number of other policy objectives in urban planning, such as accessibility for residents, air quality, and public health.

Minimum parking standards have been criticised for leading to urban sprawl, extensive land use, increased construction and living costs, fewer flats, as well as to increased car use and consequently higher CO_2 emissions (Shoup, 1997; Marsden, 2014; Liljenström et al., 2015; Andersson et al., 2016; Christiansen et al., 2017; Millard-Ball et al., 2020; Franko, 2020). For instance, Millard-Ball et al. (2020) show that more on-site parking spaces lead to higher car ownership and car driving in San Francisco, and that these effects are not due to self-selection biases. Shoup (1997) and Franko (2020) argue that the cost of free parking is paid either through higher living costs, or through higher

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retail prices. Liljenström et al. (2015) further show that building parking spaces in garages causes considerable CO_2 emissions. In light of these criticisms, many municipalities have revised their parking standards. Some cities use maximum parking standards, as is the case with London (Li and Guo, 2014), and some cities use flexible parking standards, like in Stockholm, where focus is shifted from parking spaces to providing mobility and accessibility for residents (Johansson et al., 2019). Furthermore, a range of policy innovations are discussed, such as new ideas for earmarking parking revenues for sustainable transportation (De Lange, 2014), and even involving citizens in the decision-making process (Kolozsvari and Shoup, 2003; Johansson et al., 2017).

Despite changed policy objectives and ambitious national and municipal climate objectives, current parking policies in a country like Sweden do not seem to steer towards a future where the climate objectives are reached. Municipalities such as Stockholm require parking spaces to satisfy the current demand for parking, with some discount for mobility services (e.g., City of Stockholm, 2015; Envall and Johansson, 2020), without taking fully into account the Paris Agreement. Stockholm is expected to build 30,000[1] new parking spaces between 2020 and 2030. At the same time, our estimates indicate that about 60,000[2] residential parking spaces should be removed in Stockholm during these ten years to be in line with the Paris Agreement. This paper explores a policy path where a shift in parking policy is seen as necessary in order to meet the obligations of the Paris Agreement. This entails a new policy paradigm where climate goals are not assumed to be met merely through technological improvements to vehicles, as is at least implicitly assumed in many current parking policies.

There are previous studies analysing how the transport sector can develop in line with climate targets (e.g., Höjer and Åkerman, 2006; Hickman and Banister, 2007; Lopez-Ruiz and Crozet, 2010). However, there is less research on how parking management can be designed to be consistent with the Paris Agreement. In this article, we will intend to fill this research gap.

1.2. Aim

The aim is to explore strategies for parking and mobility that are in line with the emission reductions required in the Paris Agreement. This is done by presenting a future vision for the year 2030, when the terms of the Paris Agreement are reached, and identify a pathway towards this vision. The aim is furthermore to discuss the effects of this future vision on equity, and how a transition towards this future image can be made equitable.

The scope of this article is limited to residential parking and mobility. Stockholm is used as a case study, since a case allows for a deeper analysis of the complex and site-specific planning situation in a large city (Johansson, 2005; Flyvbjerg, 2006).

1.3. Introduction to the case study - planning practice and regulation of parking and mobility services in Stockholm

In Sweden, parking standards are regulated by the Planning and Building Act (PBL). The law states that there must be a reasonable number of parking spaces in proximity to the residence (Planning and Building Act, 2010, Chapter 8, Section 9), but it is up to the municipalities to decide what is reasonable and what distance is considered to be in proximity. PBL thus gives municipalities considerable authority to design their own guidelines for parking, and some municipalities permit flats to be built without parking spaces, which has been tested in pilot projects (see e.g. Gunnarsson-Östling, 2021; Smith et al., 2019). However, PBL cannot directly be used to require developers to provide other mobility services than parking (e.g., car or bicycle sharing), or to set quality requirements for parking (e.g., the design of bicycle parking) (Envall, 2020; Swedish State Public Investigations, 2021).

The City of Stockholm has used minimum parking standards since the 1950 s (Lundin, 2008). The standards were copied from the United States, and took into account an expected increase in future car ownership. In 2015, the City of Stockholm revised its guidelines for parking, and went from having minimum parking standards to so-called Green Parking Standards (City of Stockholm, 2015). The current standard is divided into two parts. The first part is a minimum standard based on car ownership in Stockholm in the year 2015. The standard is an interval between 0.3 and 0.6 parking spaces per flat depending on the property's location (e.g., access to high quality public transport, proximity to central Stockholm and urban activities). The second part is voluntary, and aims to reduce the demand for parking spaces. Developers are given the opportunity to reduce the parking requirements by up to 25% if they provide mobility services such as car and bicycle sharing, high-quality bicycle parking, and conduct informational campaigns. Most developers choose mobility services that give 15 % discount (Lövfling, 2020).

However, the Stockholm Green Parking Standard omits some vital -prerequisites for meeting the city's policy objectives, and the current policy guidance is not clearly linked to the city's CO_2 emission goals. The standard does not take into account:

- the interconnection between the on– and off-street parking supply, and that residents may choose to use cheaper on-street parking rather than more expensive garages.
- that new blocks of flats built on land previously used for surface parking may lead to significantly higher parking fees (densification in Stockholm normally means that only garage parking is supplied and that cheaper surface parking is limited). When parking costs go up, parking demand goes down. Increased parking costs also improve the competiveness of car share services, which generally leads to reducing residential parking demand (Martin et al., 2010; Schreiner et al., 2018).
- the construction cost of new parking spaces when setting the parking requirement. This may mean that high costs of parking reduces the number of flats built on a particular site.
- the opportunities to reduce parking demand in the neighbourhood around a new development by offering access to mobility services. Offering mobility services could reduce the need to own a private car at the same time as local residents' access to personal cars is improved.

Planning officers may to some extent, and at their discretion, take into account the above-mentioned points, but they are seldom known to do so even when decision support suggests that doing so is important for a functional parking market (Envall, 2021).

A new plan for on-street parking fees was implemented in Stockholm in parallel with the Green Parking Standards. In the inner city, the time that parking fees were charged was extended from 9 am – 5 pm to 7 am – 7 pm to reduce the incentive to commute to work by car (but there are still no fees charged during the night). On-street parking fees were also introduced in suburbs closest to the inner city. The implementation of on-street parking fees was made more difficult by legislation passed in 1957. This law gives municipalities the right to charge for on-street parking, but only to manage traffic, and it is questionable whether parking fees can be used to further environmental goals (Johansson

[1] 80,000 flats built with 0,45 parking spaces per apartment, and with a 15 % discount for mobility services (see appendix).

[2] The population in Stockholm is expected to increase by 14 % between 2019 and 2030 (City of Stockholm, 2021a). A 27 % reduction in car ownership (which is assumed to be needed to reach the Paris Agreement, see chapter 3) leads to 60,000 fewer residential parking spaces, with the assumption of one residential parking space per car (see appendix).

et al., 2017). The City of Stockholm also uses residential parking permits, which gives residents in an area the right to park at a subsidized tariff[3]. Furthermore, Stockholm has plans to implement mobility hubs to increase the availability of vehicle sharing (Lövfling, 2020). However, national legislation does not allow municipalities to reserve on-street parking spaces for vehicle sharing, which makes implementation of mobility hubs more difficult.

2. Analytical framework and method

2.1. Analytical framework

When studying the future, a common approach is to make predictions about the future based on trends and causal relationships observed in the past. These predictions depict one possible future. However, trends and causal relationships from the past do not necessarily continue in the future (Hickman and Banister, 2007). Historical studies (e.g. Geels, 2012) show that new technology and institutional arrangements often are disruptive and may change the rules of the game. When desired goals are not likely to be met with current trends, backcasting may be a more suitable approach (Dreborg, 1996; Höjer and Åkerman, 2006; Hickman and Banister, 2007; Lopez-Ruiz and Crozet, 2010; Soria-Lara and Banister, 2017).

The idea behind backcasting is to set targets and to envision futures where these targets are met (Börjesson et al., 2006). Backcasting can also be used to construct pathways to these future scenarios, and is particularly useful when radical change seems to be needed. Within backcasting the concept *future image* is commonly used for a scenario depicting a future state in line with the normative targets of the study. The underpinning idea of this article is thus to present such a future image (among many possible ones) where the terms of the Paris Agreement are met. This approach intends to open up the scope of planning strategies that seem possible and useful, as starting points, for a discussion about what policy measures could facilitate reaching the targets. The future image in this article is placed nine years into the future, when much of the infrastructure is expected to be intact. However, social structures and patterns of action related to vehicle ownership and car use are expected to develop in new ways within the time span (of nine years). The development of the future image is guided by transition theory (Geel, 2012). In line with this, practices that are marginal today (e.g., car sharing) are seen as niche practices that grow and develop into a future parking policy regime, supported by changes at a landscape level. The future image illustrates a future where such a regime has been realised.

2.2. Method

We, the authors, have chosen a multi-method approach with several iterations for our study. The future image has been constructed as a normative, transformative scenario (Börjeson et al., 2005). A backcasting method often contain four steps, namely, a) to define the targets, b) to assess current trends, c) to present a future image and pathway and d) to analyse the future image and pathway. This paper follows these steps, with a particular focus on step c) and d).

Backcasting studies normally includes several contrasting future images, as a way to show different possible futures. In this article, however, we have chosen to focus on only one future image, to make it possible to discuss the pathway more in depth. The pathway is contrasted with the current parking policy. The reader should be aware that other other goal-fulfilling futures are possible, and it should also be fruitful to look into different governance options (e.g. market, public authorities and public participation).

To create the future image we used ongoing research (i.e. a parallell project on CO_2 targets for transportation), a literature review, workshops and interviews to come up with useful ideas for our purpose (see Fig. 1 for the process). The first step included collecting inputs from statistics, other research projects and academic literature on parking and car sharing. This was followed by a Researchers' WS (step 2), in which problems in current planning for parking were identified, and ideas for improvements in relation to these discussed. The authors of this paper developed these ideas into a scenario element draft. This was followed by a Practitioners' WS (with participants from municipalities, mobility service providers and consultants. See step 3 in the figure below). This WS started with a discussion of the scenario element draft, and of the potential and drawbacks of draft measures. Then the practitioners were asked to come up with additional ideas and proposals. Following this, interviews were made with the participants in the practitioners' WS, in order to further develop ideas they had brought up in their WS. The ideas and views from the participants in the practitioners' workshop were used together with the literature review to develop the scenario elements. The scenario elements were then used to develop a future image (step 4) and a pathway towards the future image (step 5), but the final pathway was developed by the authors of the article. In futures study terminology, the paper is thus an expert driven study with input from different stakeholders. In the end of the paper we analysed the pathway in terms of distributional equity, acceptance and feasibility with the use of literature (step 6).

3. Climate targets and implications for parking and mobility

In this paper, we assume that greenhouse gas emissions should be reduced so that global warming is limited to 1.5 to 2 degrees Celsius in accordance with the Paris agreement. Assuming a "contract and converge" development of emissions, this means that Swedish consumption-based emissions should be almost halved between 2010 and 2030. The Swedish target for direct emissions from domestic transport is a 70% reduction between 2010 and 2030. This target, however, does not include sea and air transport or emissions associated with the production of fuels, manufacturing of vehicles, and infrastructure building and maintenance. Annual indirect infrastructure-related emissions amount to nearly 2 million tonnes of carbon dioxide, and those associated with the manufacturing of vehicles amount to around 3 million tons (Liljenström et al., 2021). These figures may be compared to the total direct emissions of Swedish road transport, which in 2019 were 14.8 million tons (Swedish Transport Administration, 2020a).

Regarding emissions from building parking garages, which are not included in the above figures, data is scarce. An assessment has been made of GHG emissions from the building of a garage under a block of flats in Upplands Väsby, a suburb of Stockholm. The emissions per parking lot was estimated at around 10 tons of carbon dioxide (Ejlertsson, 2019). If 50% of the parking lots built every year in the city of Stockholm were garages, that would correspond to roughly 15,000 tons of carbon dioxide.

With the electrification of the car fleet, the relative share of emissions that stems from such "indirect emissions" tend to increase. The relatively high emissions for manufacturing cars means that the number of cars need to be limited to some extent, including electric cars. Furthermore, due to the longevity of cars, it will be difficult to electrify more than one third of all vehicle-kilometres by 2030.

In this paper, focus is on the demand for residential parking, which obviously corresponds well to car ownership. Table 1 presents key characteristics of an Image of a future transport system for Stockholm 2030 that is in line with the national target of reducing total domestic transport emissions by 70% between 2010 and 2030. The figure for car travel is based on scenario D3 by the Swedish Transport Administration

[3] Residential parking permits cost 1,100 SEK /month (or 75 SEK /day) in the city centre, 500 SEK /month (or 35 SEK /day) in suburbs closest to city centre, and 300 SEK /month (or 20 SEK /day) in suburbs farther away from the city centre.

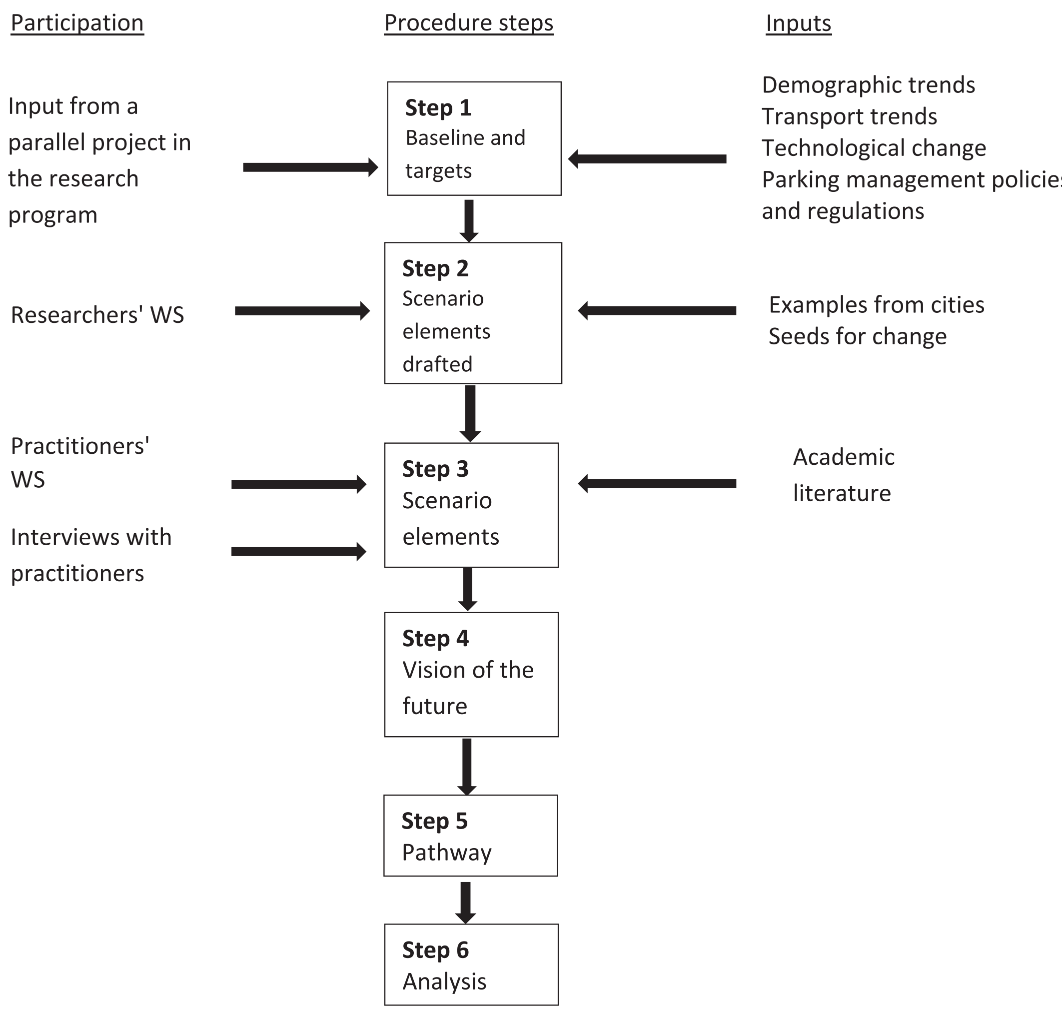

Fig. 1. Scenario building procedure (presentation inspired by Hickman and Banister, 2007).

Table 1
Key characteristics of a future image for Stockholm reaching the climate target for 2030.

Indicators	2018	Future image 2030
Car travel per capita	5640 km per inhabitant (City of Stockholm, 2021b)	−25% compared to 2018
Car intensity	370 cars/1000 inhabitants (City of Stockholm, 2021c)	−27% compared to 2018
Share of households that use car sharing	2 % (City of Stockholm, 2021d)	15%
Share of km travelled in electric mode	0.4% (Swedish Transport Administration, 2020b)	30%

(2020b) in which car travel nationally is reduced by 19% compared to 2018 in order to meet the target for 2030. In scenario D3 the supply of biofuels is exclusively from sustainable domestic sources. Considering a national population growth of 6% between 2017 and 2030 (SCB, 2021) this would yield that a 23.5% reduction of car travel per capita is needed. Since the potential for reduced car travel is higher in large cities we have assumed a 25% reduction of car travel per capita in Stockholm. The potential for car sharing is highly uncertain and estimates are rare. The Swedish Road Administration (2003) has estimated the theoretical potential to 25% of all households in Sweden. In the Future Image we have assumed that 15% of the households in Stockholm participate in car sharing schemes, which is roughly in accordance with Persson et al. (2019). We have also assumed that shared cars have a twice as high yearly mileage compared to the average car in the fleet. In combination, the two asumptions mean that the car fleet will be reduced slightly more than the distance travelled (see Table 1). The modal share of electric car travel is also derived from scenario D3 in Swedish Transport Administration, 2020b.

4. Scenario-elements

This chapter describes the scenario elements used to develop the future vision and the pathway. The scenario elements are divided into three areas: 1) Parking policy, 2) Mobility services, and 3) Measures for acceptance and equity. This section is a result of the literature review and the two workshops (see section 2).

4.1. Parking policy

This chapter consists of three types of measures: removing parking subsidies, converting parking spaces, and planning for alternative uses of parking. These measures are in line with what previous articles have recommended. Mingardo et al. (2015) argues that parking should be a part of a citýs travel demand management strategy, and that it should include both off- and on-street parking fees, and travel demand strategies. Kirschner and Lazendorf (2019) have identified five themes on how parking policies can both contribute to sustainability and livability: maximum parking requirements, physical detachment of parking spaces from residences, residential parking permits and limitation of available parking, performance based parking, and parking as a demand strategy.

4.1.1. Removing parking subsidies

One of the arguments against minimum parking standards is that they lead to parking being subsidized by those not owning a car (Shoup, 1997: Franko, 2020; Andersson et al. 2016). Minimum standards steer towards an increased supply of parking, which leads to lower parking fees. Envall et al. (2014) have estimated that the subsidy for off-street residential parking in Stockholm is 26% – 56%. Franko (2020) estimates that minimum parking standards in Los Angeles increases construction costs for apartment buildings 24% – 75% depending on the area. In addition to discussions about fairness, lower parking fees contribute to a reduction in the costs associated with car ownership, which can lead to higher car ownership.

Some cities use maximum parking standards (Marsden, 2014; Li and Guo, 2014). An example is in London, where the minimum parking standard was replaced with maximum standards in the early 2000 s (Li and Guo, 2014). A ceiling was set on how many parking spaces are allowed to be built on a property, and the standard makes it possible to build homes without parking spaces (as many developers did in central London). On-street parking was regulated at the same time, and residents with cars can rent parking space from commercial operators (Li and Guo, 2014). Mexico City has also replaced their minimum standard with a maximum standard. In Mexico City, developers have to pay a fee if they build more parking spaces than half the maximum ceiling, and the revenues are used to finance public transport and affordable housing (ITF, 2021). Zurich has used a maximum ceiling for parking since the 1990 s (Gies et al., 2021). Unlike the other examples, the maximum ceiling concerns central Zurich and includes all parking spaces. The maximum number of parking spaces in central Zurich is set at the 1990 level (comprising about 7,600 parking spaces), and when an off-street parking space is added it is stated that an on-street parking space should be removed (Gies et al., 2021).

The possibilities for charging parking fees that cover operating and investment costs are closely linked to how parking in the adjacent area is regulated. If, for instance, it is free to park on the street in an area, it will be difficult to charge high parking fees for off-street parking. A prerequisite for removing parking subsidies is thus to regulate on-street parking. Several reports also point out that parking should be separated from the residence (e.g. Kirschner and Lazendorf, 2019). An example of this is in Vauban (in Freiburg, Germany), where parking is sold separately from the residence (Foletta and Field, 2011).

4.1.2. Conversion of parking spaces

Parking takes up a lot of space, and the space that is freed up when parking is removed can be used for other purposes, such as for other means of transport or for places such as outdoor cafes and parks. There are examples of cities that are already working according to these principles, such as Amsterdam, Oslo, Paris, and Barcelona.

In 2020, the mayor of Paris announced that 72% of Paris' on-street parking spaces should be removed to accommodate cyclists (60,000 out of 83,500 parking spaces) (PARK4SUMP, 2021). Amsterdam is aiming to remove 11,000 on-street parking spaces in the city centre by 2025 by reducing the number of residential parking permits with 1,500 per year, and using the space for trees, wider sidewalks, and bicycle parking. In Amsterdam, no new parking permits are issued, which makes it possible to remove 1,100 permits each year without having to revoke anyone's permit (O'Sullivan, 2019).

Parking garages are also being converted in several places. In Los Angeles, several garages in residential buildings have been converted into housing, even though it was not allowed according to the parking standard (Brown et al., 2020), and in Södermalm in Stockholm, 1,300 parking spaces in garages have been converted into shops and other premises (Envall, 2012).

4.2. Mobility services

Municipalities and other stakeholders probably need to pave the way for shared mobility in several ways and at several levels to enable the necessary rapid and big transition towards vehicle sharing. There are cases of residencies where the parking standard has been reduced in exchange for mobility services, e.g. in two Homeowners' Associations in Stockholm County (Johansson et al., 2019), as well as in other Swedish cities (see e.g. Sprei et al., 2020). A survey among the households living in these two HOA:s in Stockholm County showed that 10–20% of the households had used car sharing within a year after moving in, whereas less than 1% were members of car-sharing schemes before they moved (Johansson et al., 2019). This survey also indicates that it is mainly those who do not own a car that use the car sharing. In the same study, interviews indicate that the availability of car sharing has motivated some residents to get rid of a private car, and others to not acquire one (ibid). There are also a limited number of on-going pilot projects in which car parking in already built areas is restricted and mobility services are provided (Sopjani, 2020). In these pilot projects, parking fees are increased, and the revenues are used to finance mobility services (e.g., car and bike sharing). Evaluations of these projects are still scarce.

There is more literature on car sharing services. Several studies indicate that car sharing leads to lower car ownership and reduced car use (Martin et al., 2010; Åkerman and Nyblom, 2014; Schreiner et al., 2018; Johansson et al. 2019) even though most who join car sharing services do not own a car (Martin et al., 2010). At the same time, car sharing can improve accessibility for those who do not own a car (Johansson et al., 2019). Car sharing can also reduce the environmental impact through, for instance, reduced resource consumption due to lower car ownership and fewer parking spaces, and because car-sharing vehicles are newer and more energy efficient (Chen and Kockelman, 2016). Chen and Kockelman's study (2016) shows that car-sharing members' CO_2 emissions from local transport are reduced by 51% from a life cycle perspective.

Martin et al. (2010) show in an article that each car-sharing vehicle replaces an average of 9–13 privately owned cars (includes those who did not acquire a car because of car sharing). Round-trip car sharing seems to reduce car ownership more than one-way (free-floating) car sharing (Shaheen et al., 2019).

Private car sharing, commonly called peer-to-peer (P2P), has grown in recent years. Private individuals can rent out their private car to others through a digital platform. According to Dill et al. (2019), P2P car sharing has the potential to spread in areas where traditional car sharing is difficult to sustain economically. Evaluations are still scarce, and they indicate that more people get access to a vehicle, but the effects on car travel and car ownership are less conclusive. An evaluation by Shaheen et al. (2018) indicate that P2P car sharing can lead to slightly increased car travel and slightly reduced car ownership.

Our conclusion is that car sharing enables more people to have access to a car at the same time as car ownership declines. Furthermore, car sharing is an important measure to increase acceptance of other measures leading to reduced car ownership. Even if certain forms of car sharing may contribute to increased car use by some groups, car sharing is important as it can increase acceptance for a whole package of other measures that steer towards the 2030 goals.

4.3. Measures for acceptance and equity

Restrictive measures, such as parking fees, are often unpopular. However, research indicates that a package of measures in which restrictive measures are combined with improved mobility may increase popularity (e.g., Kirschner and Lanzendorf, 2020). Kirschner and Lanzendorf (2020) also show that many people are positive about removing parking spaces if the space freed up is used for something else. Other studies suggest that citizen participation also may increase the acceptance of parking fees (Kolozsvari and Shoup, 2003).

One way of involving citizens in the decision-making process is through mobility funds. An example of a mobility fund, where citizens are involved in the decision-making process, is Seestadt Aspern in Vienna, Austria (Johansson and Envall, 2020). There are also examples of mobility funds that have been introduced in existing residential areas. In the USA, there are examples of Parking Benefit Districts, where on-street parking fees are implemented, and the revenues are earmarked for measures in the area. Residents in the area are involved in deciding which measures are to be implemented (Kolozsvari and Shoup, 2003; Johansson et al., 2017). One of the main reasons for Parking Benefit Districts has been to increase acceptance of parking fees (Kolozsvari and Shoup, 2003). However, Johansson et al. (2017) claim that participation in itself can be positive (e.g., through empowerment).

Many of the scenario-elements discussed are used in cities around the world, but there is a lack of policy packages for parking and mobility services that are in line with the Paris Agreement.

5. Parking and mobility in Stockholm 2030 – A future image

In this chapter, we present a future image of parking and mobility, which shows how policy opportunities can be taken advantage of when striving to achieve the goals indicated in Chapter 3. The future image illustrates one possible configuration of everyday practices in Stockholm in 2030 that are enabled by policies implemented in the 2020 s (see Ch. 6). We use the present tense as if the measures and scenario-elements were already in place:

In year 2030 Stockholm is characterized by efficient and climate friendly utilization of resources, such as sharing of vehicles. Experiences and views regarding sharing have changed, and an increasing part of the population takes sharing in urban travel for granted and expect it to continue developing. Appreciated aspects include not having to perform maintenance on vehicles or worry about unforeseen expenditures. Being able to access a wide variety of vehicles, including vehicles you could otherwise not afford, is commonly perceived as a benefit. These were preferences that vehicle-sharing users already expressed in the 2010 s (Svennevik et al., 2020), and now they have become more widely embraced. In 2030, about 15% of Stockholmers use a car-sharing service regularly (compared to 2% in 2018). Sharing has gained the most ground in the city centre and among younger people who join car sharing services and thereby postpone buying a car. The use of car sharing has also become widespread among pensioners, who get rid of cars when they retire and start using car sharing instead, as they no longer use a car as often and can reduce their costs (Johansson et al., 2019). Car sharing is also, to some extent, replacing a household's second car.

In 2030, Stockholmers have access to a wide range of mobility services in their vicinity; electric cars of various sizes, including microcars, and bicycles and cargo bikes. Sharing services come in a variety of forms, from commercial operators to cooperatives. Private households also rent out their vehicles through digital platforms. In total, there are about 7,500 cars and at least 7,500 bikes [4]in the vehicle-sharing (excluding P2P vehicles) system in Stockholm. In addition, informal car sharing has increased considerably, such as within the family, and between friends and neighbours. This has been facilitated by new possibilities to co-own vehicles.

In 2030, car ownership and car travel per capita have decreased by 27% and 25%, respectively, compared with 2018. The changes in car ownership and car travel are associated with a number of other changes in society. The proportion of employees who work at home and the proportion of digital meetings have continued at a high level after the Coronavirus pandemic ended, but the proportion is significantly higher among those who can work from home (and higher among those with higher-incomes). Commuting by car and business trips by car is low, and people are instead travelling by public transport and bike, and are using digital meetings/working from home. Those who still commute by car, especially to attractive workplace locations, have to pay parking parking fees at work. Shopping trips by car have also decreased considerably by 2030. External shopping centres have become less frequented, and more people do their grocery shopping by foot or with cargo bikes at their local centre (which has grown and now has local markets every Sunday). Many Stockholmers still use cars for leisure trips and vacations (even though car use has also decreased for these trips), and many use car sharing for these trips. An increasing number of people also travel by train and rent a car at their destination, which reduces the distances travelled by car.

Travel patterns vary considerably between different parts of the city. In the inner city, which has a higher proportion of affluent households, car use and car ownership is very low. City centre dwellers have good access to urban amenities in their neighbourhoods, and many do not need a car. They have access to good public transport and bike infrastructure, and can receive home delivery to the local mobility hub. When they need a car (e.g., for vacations), they can use car sharing. Many people who did not own a car or bike before have access to a variety of cars and bikes near their home. Car owning households park their cars in car parks legally separated from their residence and pay on average 2,000 SEK per month.

Car dependency is higher in the suburbs (especially farther away from the city centre, where 30% of trips were made by cars in 2019, Region Stockholm, 2020) even though car dependency has decreased considerably since the 2020s. Car ownership has also decreased, although mostly among young people (who postpone car ownership) and pensioners (who sell their car when retiring), but to a lesser extent than in the city centre. The public transport supply varies. Most areas have good public transport towards the city centre, but they are not as well served for trips between suburbs. Local centres have been strengthened, and have a larger supply of services and amenities than in the 20 s, which has led to more errands being carried out locally. There are also mobility hubs in the local centres where Stockholmers can pick up home deliveries, leave things they need to get rid of, and rent vehicles. Many Stockholmers, who did not have access to a car/bike before, use these services frequently. An increasing number of households, especially low-income households, own vehicles together with family members and friends, and many also rent out their car through a P2P platform. Car-owning households in these suburbs park their cars in car parks, but to some extent also on the street (especially people living in new residences built without parking spaces). The suburban car parking fee is on average 1,500 SEK per month for a parking space.[5]

Finally, 2030 is characterized by higher civic participation. The City of Stockholm has developed various forums for this, and citizens are given the opportunity to actively participate in the design of their neighbourhood. Stockholm was inspired by several other European and South American cities when they introduced mobility funds and participatory budgets. Each district in the city has a mobility fund that the residents in the district decide over.

6. A pathway towards a Stockholm in line with the Paris Agreement

This chapter describes a path to the future vision for 2030. This chapter is also written in the present tense as if the transition already has taken place:

[4] There were about 900 car-sharing cars and 1500 cars in P2P car sharing in Stockholm in 2020 (City of Stockholm, 2021e). We base these figures on the ratio 1 car/bike per 10 user of the vehicle service. If 15 % of the population use car/bike sharing 7,500 cars/bikes would be needed.

[5] 30% of stockholmers could park for free near their residence in 2019 (Region Stockholm, 2020).

6.1. Mobility services

To make car-sharing vehicles available, the City of Stockholm used several strategies.

- Mobility standard for building permits
- Conversion of Stockholm Parkering's car parks into mobility hubs
- On-street mobility hubs
- Mobility funds
- Co-financing of mobility funds from the state

In the beginning of 2022, the City of Stockholm started to use mobility standards for new housing. The new policy was implemented shortly after changes were made to the Planning and Building Act (PBL), which made it possible for municipalities to set requirements for mobility services in new buildings (Swedish State Public Investigations, 2021). The requirement of building a minimum number of parking spaces per housing unit (the parking standard) was removed, and it became possible for developers to build residencies without car parking. Instead, a study is carried out to develop context-specific mobility solutions in line with the cap on parking spaces (see Chapter 6.2) and the climate goals. With the new legislation, the municipality can demand that residents have good accessibility, and guarantee that a minimum of mobility services are available. The City of Stockholm used its new mobility standard to require mobility services in new apartment buildings.

This means that households in 80,000 new flats have access to mobility services near their homes. Furthermore, Stockholm Parkering, the municipal parking company, was commissioned to convert their parking garages into mobility hubs at the beginning of 2022 in order to offer both car parking and other mobility services. Stockholm Parkering also implemented on-street mobility hubs in several areas, which was made possible by a change in legislation. The mobility hubs also offer home delivery boxes and a service to transport things away from home. Furthermore, several property owners provided incentives for private car sharing by reserving parking spaces for vehicles shared through a P2P platform.

Finally, the City of Stockholm implemented mobility funds called Mobility Benefit Districts (MBD), where the revenues from parking fees are earmarked for measures targeting sustainable mobility, and citizens are involved in how the money is to be used. MBD are used in the whole city, and each city district has its own fund. The MBD are financed through several mechanisms:

- Revenues from on-street parking fees, and a proportion of the revenues from Stockholm Parkering's car parks[6].
- Revenues from the tax on off-street parking.
- 50% co-financing from the State through urban environment agreements[7].

The MBD is used to finance mobility services and infrastructure that promotes sustainable mobility in the area. The selected measures are introduced at the same time as the parking restrictions to increase acceptance (see Ch. 6.2). To increase equality, Stockholm chose to distribute revenues through distribution keys. Areas with more low-income households received a larger share of the funding per capita than areas with fewer low-income households.

6.2. Parking policy measures

Parking-related measures were introduced in parallel with the implementation of mobility services. The following measures were introduced:

- Cap on number of parking spaces in the city
- Increased fees for, and gradual removal of, residential parking permits
- Extension of on-street parking fees
- Diversified on-street parking fees depending on vehicle size
- Removal of on-street parking, and conversion to other uses
- Separating parking from residential buildings (unbundling)
- Provision of a digital platform so that Stockholm Parkering can rent out vacant parking spaces
- Building standards that facilitate the conversion of off-street parking

The first measure was to concretize the cap for parking spaces in the city. Stockholm set a goal of removing 6,000 parking spaces per year for ten years[8]. On-street parking was mainly removed[9], but also off-street parking. The cap applies to the entire city of Stockholm, but specific parking and mobility studies are made for each area to ensure that all citizens have good accessibility and access to mobility. The study includes an assessment of how many parking spaces can be removed in an area, the need for a walking, cycling, and public transport infrastructure, as well as the need for mobility services. The cap works as an overall framework for the parking policy, and is linked to the municipal traffic strategy and national transport planning through an urban environment goal (Tennøy and Hagen, 2020; National Board of Housing, Building and Planning et al., 2020).

The second step was to extend the charging period for on-street parking to 24 h a day (to reduce the possibilities of parking for free by commuting to work), and to gradually expand on-street parking fees to the entire city. In the beginning of the 2020 s, the legislation made it hard for Stockholm to extend the parking fees, but it changed in 2023, thus permitting parking fees to be charged in order to steer towards environmental goals. The city of Stockholm also diversified on-street parking fees depending on the size of the cars. Longer cars take up more space and thus have to pay a higher fee. These reforms have reduced the possibilities of parking more cheaply on the street than in car parks.

The third step was to increase the fees for residential parking permits[10], and then to gradually remove the permits. The possibility of having a residential parking permit for a period shorter than one month was removed 2022[11], which meant that more than 40,000 residential parking permits could be removed. The next step was to gradually reduce the number of residential parking permits and remove the same number of on-street parking spaces (about 30,000 out of 37,000 on-street parking spaces in the city centre, and approximately 20,000 spaces in the suburbs). The parking spaces that were removed were converted into public transport lanes, cycle paths, wider sidewalks, mobility hubs, etc. In parallel, off-street parking was gradually removed. In some places, parking spaces were removed when new homes were built on car parks. To a certain (but lesser) extent, car parks have been converted into homes and other premises.

[6] The revenues from on-street parking was 835,6 million SEK in 2020 (excl. VAT) (Jonsson, 2021).

[7] This requires a change in legislation, permitting the Swedish Transport Administration to finance measures that reduce the need for transport (Johansson et al., 2018).

[8] 60,000 parking spaces corresponds to about 15% of the residential parking spaces in the city.

[9] In 2020 there were about 65,000 on-street parking spaces with parking fees in Stockholm, and there are large areas without on-street parking fees.

[10] In the city centre, the fees were increased from 1,100 SEK to 1,800 SEK per month. In the suburbs closest to the city centre from 500 SEK to 1,500 SEK, and in the outer suburbs from 300 SEK to 1,200 SEK a month.

[11] In 2020, 68,000 Stockholmers had residential parking permits whereas 25,000 people had monthly subscriptions.

The fourth reform dealt with unbundling (separating) parking from the residential building. The public housing companies (Stockholmshem, Familjebostäder, and Svenska bostäder) took the lead at the beginning of 2023 and gradually handed over responsibility for their parking spaces to Stockholm Parkering. Stockholm Parkering was given responsibility for the parking spaces and charged fees that covered operation and investment costs for parking. The parking spaces are open for rent to everyone and are no longer connected to a specific property. This, together with regulated on-street parking, led to a removal of parking subsidies and made it possible to reduce the rents with approximately 300 SEK per month (Andersson et al., 2016). Other property owners and homeowners' associations followed suit.

Some homeowners' associations are still responsible for their parking spaces in 2030. For these associations, there is a digital platform (managed by Stockholm Parkering) for renting out vacant parking spaces outside the association. When car ownership decreased, many parking spaces remained vacant, and several homeowners' associations began using this service to reduce their costs. Several homeowners' associations also have reserved parking spaces for P2P car sharing, increased their parking fees, and reduced the association fees.

The fifth policy reform was to introduce a tax on off-street parking. Stockholm was inspired by Perth and Nottingham (Envall and Renhammar, 2013). Tax on off-street parking, also called parking levies, have reduced the number of car parking spaces by 10% in Perth, Australia (Nottingham, 2008, p. 42). Tax revenue also gives public authorities the resources needed to expand public transport networks (UK Parliament Session, 2013) and support increased availability of car and cargo bike-sharing services. A change in legislation in 2024 made it possible for municipalities to charge taxes for off-street parking, which the City of Stockholm did at the beginning of 2025. Revenues from the tax are earmarked for the mobility fund and returned to the municipality provided that they follow the urban environment goal (to reduce car traffic in accordance with the Paris Agreement).

The final policy measure was to facilitate the future conversion of off-street parking when building new car parks. In 2030, most new flats are built without new parking spaces, and residents are instead directed to existing parking in the area. However, there are a number of new urban development areas (e.g., Årstafältet) where there are no existing buildings in the vicinity. In these areas, Stockholm Parkering has built new mobility hubs with both mobility services and car parks. The parking spaces are separated from the residences and rented out without a subsidy. Since car ownership is gradually declining, these parking spaces have been built flexible in order to facilitate their conversion into something else as the decline continues. Two strategies were used:

- Off-street parking was built to facilitate its conversion into natural land or parks when parking is no longer needed.
- Parking in garages is built with future conversion in mind. This means, for instance, that they are built in buildings that have higher ceilings and are not too "deep" (to ensure enough sunlight in the whole building).

These parking spaces are also included in the cap for parking, which means that for each new parking space provided, another parking space is removed elsewhere in the city.

7. Analysis of the pathway

7.1. Distributional effects and equity

In order to analyse distributional effects in a comprehensive way, we first deal with the mobility and accessibility measures of our scenario, and then with parking restrictions.

7.1.1. Mobility and accessibility measures

Behind mobility measures such as requirements for vehicle sharing lies policymakers' intentions to improve travel opportunities for inhabitants without their own cars. Correspondingly, the intention of measures for citizen participation is to adapt the local living and traffic environment to facilitate modes of transport other than private motoring.

More generally, the alleged purpose is to, in a fair way, suit all groups' needs for accessibility. In practice, the measures should lead to that resources such as land and financial resources can be used to a greater extent for green areas and for less energy-intensive modes of transport than today, mainly by making investments in pedestrian, bicycle, and public transport (and to disinvest in parking lots and underground parking).

Groups with low mobility are to a greater extent dependent on local environments and activities. In large European cities, groups with low income are more dependent on public transport and active modes of transport, compared to high income groups (cf. Nicolas and Pelé, 2018). Therefore our conclusion is that the measures for mobility and accessibility we have addressed could particularly benefit low-income groups and/or groups with low mobility, but still have mainly positive effects for all groups. The same goes for the aspect of the parking measures intended to finance investments in walking, cycling, and public transport, and provide space for activities other than traffic on streets. One such measure is to increase parking fees (but less so for shorter/smaller cars). Another parking measure is intended to free up land currently used for parking for purposes such as natural land/parks, and correspondingly, to free up parking garages for conversion to other uses (e.g., storage, housing and other premises for companies and association activities). Our analysis is therefore that increased street space for walking and cycling (and other means of micromobility) should be positive for all income groups, while the other intended accessibility effects we have discussed particularly benefit low-income groups. In addition to the fact that the measures we discuss are intended to create accessibility and space for other uses than car traffic, they also contain restrictions on parking and private motoring, which will be dealt with next.

7.1.2. Distributive effects of parking restrictions on access to a car

Among low income groups of larger cities, car ownership is generally low (Nicolas and Pelé, 2018). Nevertheless, there is a large minority of car owners in these groups as well, especially in suburban multi-person households with adults who work or study (ibid). Therefore restrictions could be expected to have more just distributive effects when applying them where low income groups have a wide spectre of alternative means of transport, e. g. currently in more central parts with good access to public transport and vehicle sharing. Even though a large part of the group can benefit from the mobility and accessibility measures, as well as the redistributive aspects of parking measures, car owners with low or uncertain income could be expected to react early to parking restrictions (that overall make parking more expensive and not so easily available). These car owners could be expected in the short term to seek cheaper parking further from home, and in the slightly longer term not to have a car of their own anymore. Alternatively, they could be expected to spend an ever higher share of their income on parking because they have reasons such as job, family or health related obligations (cf. Mattioli et al., 2018; Ortar, 2018). Demonstrated ways to exit car ownership in these groups are currently to sell it, or give it to family and relatives who live in more suburban or rural areas with access to less expensive parking. They could also keep the car but park it with their relatives (Johansson et al., 2019). Groups with higher and more secure incomes are, to a lesser extent, expected to change car ownership or parking location. This means that a distributional effect of the parking measures is expected to increase the car ownership gap between groups with low and high incomes.

The accessibility to cars that are shared commercially or cooperatively is currently lower in low-income areas, than other urban areas (cf. Kyeongsu, 2015). If this difference persists when car sharing possibly increases in society, it will further widen the gap between high- and low-income earners' access to cars. To some extent, cars that are shared within family and among relatives can possibly compensate for this, as this form of sharing currently seems to be more evenly distributed between income groups (Johansson et al., 2019). The conclusion of the analysis of the distributional effects of the parking restrictions on access to a car is that these in themselves risk increasing the accessibility gap between high- and low-income earners. It is therefore even more important that the mobility and accessibility measures that are linked to the parking restrictions have the opposite effect, which is to reduce the accessibility gap between income groups. One aspect of this, we argue, is that among low-income groups, the occasional need to use a car should also be provided for, e.g. by measures stimulating the supply of affordable carsharing (Kyeongsu, 2015). This might be through specific forms of car sharing that are also perceived as low-risk, such as in terms of insurance deductibles.

7.2. Lock-ins and feasibility

The measures described in chapter 6 signify a rapid shift in how cities plan for parking and mobility. Many of the measures proposed in this article have already been implemented in various cities, which indicates that they are feasible. The innovation in this article is to take a holistic approach to parking and mobility, where car-restrictive measures are implemented together with mobility measures. Several of the measures proposed require changes in legislation. Since there are less than 9 years left until the year 2030, and it takes time to prepare new legislation, the work preparing new legislation must begin immediately (for timely implementation to appear feasible). Alternative strategies may also be needed while waiting for new legislation to be passed or new practices to develop and spread. For instance, public housing companies and property owners can start working with parking and mobility measures such as raising parking fees, and offering mobility services and possibly lower rent, all while waiting for the implementation of new guidelines from the municipality and new legislation that enables a major transition.

Another major challenge is the acceptance of the measures (Sørensen et al., 2014). Several measures entail restrictions in the form of higher parking fees and fewer parking spaces. These are measures that question the current structure (car use and car ownership) and require changed travel patterns. There is a risk that many, at least initially, will oppose the change. Therefore, it is desirable to implement measures that facilitate for using alternative means of transport at the same time, or shortly before, the restrictions are imposed (Johansson et al., 2017). Research also suggests that citizen participation may increase acceptance (Kolozsvari and Shoup, 2003). Allowing citizens to propose measures that are implemented can empower people and increase the legitimacy of the policy. One challenge is that participation tends to be skewed towards a homogenous group of people, which can lead to increased inequality (Johansson et al., 2017). To reduce this risk, municipalities can work actively to recruit certain groups. Another alternative is participation through representation, meaning that those who live in the area choose a number of people who, together with the municipality, develop measures to be implemented. This is a model that has been tested in a district in Gothenburg.

Car ownership and travel patterns are linked to parking fees and mobility services, but to an even greater extent they are linked to how society is organized and to the laws, rules, and practices in other areas. For instance, rules and practices can be related to work (the opportunity to work at home, how business trips and digital meetings are conducted) and other errands (where people shop, go for vacation etc.). In order for a transition to be successful, measures are needed in the parking area, but also in a number of other areas that have not been addressed in this article.

8. Discussion and conclusion

This paper has analysed strategies for parking and mobility needed to steer towards a society where the Paris Agreement is reached by 2030 and has discussed how such a transition can be designed to increase equity and acceptance. The paper presented a future vision for 2030 in which the Paris Agreement is likely to be met, as well as a pathway towards this vision. Stockholm citýs current parking policy omits vital prerequisites for meeting the citýs policy objectives, and it is not clearly linked with the city's CO_2 emissions goals. Stockholm is, for instance, expected to build 30,000 new parking spaces between 2020 and 2030. At the same our estimates indicate that about 60,000 residential parking spaces should be removed for Stockholm to be in line with the Paris Agreement. The paper also presented a pathway to reach such a vision, including measures for parking restrictions, shared mobility, local accessibility, and citizen participation. The article used a set of indicators to illustrate the scope of change needed to reach the aims of the Paris Agreement. We found this approach useful for designing the pathway for parking management in line with the Paris Agreement.

Previous studies on parking proposes similar polices as in this paper, such as those by Mingardo et al. (2015), and Kirschner and Lazendorf (2019). However, these studies do not provide policy packages that are directed towards the Paris Agreement. We found the approach in this paper useful for identifying shortcomings in the current planning paradigm, as well as for providing insight into the scope of change needed to reach the aims of the Paris Agreement. For instance, decreasing car ownership frees up parking spaces that can be used by households in new residences, which require a change in how cities plan for parking. Another insight was the need to move from parking standards to mobility standards, where focus is shifted from physical parking spaces to people's mobility and accessibility, which is in line with Banister's sustainable mobility paradigm (Banister, 2008).

An important challenge is to make a policy pathway acceptable, as people negatively affected may otherwise oppose certain measures. We believe that it is important to start by implementing measures that improve resident's more sustainable mobility options and to ensure that citizens can influence which measures are to be implemented. Restrictive measures should thereafter be implemented gradually to ensure that car ownership and the number of available parking spaces decrease at the same pace, such as in Amsterdam where residential parking permits are not renewed, and thus gradually removed. Research indicates that it is often easier to postpone car ownership with the help of car sharing than to get people to actively give up their car (Johansson et al., 2019; Martin et al., 2010). This would mean that car ownership gradually decreases as young people postpone buying a car. Another challenge concerns equity. Many households in Stockholm and in other cities do not have access to a car, and the measures proposed in this article can improve their mobility and accessibility. However, there are also households that cannot afford a car when the costs of car ownership rise, or that would need to spend a large part of their income (cf. Mattioli et al., 2018). It is important to ensure that other measures compensate for this, for instance by ensuring that the alternatives to private car ownership are accessible to low-income groups to reduce the risks of inequity (cf. Diaz Olvera et al., 2004). This paper therefore included the measure of a mobility guarantee (where citizens are guaranteed a certain mobility standard, inspired by the Amartya Sens Capability Approach (cf. Pereira et al., 2017), and an extensive citizen participation process (where more funds are given to low-income neighbourhoods).

The process and the measures discussed in this article should be applicable also to other European cities. We believe that it can be useful for other cities to set targets and outline pathways for parking policies that are in line with the Paris Agreement. The challenge is to design a policy package that not only is in line with the Paris Agreement, but also considers equity and local preconditions. For instance, some cities are more car dependent (with longer distances between urban amenities and less performant public transport system) than others. These contexts need to be taken into account when discussing a local parking and mobility transition.

The Covid-19 pandemic has led to some changes in travel patterns in line with the future image in this paper. Telecommuting has increased considerably and digital meetings have replaced business trips, and car use decreased by 5 % in 2020[12] (City of Stockholm, 2021f). Some of these changes may remain after the pandemic, which reduces the need to travel as well as the need to own a private car. However, public transport use has decreased more than private car use and the modal split for cars have increased. In order to steer towards the emission reductions stipulated in the Paris Agreement, it is therefore important that public transport usage recovers after the pandemic, which may require public policies to support public transport.

CRediT authorship contribution statement

Fredrik Johansson: Conceptualization, Methodology, Writing – original draft. **Jonas Åkerman:** Supervision, Writing – original draft. **Greger Henriksson:** Supervision, Writing – original draft. **Pelle Envall:** Supervision, Writing – original draft.

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