Minimum parking requirements and car ownership: An analysis of Swedish municipalities

Citation for the original published paper (version of record):
McAslan, D., Sprei, F. (2023). Minimum parking requirements and car ownership: An analysis of Swedish municipalities. Transport Policy, 135: 45-58. http://dx.doi.org/10.1016/j.tranpol.2023.03.003

Transport Policy 135 (2023) 45–58

Contents lists available at ScienceDirect

Transport Policy

journal homepage: www.elsevier.com/locate/tranpol

Minimum parking requirements and car ownership: An analysis of Swedish municipalities

Devon McAslan *, Frances Sprei

Physical Resource Theory, Department of Space, Earth and Environment, Chalmers University of Technology, SE-412 96, Gothenburg, Sweden

ARTICLE INFO

Keywords:
Parking
Minimum parking requirements
Parking regulation
Car ownership
Sustainable transport
Sweden

ABSTRACT

Transportation is a major contributor to anthropogenic climate change driven primarily by private automobility and for nearly a century, cities have used a suite of policies and regulations that reinforce high rates of car ownership. One such regulation is minimum parking requirements, enacted to ensure that private properties can accommodate the storage of private vehicles. In recent years, cities have begun to reevaluate these parking requirements, with some municipalities reducing them, others providing opportunities for flexible parking, and some even removing parking requirements in part or all of the city. This article explores the relationship between parking requirements and car ownership by analyzing a survey of 56 municipalities across Sweden. In this paper, we develop two methods for comparing different parking metrics that municipalities use (parking spaces per apartment and parking spaces per building area). Our analysis examines variation between different sizes and classifications of municipalities. We find that across all municipalities, there is a positive relationship between minimum parking requirements and car ownership, meaning that higher minimum parking requirements are associated with higher rates of car ownership. City size is an important factor in rates of car ownership, but our analysis shows that even among similarly sized municipalities, minimum parking requirements tend to be associated with higher rates of car ownership. These findings show that reducing parking minimums can be an effective policy to reduce car ownership, but it is important to consider that these changes only impact new development and repurposing parking areas in existing housing areas may be an equally effective policy to curb car ownership.

1. Introduction

Effective parking management and the reduction or even elimination of minimum parking requirements is an increasingly common strategy used by cities in Europe and North America to encourage shifts to more sustainable transport modes. Minimum parking requirements have existed in cities since the 1920s, and by the 1950s they had been widely adopted by cities in Sweden (Lundin, 2010) as a way to ensure that new development could accommodate the parking it would generate (Ferguson, 2004). Parking requirements focus on the quantity of parking, which negatively impacts the built environment (Mukhija and Shoup, 2006). Parking can be seen as a primary link between land use and transportation planning (Genter et al., 2013; Richardson, 2014). The supply of parking requires considerable amounts of land and building area and the availability of parking impacts levels of car use (McCahill et al., 2016; Weinberger, 2012; Weinberger et al., 2008b).

As cities engage in planning to reduce automobile use and dependence, minimum parking requirements (MPRs) are increasingly debated. Many municipalities are taking steps to reduce or eliminate parking minimums in part or all of the city, introduce maximum parking requirements, and allow for flexible parking arrangements that better allow new development to meet context specific characteristics that influence travel behaviors (Mingardo et al., 2015; Parking Reform Network, 2021; Rosenblum et al., 2020; Weinberger, 2014). As reduced parking minimums are increasingly allowed, car-reduced developments and neighborhoods are becoming more common in cities as a way to promote sustainable transport practices (Selzer, 2021; Sprei et al., 2020) and reduce climate impacts from the transport sector.

In Sweden, there is a national goal to reduce climate emissions from transport by 70% by 2030 compared to 2010 and by 2045 have zero net emissions (Ministry of the Environment, 2021). To achieve this, Sweden focuses on transport efficiency, renewable fuels and electrification, and energy efficient vehicles and ships (Government Offices of Sweden, 2022). Within transport efficiency, there is a dual effort to electrify

* Corresponding author.
E-mail addresses: devon.mcaslan@chalmers.se (D. McAslan), frances.sprei@chalmers.se (F. Sprei).

https://doi.org/10.1016/j.tranpol.2023.03.003
Received 30 August 2022; Received in revised form 25 January 2023; Accepted 5 March 2023
Available online 15 March 2023

personal transport and to reduce private car use. Parking reform is increasingly seen as a strategy for reducing car ownership and use. Many municipalities have recently updated or are in the process of updating their parking regulations to better align with sustainable transportation goals. The research presented in this article is part of a project done in collaboration with Klimatkommunerna (The Climate Municipalities), which analyzes the prospects and potential barriers to implementing parking management tools and aims to increase the knowledge of municipalities about the possibilities, effects, and feasibility of new and existing parking management tools.

While the relationship between car use and the availability of parking has been researched before (Liu et al., 2017; Weinberger, 2012; Weinberger et al., 2008b; Yin et al., 2018), it stems from the recognition that minimum parking requirements increase the availability of parking (Kimpton et al., 2021; Shoup, 2011). Recent research has started to link parking requirements to the amount of parking that actually gets built (Corcoran et al., 2020; Gabbe et al., 2020; Kimpton et al., 2021). While this is a positive trend, there remains little research that examines the effects of MPRs on city-wide levels of car ownership across large samples of municipalities. This paper contributes to past efforts at understanding the impact of parking on car ownership by studying the relationship between MPRs and car ownership in 56 Swedish municipalities and considers how the size and character of municipalities impacts this relationship. Understanding the broad relationship between parking norms and car ownership is useful for urban planners and policy makers as they think about parking reform, as many Swedish municipalities currently are.

A secondary goal of this paper is to discuss two methods we developed in order to compare and analyze two different types of parking numbers commonly used in cities around the world. This includes parking numbers based on the number of parking spaces per apartment and those based on parking spaces per building area. While many municipalities worldwide use parking spaces per apartments for residential parking numbers and parking spaces per building area for retail and office buildings, many Swedish municipalities use parking spaces per area for both residential and commercial uses. Thus, to conduct our analysis, it was necessary to methodologically determine how best to compare and analyze these different parking numbers.

The following section details past research on parking and its impact on car use and ownership and discusses the different impacts associated with minimum parking requirements. We then outline our research methods and describe the two methods we develop to analyze parking numbers across our sample of 56 municipalities. Lastly, we present our research findings and conclude with a discussion about the implications and limitations of our research findings for parking planning and reform.

2. Minimum parking requirements and their impacts

Minimum parking requirements (MPRs) regulate how much parking gets built in new development and were initially meant to meet the demand for parking within a development and to not over-burden public parking facilities (e.g., street parking) (Shoup, 2011). Although regulated by land use codes and zoning ordinances, parking links land use and transportation planning (Genter et al., 2013), since it impacts both the built environment and travel behaviors. MPRs increase the supply of parking (Shoup, 1999), and even in places served by high quality public transport (e.g., mixed-used districts and transit-oriented developments) there has been an observed over-supply of parking (Cervero et al., 2010; Ewing et al., 2021; Manville et al., 2013; Weinberger and Karlin-Resnick, 2015). The over-supply of parking also results in greater congestion and inhibits street life (Manville et al., 2013; Manville and Shoup, 2005).

Studies show that parking influences both car ownership and travel patterns. In an analysis of parking supply in nine cities between 1960 and 2000, McCahill et al. (2016) find that an increase from 0.1 to 0.5 parking spaces per person increased the commuting share of driving by 30%. Weinberger et al. (2008a,b) find that New York City parking requirements increase car ownership, with residents in new development with more required parking being 40%–50% more likely to own a car. Higher levels of guaranteed parking at home (e.g., off street parking) results in higher car ownership and more driving to work (Weinberger, 2012; Weinberger et al., 2008b). At the same time, as the supply of parking increases, resulting lower density development increases car use (McCahill and Garrick, 2012, 2014).

Weinberger (2012) emphasizes that this is true even in neighborhoods close to subway stations, showing that parking policies can negate benefits of public transport. De Gruyter et al. (2020) find that while proximity to high quality transit is associated with lower demand for residential parking, this association is not significant when controlling for other factors. They find that transit frequency and quality is significantly associated with lower car ownership (De Gruyter et al., 2020). Similarly, an analysis of travel behaviors in Norway (Christiansen et al., 2017a) shows that poor access to transit increases car use even when there are policies in place that would otherwise reduce car use, such as paid parking at work. This shows the need to consider parking within the broader context of sustainable mobility.

The type and location of parking has an impact on car ownership and travel patterns. The availability of dedicated parking is associated with higher car ownership and higher car use (Christiansen et al., 2017b; Guo, 2013a; Weinberger et al., 2008b). Guo (2013b) finds that free residential street parking in New York City increases car ownership by 9%. However, farther distances from home to one's home parking location reduces the likelihood of using a car (Christiansen et al., 2017a). Multiple studies show that poorly managed on-street parking is over-used even when those who use it have access to private off-street parking (Scheiner et al., 2020; Taylor, 2020). Taylor (2020) finds that 80% of on-street parking is used by residents of single-family homes who also have available off-street parking, while only about two thirds of parking in new high density apartments is being used, providing evidence that new development doesn't over-burden existing on-street parking as many critics argue.

Requirements for too much parking result in higher development costs (Shoup, 2014). Since a majority of parking in cities is 'free', the costs to build parking are indirectly passed on to all end users whether they use the parking or not (Shoup, 1999). The costs to build and maintain parking are passed on to end users through higher rents in commercial office spaces and higher cost of goods and services in retail centers (Shoup, 1999). MPRs also increase the cost of housing. Litman (2021) shows that requiring one to two parking spaces per unit can increase the development cost of affordable housing by 12.5% and 25% respectively. Since low income households also have lower rates of car ownership, they effectively pay for parking when they do not need it (Litman, 2021). In addition to passing on the cost of parking to renters and homeowners, Lehe (2018) also argues that high MPRs discourage the construction of small units (e.g., micro-apartments or studios) which are promoted as more affordable. Only recently have policies that allow parking to be unbundled from housing units started to address this problem by requiring those with cars to pay additional fees for parking spaces.

High parking requirements result in more expensive construction costs which are typically passed on to renters and homeowners. In Seattle, Gabbe et al. (2020) found that the municipal parking reform that allowed fewer parking spaces to be built in urban villages resulted in an estimated savings of $540 million in construction costs over a five year period and prevented nearly 18,000 fewer parking spaces being built in the city. It remains unclear, however, how much these construction cost savings resulted in lower housing costs.

Numerous strategies have been developed to more appropriately manage parking supply and demand to achieve desired goals. Paid parking has been shown to be an effective tool that helps to reduce driving (Hess, 2001; Pierce and Shoup, 2013; Shoup, 2021). Physical separation of parking and residence (e.g., park once districts), residential parking permits, and performance-based parking (e.g., dynamic pricing that can change depending on time and location) are other common parking reform strategies (King, 2022; Kirschner and Lanzendorf, 2020). Reducing the supply of parking is another approach and is achieved through changing MPRs.

Over the last decade, numerous cities, have reduced their MPRs, enacted maximum parking requirements, and even eliminated parking requirements in all or part of their city (Parking Reform Network, 2021). In the last five years, only a handful of cities in Europe and the U.S. have fully eliminated MPRs city-wide, leaving the decision of whether to build parking up to developers. In London, Li and Guo (2014, 2018) find that a switch from minimum to maximum parking requirements resulted in fewer multi-family developments being built in outer London and more in inner London, many of which were built without parking. The switch to parking maximums resulted in 40% less parking in new development (Guo and Ren, 2013).

Flexible parking strategies which set a MPR that can be reduced if certain criteria are met, is becoming a common parking reform measure. Proximity to public transit, access to commercial and retail areas, the provision of mobility services (e.g., car sharing), or free public transit passes to residents can allow developers to reduce the amount of parking they are required to build (Johansson and Rosendahl, 2021; Johansson et al., 2019; Sprei et al., 2020). While these flexible parking measures can impact travel patterns, they are most effective in combination with other policies that encourage less car ownership and use (Eriksen, 2018). Residential self-selection can also impact these factors since those without cars are likely more willing to live in developments with reduced- or zero-parking, while those with cars may choose to live in places with ample and perhaps free parking (Cervero, 2007; Sprei et al., 2020).

Previous research on parking, highlighted above, emphasizes three important points. First, MPRs increase the supply of parking in cities, impacting travel patterns – more parking results in more car use. Second, MPRs result in several non-transportation related impacts, including higher development costs, more expensive housing, and lower urban densities. And third, while many studies consider the effects of the availability of parking on car ownership, only a handful of studies examine the effects of car ownership and car use in relationship to the mandated parking required in municipalities. Those that do, typically do so for only a single city which is the subject of that study. This paper addresses this gap by analyzing the impact of minimum parking requirements on levels of car ownership in Swedish municipalities.

3. Methods and data

In this section we describe our methodologies for data collection and analysis. A main focus is on the two methods we develop for comparing the two types of Swedish parking numbers, which is a main contribution of this paper to parking research. Later in our discussion, we highlight the pros and cons of these methods and how they advance our ability to analyze parking regulation between municipalities.

Our primary source of data is a survey we conducted with municipalities in Sweden. We contacted 80 municipalities by email to invite them to participate in an online survey about their municipality's parking policies. In each municipality we identified and contacted staff who work on parking within their municipality. Of the 80 municipalities we contacted, half of the municipalities are part of Klimatkommunerna and half are not. The non-climate cities were selected to represent a comparable sample to the climate municipalities, taking into account different municipality classifications (see below). We received a total of 56 responses from municipalities - 31 from climate municipalities and 25 from the others. The survey included questions in six topic areas of interest with a total of 25 questions. The topic areas included (1) objectives for transport planning; (2) basic parking planning and regulation; (3) building adaptations that can reduce parking; (4) mobility solutions that can reduce parking; (5) contract issues that regulate parking; and (6) if municipalities conduct any follow-up or evaluation.

We use self-reported parking numbers for residential multi-family housing (e.g., apartment buildings) provided by survey respondents. Survey question B1 asks if municipalities use a basic number or basic interval for parking planning when building new apartment buildings, asking respondents to provide the values or range. It also asked about how many parking zones the municipality has. In total, 45 cities provided self-reported parking numbers. At times, our analysis uses this sample of 45 municipalities and in other instances the full sample of 56 municipalities. Table 1 provides a summary of the full sample of 56 municipalities that responded to the survey and key statistics used in this analysis.

Swedish municipalities determine parking requirements by designating different zones throughout the city (e.g., city center, inner neighborhoods, transit served neighborhoods, etc.). A majority of cities have 2–3 parking zones, while the range is between one and five. Our analysis uses only Zone 1 parking numbers due to this being the only zone all municipalities have in common. In municipalities with multiple zones, Zone 1 comprises the most central areas of the city, meaning that this zone has higher accessibility. This in turn makes transit, cycling, and walking attractive alternatives to driving and helps to decrease the overall need for parking. In many Swedish municipalities, new apartment development is also occurring in central Zone 1 areas, which may not be the case in other urban contexts.

In our analysis, we examine similarities and differences between Swedish municipalities of different sizes and types. For this, we utilize the *Municipal Group Division* developed by Sveriges Kommuner och Regioner (SKR) (Swedish Association of Local Authorities and Regions). This classification divides municipalities into nine groups based on population and commuting patterns (SKR, 2016), and are described in Table 2 and shown in Fig. 1. In our analysis, we combine B4 and B5 municipalities into a single group and C6, C7 and C8 municipalities into a single group. No C9 municipalities were included in the sample.

Additional data was collected for the year 2020 from Statistics Sweden (Statistics Sweden, 2020). The relevant data reported in this paper come from population and car ownership. To better understand the Sweden context, we also analyzed trends from 2002 to 2020–2002 is the earliest year for which annual car ownership rates are publicly available online. An important note on car ownership data, Sweden collects data and differentiates between cars 'owned by natural persons' and total cars in a particular geography. Vehicles owned by natural persons refers to privately owned vehicles, while total cars include leased cars and company cars that private individuals use for work and may have access to regularly (i.e., they are parked at home and are used for both work and personal uses). In our analysis, we look at the total number of passenger cars, since any cars being used require parking.

3.1. Comparing different parking numbers

To understand the relationship between MPRs and car ownership, it was necessary to compare two different types of parking numbers used by municipalities. The first approach is minimum parking spaces per apartment (P/APT) – 21 municipalities use this method and parking numbers in our sample range from 0.2 to 2 parking spaces per apartment. The second approach is based on the total dwelling area of a residential building (*bruttoarea* in Swedeish, or BTA) and sets MPRs per 1000 square meters of residential space in the building. The MPRs for municipalities using this approach range from 0 to 16.5 parking spaces per 1000 m^2. To compare the two approaches, we develop two ways to convert the different parking numbers.

In method one, we convert both P/APT and BTA parking numbers to a single scale. In method two, we convert P/APT parking numbers directly to BTA parking numbers. The goal of multiple methods was to determine if the same trends would emerge from different conversion approaches, which strengthens the reliability of our findings. Among the 45 municipalities that reported on their parking numbers, some use a

Table 1
Characteristics of the 56 municipalities surveyed.

Municipality	Population (Dec 2020)	SKR city group[a]	Climate City? (Y/N)	Total cars per 1000 people (2020)	Total cars per 1000 natural persons[b] (2020)
Borlänge	52,394	B3	N	524	448
Borås	113,714	B3	Y	482	403
Botkyrka	94,847	A2	Y	325	281
Boxholm	5441	C7	Y	599	507
Ekerö	28,879	A2	N	449	374
Eskilstuna	106,975	B3	Y	462	404
Falkenberg	46,051	C6	N	564	457
Falköping	33,238	C6	Y	545	440
Finspång	21,765	B5	Y	539	479
Forshaga	11,524	B4	Y	569	503
Göteborg	583,056	A1	Y	332	262
Halmstad	103,754	B3	N	499	422
Haninge	93,690	A2	N	367	315
Helsingborg	149,280	B3	Y	441	365
Huddinge	113,234	A2	N	347	294
Hudiksvall	37,531	C6	N	575	464
Järfälla	81,274	A2	Y	368	319
Kalmar	70,329	C6	N	506	424
Karlstad	94,828	B3	Y	480	400
Kristianstad	86,217	C6	Y	511	427
Kungsbacka	84,930	A2	N	525	441
Landskrona	46,305	B4	N	432	381
Lerum	43,020	A2	N	482	425
Lidköping	40,328	C6	Y	562	462
Linköping	164,616	B3	Y	424	352
Lomma	24,876	A2	Y	496	439
Luleå	78,549	B3	N	508	413
Lund	125,941	B3	Y	518	299
Malmö	347,949	A1	Y	355	277
Mora	20,492	C8	Y	648	474
Mönsterås	13,264	C7	N	575	489
Nacka	106,505	A2	N	480	289
Nykvarn	11,222	B4	N	503	446
Nynäshamn	28,811	A2	Y	437	378
Nässjö	31,563	B5	N	524	431
Olofström	13,311	C7	Y	540	460
Skellefteå	72,840	C6	Y	546	423
Sollentuna	73,990	A2	Y	452	315
Stockholm	975,551	A1	Y	369	201
Sundsvall	99,439	B3	N	513	429
Sunne	13,335	C8	N	646	432
Svedala	22,665	A2	N	522	460
Södertälje	100,111	B3	Y	494	329
Tyresö	48,678	A2	Y	370	322
Täby	72,755	A2	N	430	361
Umeå	130,224	B3	N	434	351
Uppsala	233,839	B3	Y	373	312
Vallentuna	34,119	A2	N	472	404
Vara	16,096	C7	N	612	455
Vänersborg	39,624	B4	N	552	458
Värmdö	45,566	A2	Y	426	359
Västerås	155,551	B3	Y	456	397
Växjö	94,859	B3	Y	470	382
Ängelholm	42,910	B4	N	549	459
Örebro	156,381	B3	Y	435	363
Östersund	63,985	B3	Y	520	410

[a] SKR municipality groups: A1: large city; A2: immediate suburb/commuter town to A1 city; B3: medium-sized city; B4/B5: suburb and/or commuter city to B3 city; C6: small town with at least 15,000 population; C7: commuting municipality to C6 town; C8: small town under 15,000 population.
[b] Car ownership by natural persons only includes cars owned by individuals and not by companies or other entities.

fixed parking number while others use a range. In our analysis, we use either the single value provided by cities, or the middle value of the range provided. Table 3 shows the parking numbers provided by each of the 45 municipalities that reported them, as well as the converted parking numbers that we report in our findings. Below we describe how the converted parking number values were calculated.

Table 2
Municipal group classification descriptions developed by Sveriges Kommuner och Regioner (SKR) (Swedish Association of Local Authorities and Regions). Source: SKR 2016.

SKR group	Definition	Study group	Number in study sample
A1	Large cities with a population of at least 200,000 residents	**A1**	**3**
A2	Commuting municipalities near large cities where more than 40% of working population commute to large city or nearby municipality	**A2**	**16**
B3	Medium-sized cities with at least 50,000 residents	**B3**	**17**
B4	Commuting municipalities near medium-sized cities where more than 40% commute to medium-sized city	**B45**	**7**
B5	Commuting municipalities near medium-sized cities where less than 40% commute to medium-sized city		
C6	Small towns with at least 15,000 residents	**C**	**13**
C7	Commuting municipalities near small towns where more than 30% of working population commute to another town		
C8	Rural municipalities of less than 15,000 inhabitants		
C9	Rural municipalities with a mostly tourism-based economy		**0**

3.1.1. Method 1: converting BTA and P/APT scales to a single scale

The first method used to analyze the BTA and P/APT parking numbers is a single common scale, ranging from 0 to 4. To convert the provided parking numbers, BTA values were divided by 4 and P/APT parking values were multiplied by 2. This means that a parking number of 1 P/APT would be 2. A parking number of 8 BTA (8 parking spaces per 1000 m^2) would also be a 2 on the new scale. A main weakness of this method is that it does not necessarily allow for a direct comparison between the two parking number types. It does, however, allow us to better compare higher or lower parking numbers relative to their original scales. In this way, we are able to compare differences in the two scales, but not directly compare a BTA and P/APT parking number. The second conversion method was developed to address this shortcoming.

3.1.2. Method 2: converting P/APT to BTA

The second method converts P/APT parking numbers to comparable BTA parking numbers. In simple terms, the conversion is to multiply a P/APT parking number by 14.7. In other words, a parking number of 1 parking space per apartment becomes 14.7 parking spaces per 1000 m^2. We base this calculation on the average size of apartments in Sweden, which is 68 m^2 (or about 730 square feet) (Statistics Sweden, 2016). If we divide this area into 1000 m^2, we get 14.7. This of course assumes that the size of apartments in all municipalities in our sample are the same, which is likely not the case, as it includes large cities and smaller towns and apartments in larger cities are likely to be smaller, particularly in central areas included in Zone 1 parking. However, housing in most Swedish city centers, unlike in U.S. cities, for example, does provide a mix of unit sizes, so our assumed average could be closer to reality. Thus, without detailed data on apartment sizes in different areas of each city in our sample, this assumption is a reasonable one. Using the middle-range parking values of cities that use a range accounts for these differences in unit size, since the ranges are primarily to provide additional parking in larger sized housing units.

Being aware of this assumption is important, since more or less apartments in a 1000 m^2 area can have a large impact on our analysis. For example, if instead of 14.7 apartments per 1000 m^2, we assume there are 10 apartments per 1000 m^2 (or 100 m^2 per apartment) which would account for either larger apartments being built and/or including common areas in the residential area, we would only multiply the P/APT parking number by 10. Using the average parking number in our sample

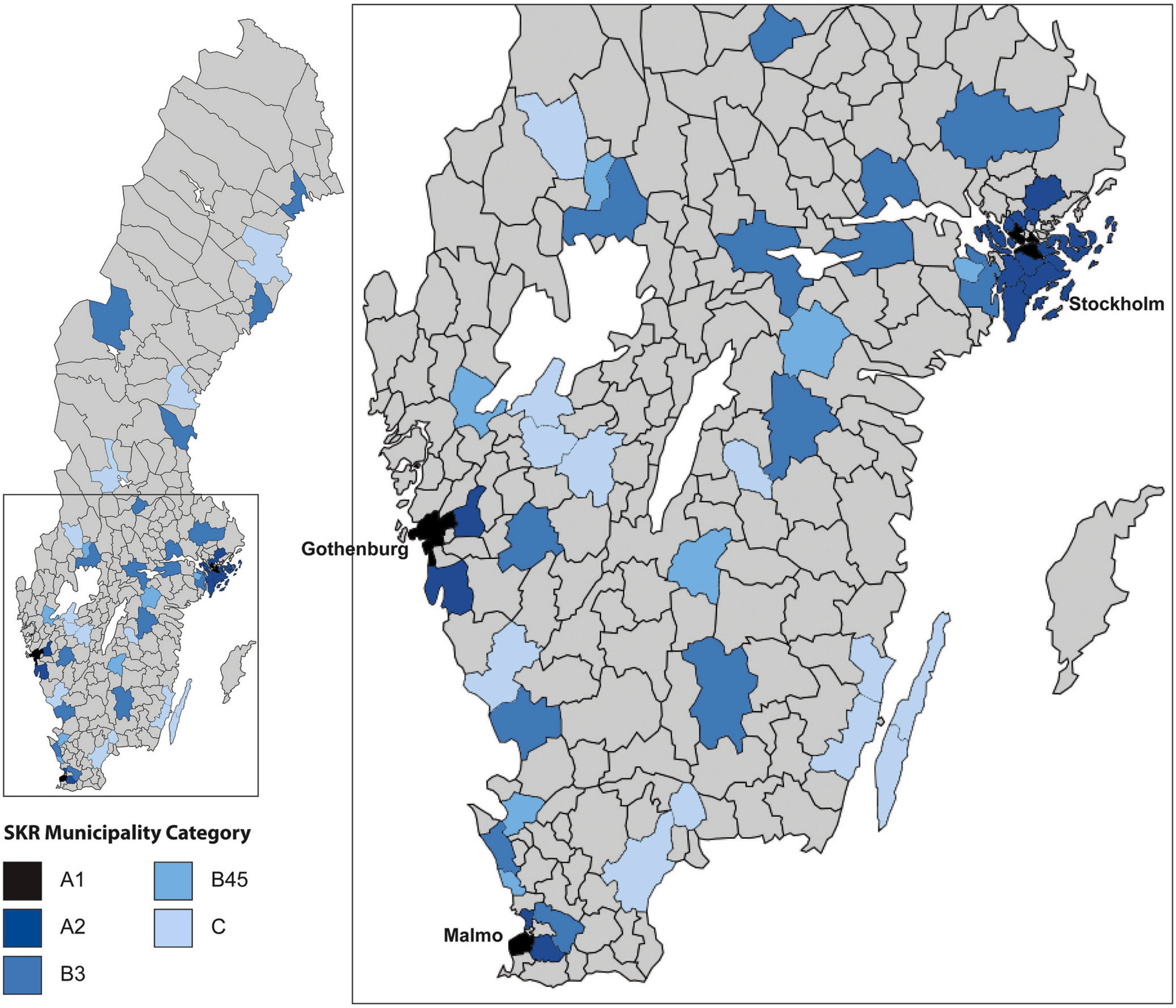

Fig. 1. Map of Sweden showing the sample of 56 municipalities included in the study and the their SKR classification.

(0.68 P/APT), yields 6.8 parking spaces per 1000 m^2, which is close to BTA average of 7.6. However, if apartments in Zone 1 are smaller than the national average, 20 apartments per 1000 m^2 could be a reasonable assumption, which would result in a parking number of 13.6 BTA (from our average 0.68 P/APT). An average of 14.7 apartments per 1000 m^2 across all cities and parking zones provides a reasonable estimate of how many apartments we might find in 1000 m^2 of residential building area.

3.2. Analysis

The analysis presented in the following section uses primarily descriptive statistics to highlight the broader relationship between minimum parking requirements and car ownership in various ways. We analyze this relationship by looking at variations across different types of municipalities. We examine how car ownership varies by city category (based on the SKR city classification system discussed previously). This analysis considered both similar and different municipalities since the size of municipality was likely to impact the results. We also examine parking numbers and car ownership between climate and non-climate municipalities, with the assumption that cities more involved in reducing their climate impact may be more actively using parking as a way to reduce car use. Lastly, we also look at differences in parking numbers between cities based on car ownership quartiles.

3.3. Sweden context

The population of Sweden in 2020 was 10,379,295. Between 2002 and 2020, car ownership increased from 452 to 476 cars per 1000 people, representing a marginal increase over two decades. Regionally, however, this growth in car ownership has not been uniform, with many cities increasing only slightly or stabilizing, and some even decreasing. Others have seen significant increases in car ownership which has outpaced their population growth rates.

There are 290 municipalities in Sweden and the survey we conducted was sent to 80, with 56 responding – or nearly 20% of all municipalities. These 56 municipalities account for 56% of the total population of Sweden and are a mix of small to large cities and towns that are geographically dispersed throughout the country (see Fig. 1). Looking at the car ownership in these 56 municipalities, we see that between 2002 and 2020 a total of eight had seen declines in car ownership and six saw increases of less than one percent. These included Sweden's largest cities – Stockholm, Gothenburg, and Malmö – and several of the municipalities

Table 3
Parking numbers from 45 municipalities used in analysis.

Municipality	Provided Parking-number (Zone 1)		P-number used in analyses	P-number (normalized)	P-number in BTA (converted)
	BTA (parking spaces per 1000 m^2)	P/APT (parking spaces per unit)			
Borlänge	8.5 (+0.5)		9	2.25	9.0
Borås	7		7	1.75	7.0
Botkyrka		0.3–0.6	0.45	*0.9*	6.6
Eskilstuna	0–6.5		3.25	*0.8125*	3.3
Falkenberg	8		8	2	8.0
Falköping	6.9		6.9	1.725	6.9
Göteborg		0.2–0.5	0.35	*0.7*	5.1
Halmstad	7		7	1.75	7.0
Haninge		0.5	0.5	1	7.4
Helsingborg		0.2–0.8	0.5	*1*	7.4
Huddinge	5.6		5.6	1.4	5.6
Järfälla		0.2–0.6	0.4	*0.8*	5.9
Kalmar	8		8	2	8.0
Karlstad	1–7		4	*1*	4.0
Kristianstad	10		10	2.5	10.0
Kungsbacka		0.5–1.5	1	*2*	14.7
Landskrona		0.8	0.8	1.6	11.8
Lerum	10		10	2.5	10.0
Lidköping	9		9	2.25	9.0
Linköping	8		8	2	8.0
Lomma		1	1	2	14.7
Luleå	8		8	2	8.0
Lund	5.3		5.3	1.325	5.3
Malmö	0–6.5		3.25	0.8125	3.3
Nacka		0.7	0.7	1.4	10.3
Nykvarn	11		11	2.75	11.0
Nynäshamn	9		9	2.25	9.0
Nässjö		0.9	0.9	1.8	13.2
Sollentuna		0.2–0.7	0.45	*0.9*	6.6
Stockholm		0.3–0.6	0.45	*0.9*	6.6
Sundsvall		0.3–0.8	0.55	*1.1*	8.1
Sunne	9		9	2.25	9.0
Svedala		1 (+0.2)	1.2	2.4	17.6
Södertälje		0.6 (+0.1)	0.7	1.4	10.3
Täby	7		7	1.75	7.0
Umeå		0.2–0.65 (+0.1)	0.525	*1.05*	7.7
Uppsala	8.5		8.5	2.125	8.5
Vallentuna	12		12	3	12.0
Vänersborg		0.5–1	0.75	*1.5*	11.0
Värmdö		0.8	0.8	1.6	11.8
Västerås		0.25–1.01	0.63	*1.26*	9.3
Växjö	9		9	2.25	9.0
Ängelholm		0.8–1	0.9	*1.8*	13.2
Örebro	6		6	1.5	6.0
Östersund	5.2 (+0.8)		6	1.5	6.0
Average	7.6	0.68		1.66	8.65

in their regions. Narrowing the time horizon to look at only 2015 to 2020, 21 of the 56 municipalities now have seen declines in car ownership and an additional ten had increases of less than one percent. This shows an increasing trend among Swedish municipalities of decreasing car ownership, despite the broader national trend of continues increasing car ownership.

Although car ownership rates are decreasing in an increasing number of municipalities, there is a wide range in terms of starting points and since 2002, the gap between the municipalities with the highest and lowest car ownership rates had widened (Fig. 2). Within our sample of 56 municipalities, in 2002, Botkyrka had the lowest car ownership with 324 cars per 1000 people while Sunne had the highest at 554 per 1000 people. By 2020, Botkyrka was still the lowest with 325 cars per 1000 people while Mora had the highest with 648 cars per 1000 people (Sunne was just below with 646). In general, cities with lower car ownership rates in 2002 maintain or decrease their car ownership, while cities that started with higher car ownership rates have seen larger increases in car ownership over the same period. This trend emphasizes the compounding effects of automobile ownership – once car ownership reaches a certain level, planning policies, including minimum parking requirements, are more likely to facilitate even higher rates of car ownership, which in turn encourages further automobile ownership and use. To emphasize the impact city size has on car ownership, Fig. 3 shows car ownership in each municipality in relation to its population.

Additionally, many of the cities with decreasing or stable car ownership rates are some of the largest cities while smaller cities tend to have increasing car ownership. This is an important finding since the marginal difference in small versus large municipalities and the change in car ownership over time can have a significant impact on the total number of vehicles. For example, if the largest city in our sample (Stockholm) had experienced the highest growth we see in our sample (27.8%), the total cars would have increased by 100,000. Conversely, if the smallest city (Nacka) had experienced the largest decrease (−11.3%) in car ownership, there would be 310 fewer cars in Nacka today versus in 2002.

Overall, these trends highlight a positive move towards reducing car ownership where it has the largest impact, but at the same time highlights a growing gap in car ownership, and presumably car use, across

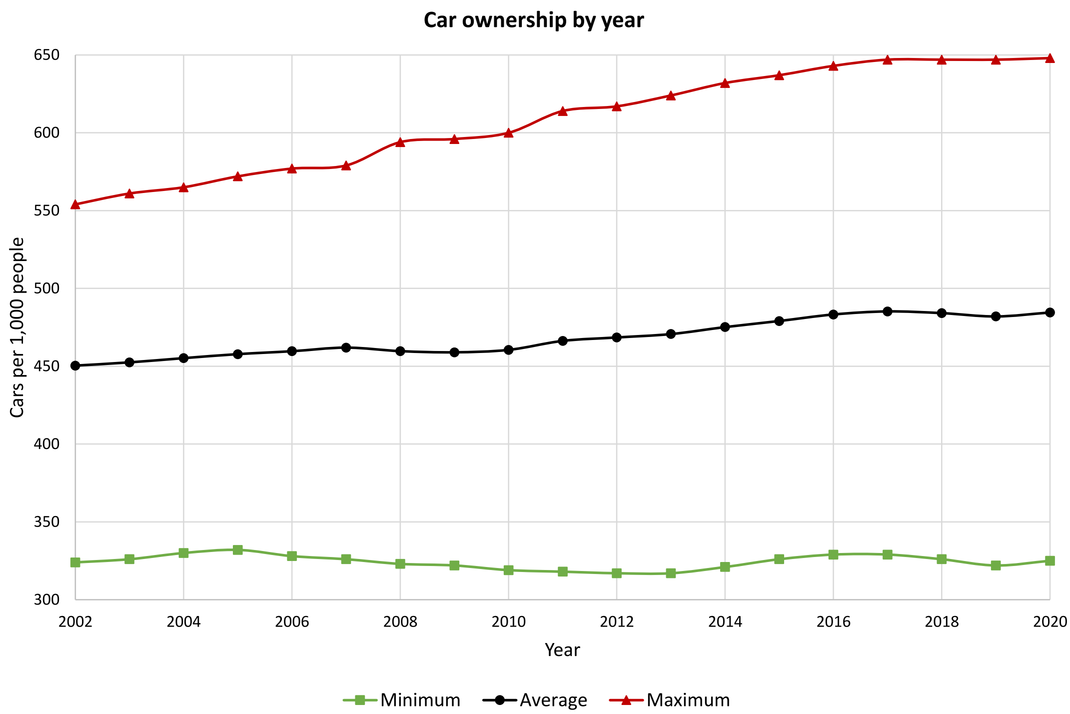

Fig. 2. Car ownership per 1,000 inhabitants in the sampled municipalities, showing the average for all 56 municipalities and the minimum and maximum car ownership levels between 2002 and 2020.

cities and regions. This is an important trend to consider as we think about car ownership in relationship to parking numbers in cities of similar and different sizes and the broader impact that parking policy has on car ownership and use. The next section presents our findings on the relationship between MPRs and car ownership in Swedish municipalities.

4. Results

Our analysis generally shows a positive, yet not statistically significant, relationship between MPRs and car ownership among our sample of Swedish municipalities. This is to say that higher MPRs are associated with higher rates of car ownership, they are not the cause. While there are numerous other factors that influence car ownership, we focus here

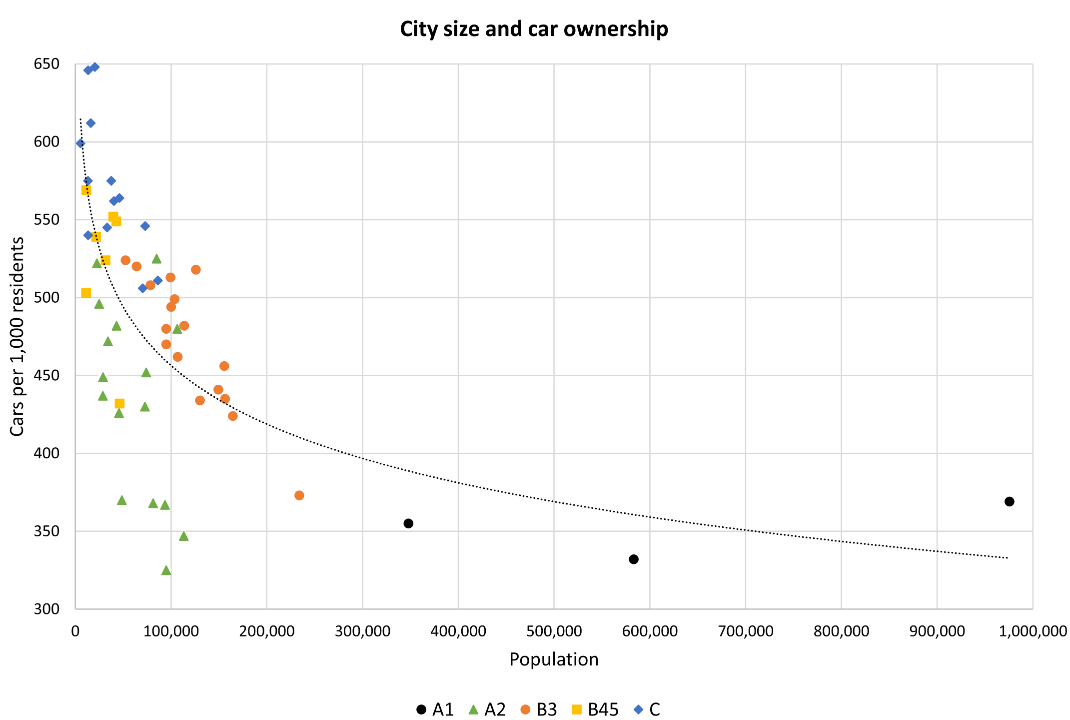

Fig. 3. Municipality size and car ownership rates per 100,000 inhabitants.

on understanding how MPRs relate to rates of car ownership by considering (1) city SKR category, which accounts for both population and commuting characteristics, and (2) commitment to climate action, based on membership in Klimakommunerna, and (3) by rates of car ownership (by quartiles). Table 4 summarizes our results, which are further detailed below. We discuss key patterns that emerge that are useful for understanding the relationship between MPRs and car ownership. We also look briefly at how MPRs may be associated with car use directly, instead of with car ownership being a mediating factor between MPRs are car use.

4.1. Minimum parking requirements and city categories

When we examine the 45 municipalities as a whole, we see a positive association between MPR and car ownership. This trend remains the same when we compare both methods for converting parking numbers, as shown in Figs. 4 and 5. Using the normalized scale where all parking numbers for cities are converted to a 0–4 scale, 27% of the variation in car ownership is explained by a municipality's parking number (Fig. 4). When considering the conversion of P/APT parking numbers to BTA, 17% of the variation is explained (Fig. 5). Fig. 6 shows the distribution of municipalities across Sweden with their BTA parking numbers.

More interesting in our analysis is looking at variations between different groups of cities. In addition to the overall trend, Figs. 4 and 5 highlight the SKR municipality groups and the ways in which they cluster. Sweden's three largest cities – Stockholm, Gothenburg and Malmö (A1 municipalities) – cluster at the lower left, indicating that their low minimum parking requirements are associated with lower car ownership. Along with these, we see a small clustering of A2 municipalities around Stockholm which we identify as suburbs of Stockholm (Botkyrka, Haninge, Huddinge, and Järfälla). Fig. 6 shows how the BTA parking figures are dispersed geographically across Sweden.

Other A2 municipalities, which are suburbs of the three major cities, also have lower car ownership rates even with increasing MPRs compared to other municipality types. A2 municipalities show the greatest range in parking numbers of any municipality group. We attribute this to the fact that while they are all commuting municipalities to large cities, some are well integrated into the urban area of the A1 city, while others are further away, are outside of the contiguous urban area, and less connected by public transport. Despite this variation, A2 municipalities do show a strong relationship between MPRs and car ownership on both metrics – normalized r^2 of 0.46 and BTA r^2 of 0.68, shown in Table 5.

Table 5 shows the relationship for all city groups in both the normalized and BTA conversions, showing both the general trend and its magnitude (positive, neutral, or negative) and the r^2 value for each separate city group. This shows that a majority of the trends are positive (+) or very positive (++), with two being neutral and two being negative. In the BTA conversion method, all the relationships are positive except for the one among B3 municipalities. That being said, a majority of them are not statistically significant relationships. However, it is important to note that the small sample size for each city group on its own is small, making this sort of analysis perhaps less meaningful.

Medium-sized cities (B3) fall in the middle range of car ownership and MPRs, though the clustering is slightly more pronounced when we convert to BTA parking numbers. On average, these municipalities have MPR of 7.3 parking spaces per 1000 m^2 and 472 cars per 1000 residents. The suburbs of these cities (B4 and B5 municipalities) cluster a bit higher, with both higher MPRs (average of 12 BTA) and higher car ownership rates (512 cars per 1000 people).

Small cities and towns (C municipalities) also cluster, although where they cluster depends on the comparison method. When using the normalized parking number, they cluster beyond B45 municipalities, but when considering them on the BTA scale, they cluster lower than the B45 municipalities. This shift is primarily because all the C municipalities use the BTA parking number metric while all but one of the B45 municipalities use the P/APT metric. Aside from this, these small cities have the highest rates of car ownership and fall in the middle range of both MPR scales.

4.2. Minimum parking requirements and climate action

As part of the broader project working with Klimatkommunerna, we examined the extent to which a municipality's involvement and commitment to climate action impacted their thinking about parking. We thus look at climate cities and non-climate cities as two distinct groups to see differences in MPRs and car ownership. Note, that of the full sample of 56 municipalities, 31 are climate cities and 25 are not. Among the 45 municipalities that provided parking numbers, 24 are climate cities and 21 are not. Results show that both car ownership and the MPRs are lower among the climate group. On average, Klimatkommunerna municipalities have 447 cars per 1000 people, compared to 494 cars per 1000 people (see Table 4, above). The parking numbers for climate cities is 1.47 (normalized) and 7.5 BTA, while the non-climate municipalities have parking numbers of 1.87 (normalized) and 10 BTA. Since the climate municipalities include a range of different sized municipalities, size does not explain this difference. From interviews, it is evident that lower MPRs and lower rates of car ownership

Table 4
Average population, car ownership, and minimum parking requirements (MPRs) among municipality groups.

Category	Population (average)	Population (range)	Car ownership (per 1000 people) (average)	Car ownership (range)	MPR (normalized) (average)	MPR (BTA) (average)
SKR Municipality groups						
A1	635,519	347,949–979,551	352	332–369	0.80	5.00
A2	65,734	22,665–113,234	438	325–525	1.71	9.94
B3	119,085	52,394–233,839	473	373–524	1.53	7.28
B45	34,325	11,222–46,305	512	432–552	1.89	12.05
C	48,250	13,335–86,217	556	506–646	2.12	8.48
Climate municipalities groups						
Climate city	165,658	24,876–975,551	447	325–562	1.47	7.48
Non-climate city	63,648	11,222–130,224	494	347–646	1.87	9.98
Car ownership quartiles *						
Q1	216,542	45,556–975,551	382	325–434	1.28	7.32
Q2	91,930	28,811–156,381	464	435–494	1.62	8.00
Q3	62,688	11,222–125,941	515	469–539	1.95	10.20
Q4	28,999	5441–72,840	577	540–648	1.92	9.53

Note: The averages and ranges for the car ownership quartiles include the full sample of 56 municipalities while the other groups include the smaller sample of 45.

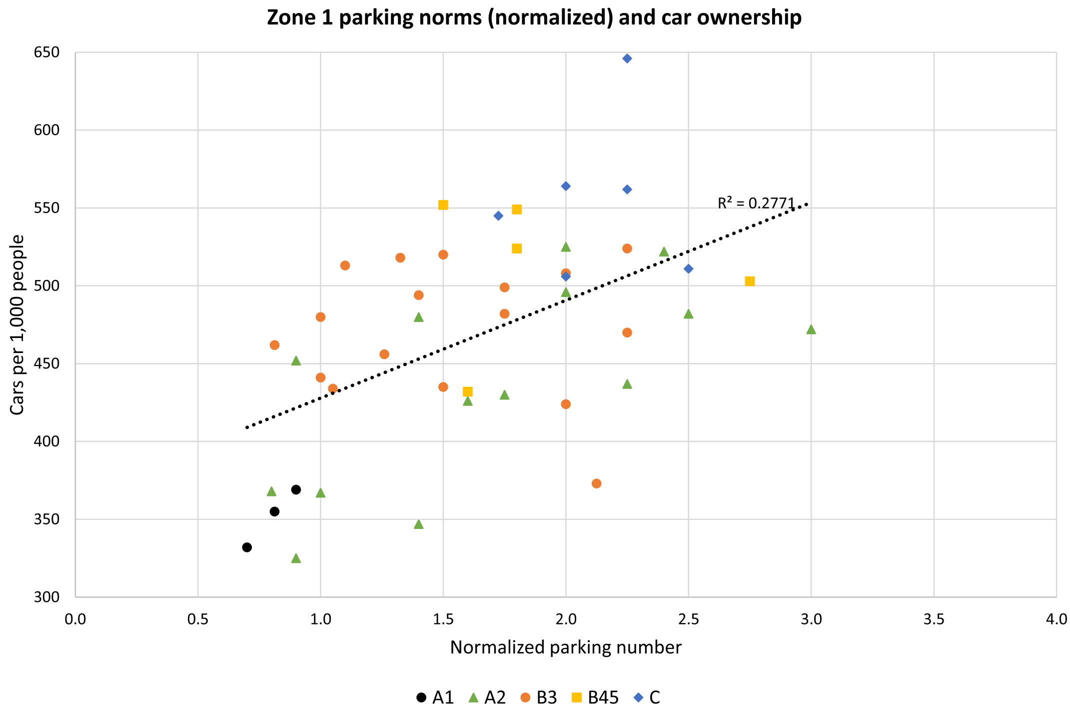

Fig. 4. Parking numbers and car ownership by municipality type using the normalized parking number.

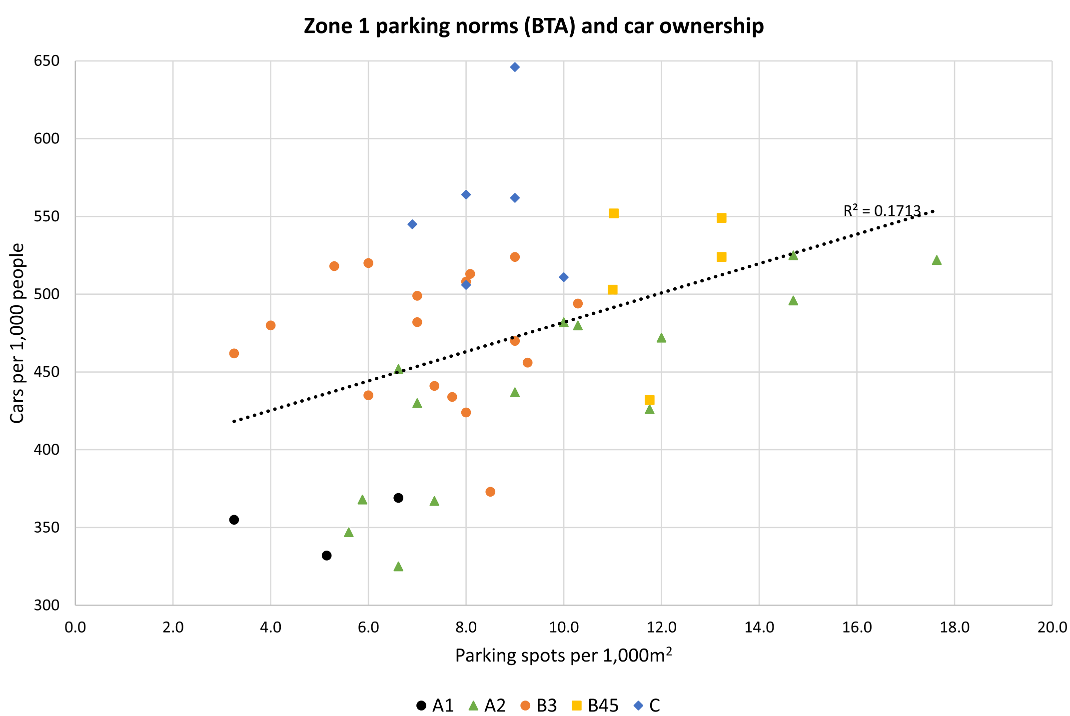

Fig. 5. Parking numbers and car ownership by municipality type using the converted BTA parking numbers.

predate commitment to reducing car use as a climate-related goal, current efforts at parking reform are closely associated with climate action. It comes as no surprise that the cities more actively pursuing parking include larger cities that are more likely to have more traffic and congestion compared to their smaller counterparts.

4.3. Minimum parking requirements and car ownership quartiles

Our last analysis examines MPRs and car ownership trends between different car ownership quartiles. Median car ownership across all 56 municipalities used in this analysis is 495 cars per 1000 people. Table 4 (above) shows the differences between the four quartile groups. Generally, lower car ownership and lower MPRs and are associated with larger cities, while higher car ownership and higher MPRs are typically associated with smaller cities and towns. This holds true for both normalized and BTA parking numbers. Of note is the fourth quartile where we do see a slight drop in both parking numbers compared to the third quartile, but this is partly due to the smaller number of cities in this group with established MPRs – 8 out of 14 municipalities in this group report having no MPR. The survey indicates that these municipalities

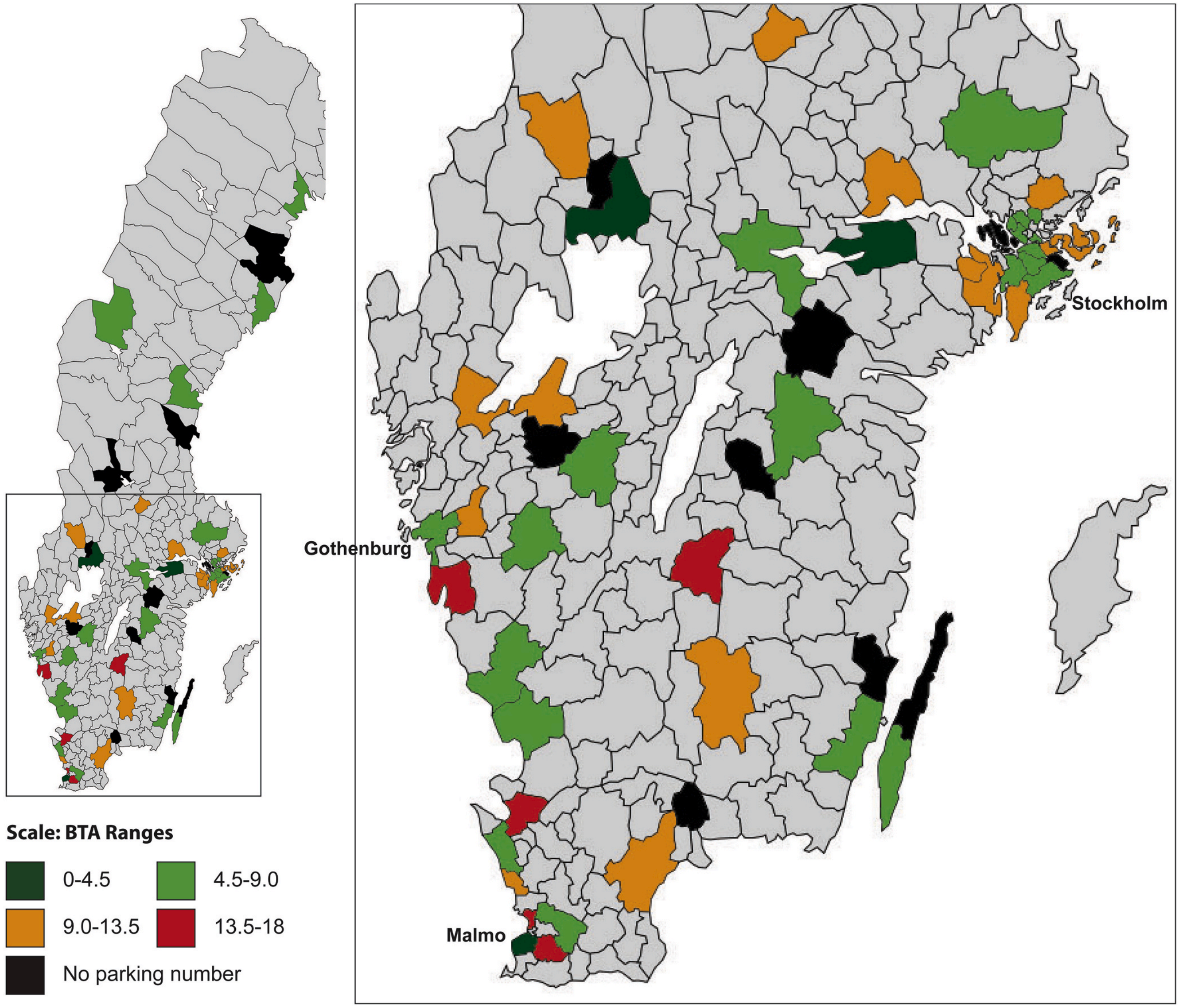

Fig. 6. Map of Sweden showing the BTA parking numbers for the 56 municipalities anlayzed.

Table 5
R^2 for each city group for both the normalized and BTA-conversion parking numbers and the direction of the trendline for each category.

Municipality SKR classification	Number (n)	Normalized		BTA	
		Trend (-, o, +)	R^2	Trend (-, o, +)	R^2
A1	3	++	0.996	+	0.094
A2	14	++	0.458	++	0.680
B3	17	o	0.001	–	0.051
B45	5	o	0.002	+	0.005
C	6	–	0.005	+	0.005
Overall	45	+	0.277	+	0.171

often set parking numbers on a case-by-case basis, and there is high likelihood that if they had MPRs, they would fall within the higher range. We also find that the lower quartiles have a higher proportion of climate municipalities (Q1 = 9, Q2 = 10, Q3 = 5, and Q4 = 7) and that a higher proportion of municipalities in the lower quartiles allow for flexible parking (either as a range in their MPR or in other ways indicated in survey responses).

4.4. Minimum parking requirements and car use

Several studies have sought to understand the relationship between the built environment (e.g., parking), car ownership, and car use and alternatively treat car ownership as a dependent (e.g., how the built environment impacts car ownership) or an independent variable (e.g., how car ownership impacts travel behavior). Other studies treat car ownership as a mediating variable between the built environment and travel behavior (see Cao et al., 2007; Scheiner and Holz-Rau, 2007; Simma and Axhausen, 2003; Van Acker and Witlox, 2010). In these studies, the built environment and parking supply impact car ownership, which in turn impacts car use.

Since a central aim of reducing car ownership relates to its ability to lower car use, it is useful to examine if MPRs have any correlation with car use itself. Since higher availability of parking has been associated with higher rates of car use (Christiansen et al., 2017a; Guo, 2013c), it would follow that if higher MPR are associated with more parking, then MPRs might be more directly associated to car use as well. We examined car use (kilometers traveled) per person. The BTA parking numbers

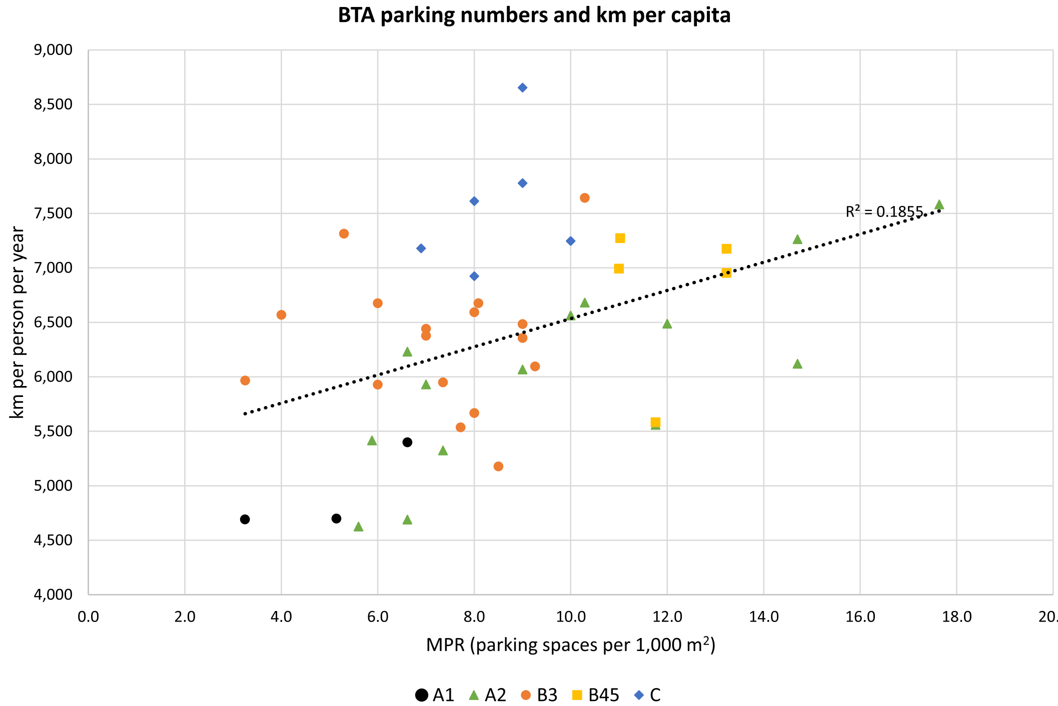

Fig. 7. Parking norms (BTA) and car use in per capital kilometers traveled per year.

explains 18% of the variation in per capita km (Fig. 7) and the normalized parking numbers account for 27%. This shows that while there is a positive association between higher MPRs and higher kilometers traveled, it is not significant. Of note is that we see similar clustering of municipality types as in our other analyses, with the exception of A2 municipalities, which have more variation.

A final finding is that when looking at per capita km traveled by car and car ownership, we see a nearly perfect 1:1 relationship between km traveled and car ownership, shown in Fig. 8. This means that when adjusted for population, distance traveled by car is almost entirely explained by rates of car ownership among our sample of municipalities.

5. Discussion

We started this paper by asking how minimum parking requirements affect automobile ownership, and by extension car use, and we find a

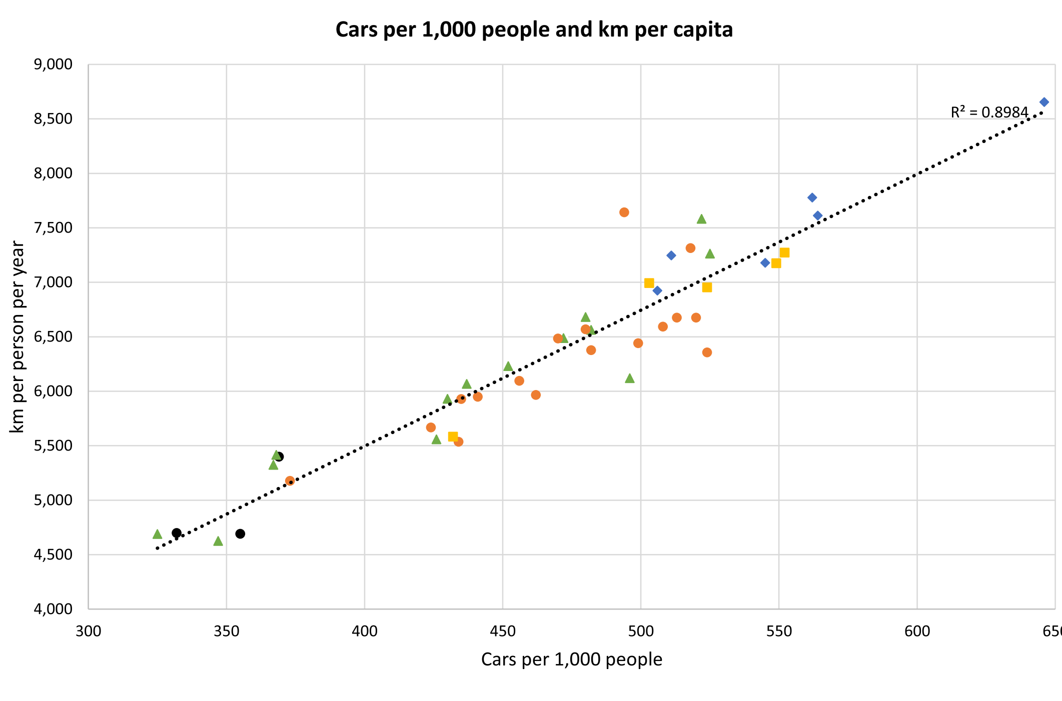

Fig. 8. Car ownership and car use in vehicle kilometers traveled (VKT) per person per year.

positive association between MPRs and car ownership. With this finding, it is worth discussing several points, including the issue of correlation versus causation, the role that city size plays, the marginal benefits of parking reform, and the assumptions that inform analyzing different types of parking numbers (i.e., P/APT and BTA). Lastly, we briefly reflect on reducing MPRs as a part of broader sets of strategies to encourage sustainable mobility.

It is important to emphasize that the relationship between MPRs and car ownership is not causal. In other words, lower parking numbers do not directly cause lower rates of car ownership, but as other research has emphasized, MPRs are only one factor that could impact rates of car ownership and based on our analysis this relationship is significant for certain types of cities. Since we see this positive association when using two different methods of converting the parking numbers and when looking at the SKR groups independently, it increases our ability to draw conclusions about the nature of the relationship between MPRs and car ownership.

The issue of correlation and causation, however, is somewhat complicated by how Swedish municipalities set MPRs. In general, MPRs are set arbitrarily and often municipalities look to neighboring cities to inform their own parking numbers (Shoup, 1999, 2011). Swedish law, however, does require that parking should be provided based on the need for parking. Swedish municipalities often base their MPRs on then current levels of car ownership and interviews we conducted also showed that historically, some municipalities also set MPRs based on anticipated increases in car ownership. This means that if car ownership is observed to be higher, a municipality has historically been likely to implement a higher MPR than may have been warranted. As other research has shown that the availability of parking is associated with higher car ownership (Weinberger, 2012; Weinberger et al., 2008b), it is likely that the approach used in Sweden to determine MPRs has been a (perhaps not insignificant) contributor to current high levels of automobile ownership. Current policies to lower MPRs have the goal of reversing the trend of increasing car ownership, but of course this ultimately is impacted by a number of factors not examined in this paper. Regardless, the full effects of implementing MPRs were not fully known for decades, and it is entirely reasonable to assume that the effects of lowering MPRs today will not be known for decades as well. Swedish cities, and many others around the world, are erring on the side of caution and hoping that lowering (or even eliminating MPRs) will reduce car ownership and use and generally help to improve the urban environment.

This is of course not a one-size-fits-all approach and different municipalities must develop policies that make sense for them based on multiple factors. This is particularly relevant when thinking about the differences in size between cities in our analysis. Our findings do show that the largest cities have the lowest rates of car ownership compared to suburban municipalities and smaller cities, which tend to be much more diverse in their MPRs. It would make sense to assume that smaller cities would have higher rates of car ownership compared to larger cities that are denser and provide more alternative transportation options. However, because we are only considering Zone 1 parking numbers, we might also expect overall parking numbers to be more similar since accessibility in many central parts of Swedish municipalities is overall quite high regardless of the size of the municipality. The fact that parking numbers are not more similar across this zone reinforces the approach taken by municipalities in setting parking numbers based on total city-wide car ownership and not more location specific needs.

It is also worth noting the marginal benefits of parking reform in different sized cities. Although every municipality should consider reforming their MPRs, the overall opportunity for Sweden to reduce the environmental impact of private car use is greater in larger municipalities. Extrapolating our results to consider the change in car ownership stemming from reducing the MPR by 1 parking space per 1000 m^2, we can predict a reduction of 9.4 cars per 1000 people. If we apply this to the largest and smallest municipalities in our sample (Stockholm and Nykvarn), the result is an absolute decrease of approximately 9200 cars in Stockholm and 105 cars in Nykvarn. This entirely hypothetical change emphasizes how much more impactful parking reform in larger cities can be when considering larger national policy goals. This does not mean that small cities should not reduce their MPRs, but instead highlights the need to balance local transportation and urban development goals with regional and national transport goals. Ultimately, there is great benefit to reducing automobile ownership in all municipalities, which reducing MPRs may contribute to in the long-term, especially if that means investing more in active transport infrastructure and public transport. These investments provide people attractive alternatives to driving and can have a significant local impact on mobility patterns.

Regarding our methodology and its limitations, we want to reiterate the fact that it is based on a number of assumptions that would impact the findings presented here as the method of converting P/APT and BTA parking numbers is rather sensitive to these assumptions. For example, we calculated the BTA parking numbers on the average size of apartments in Sweden. However, if apartments are smaller are larger, it makes a significant difference in the BTA calculation. Since Swedish apartment buildings often include a mix of studio to 3-4-bedroom apartments in all parts of the city, we are confident that the average we use is close to being accurate. This average, however, also may not take into consideration differences in apartment sizes between municipalities. It is very likely that larger cities like Stockholm and Gothenburg have smaller apartments – both due to higher housing costs and older housing units. Similarly, higher development costs today also likely mean that smaller units are being built today in larger cities than in smaller ones. To refine this research, it would be useful to have more context specific data on the size of new apartments in municipalities across Sweden and to take into consideration context specific conditions when analyzing parking numbers between multiple cities as we have done here.

6. Conclusions

Parking is an important part of the built environment that ties land use planning and transportation planning (Buehler and Pucher, 2011; Genter et al., 2013) that requires more attention in academic research and professional practice. An increasing number of studies have investigated the effects of parking on the built environment and on mobility patterns and comes as more cities are reforming parking policies, which includes the reduction or elimination of minimum parking requirements, which must be considered within the larger context of parking reform that aims to reduce the future availability of parking, which has been shown to impact car ownership and use (McCahill et al., 2016; Weinberger, 2012; Weinberger et al., 2008b).

This paper has investigated the relationship between minimum parking requirements and car ownership across a large sample of Swedish municipalities. We find that there is a positive association between MPRs and car ownership. The overall trend for all cities is not statistically significant, but for certain subgroups, it is – primarily for suburbs of large cities. Since MPRs have been argued to increase the supply of parking and parking itself has been shown to impact car ownership and use, this is the relationship we expected to see. Our findings are strengthened since we saw this positive relationship using two different methods for comparing parking numbers – parking spaces per housing unit and parking spaces per building area.

While important efforts are being taken by cities to reduce MPRs, these will not have an immediate impact on reducing car ownership and use and other parking reform measures, such as pricing, permitting, and more consideration of the relationship between public and private parking provision may have more immediate impacts on car ownership. Reform must also consider the relationship between residential parking reform, which is the focus of this paper, and commercial and office parking reform, since workplace parking which can have an impact on travel demand and car use (Evangelinos et al., 2018; Watters et al., 2006). Additionally, by reducing MPRs and the provision of off-street parking, cities may shift more demand to public street parking which may limit opportunities to repurpose street space for other uses, such as cycling lanes, sidewalks, and infrastructure for micro-mobility, which can reduce car use for short trips (Fan and Harper, 2022). These complex tradeoffs highlight the need for reducing or eliminating MPRs are part of broader policies that support sustainable transportation goals.

This paper contributes to a growing body of research that demonstrates the impacts of minimum parking requirements – in this case on car ownership – and shows that reducing the availability of parking through reductions in MPRs may contribute to lower rates of car ownership in the future and help build car-reduced cities (Nieuwenhuijsen and Khreis, 2016; Ornetzeder et al., 2008). This is particularly the case if cities invest in attractive alternatives to driving (e.g., transit, cycle infrastructure, etc.) and encourage innovative mobility solutions (e.g., car sharing, mobility hubs, etc.). As new technologies and services become more widespread in the future, the opportunities to leverage these as alternatives to private car ownership may also increase, and reducing MPRs in new development now may help encourage these modes in the future. Additional research on the impacts of parking will provide urban planners and policymakers with the evidence they need to advance further parking reform efforts in their attempts to reduce private automobile use in favor of more sustainable transport.

Declaration of competing interest

The authors report no declarations of competing interest.

Funding

This work was supported by Energimyndigheten, the Swedish Energy Agency, grant number 49726–1.

Data availability

Data will be made available on request.

Acknowledgements

This work was conducted in collaboration with researchers at IVL Svenska Miljöinstitutet [IVL Swedish Environmental Research Institute] and with Klimatkommunerna [Climate Municipalities Association]. Special thanks to Anders Roth, Fredrik Holm, Åsa Romson, Sara Sköld and Maria Ivansson for their work on the KomPark project. Also thank you to the city staff who took time to respond to the KomPark survey on parking policy in their municipalities.

References

Buehler, R., Pucher, J., 2011. Sustainable transport in Freiburg: lessons from Germany's environmental capital. Int. J. Sustain. Transp. 5, 43–70. https://doi.org/10.1080/15568311003650531.

Cao, X., Mokhtarian, P.L., Handy, S.L., 2007. Do changes in neighborhood characteristics lead to changes in travel behavior? A structural equations modeling approach. Transportation 34, 535–556. https://doi.org/10.1007/s11116-007-9132-x.

Cervero, R., 2007. Transit-oriented development's ridership bonus: a product of self-selection and public policies. Environ. Plan. A Econ. Sp. 39, 2068–2085. https://doi.org/10.1068/a38377.

Cervero, R., Adkins, A., Sullivan, C., 2010. Are suburban TODs over-parked? J. Public Transp. 13, 47–70. https://doi.org/10.5038/2375-0901.13.2.3.

Christiansen, P., Engebretsen, Ø., Fearnley, N., Usterud Hanssen, J., 2017a. Parking facilities and the built environment: impacts on travel behaviour. Transport. Res. Part A Policy Pract 95, 198–206. https://doi.org/10.1016/j.tra.2016.10.025.

Christiansen, P., Fearnley, N., Hanssen, J.U., Skollerud, K., 2017b. Household parking facilities: relationship to travel behaviour and car ownership. Transport. Res. Procedia 25, 4185–4195. https://doi.org/10.1016/j.trpro.2017.05.366.

Corcoran, J., Pojani, D., Mateo-Babiano, I., Sipe, N., Stead, D., Kimpton, A., 2020. Reclaiming lost ground: transitions of mobility and parking [WWW Document]. URL. https://parks-uq.github.io/, 12.7.22.

De Gruyter, C., Truong, L.T., Taylor, E.J., 2020. Can high quality public transport support reduced car parking requirements for new residential apartments? J. Transport Geogr. 82, 102627 https://doi.org/10.1016/j.jtrangeo.2019.102627.

Eriksen, H.C., 2018. The Effect of Flexible Parking Norms on Car Use and Car Ownership in New Residential Development: a Multiple-Case Study of Malmö. Gothenburg, and Copenhagen.

Evangelinos, C., Tscharaktschiew, S., Marcucci, E., Gatta, V., 2018. Pricing workplace parking via cash-out: effects on modal choice and implications for transport policy. Transport. Res. Part A Policy Pract 113, 369–380. https://doi.org/10.1016/j.tra.2018.04.025.

Ewing, R., Kim, K., Sabouri, S., Siddiq, F., Weinberger, R., 2021. Comparative Case Studies of Parking Reduction at Transit-Oriented Developments in the U.S.A. Transp. Res. Rec. J. Transp. Res. Board 2675, 125–135. https://doi.org/10.1177/0361198120965558.

Fan, Z., Harper, C.D., 2022. Congestion and environmental impacts of short car trip replacement with micromobility modes. Transport. Res. Transport Environ. 103, 103173 https://doi.org/10.1016/j.trd.2022.103173.

Ferguson, E., 2004. Zoning for Parking as Policy Process: A Historical Review. Transport Rev. 24, 177–194. https://doi.org/10.1080/0144164032000080485.

Gabbe, C.J., Pierce, G., Clowers, G., 2020. Parking policy: The effects of residential minimum parking requirements in Seattle. Land Use Pol. 91, 104053 https://doi.org/10.1016/j.landusepol.2019.104053.

Genter, J.A., Schmitt, L., Donovan, S., 2013. The Missing Link: Parking as the Integration of Transportation and Land Use.

Government Offices of Sweden, 2022. The transport sector is changing for the climate [WWW Document]. URL. https://www.regeringen.se/regeringens-politik/transportsektorn-staller-om-for-klimatet/, 3.20.22.

Guo, Z., 2013a. Home parking convenience, household car usage, and implications to residential parking policies. Transport Pol. 29, 97–106. https://doi.org/10.1016/j.tranpol.2013.04.005.

Guo, Z., 2013b. Residential Street Parking and Car Ownership. J. Am. Plann. Assoc. 79, 32–48. https://doi.org/10.1080/01944363.2013.790100.

Guo, Z., 2013c. Does residential parking supply affect household car ownership? The case of New York City. J. Transport Geogr. 26, 18–28. https://doi.org/10.1016/j.jtrangeo.2012.08.006.

Guo, Z., Ren, S., 2013. From Minimum to Maximum: Impact of the London Parking Reform on Residential Parking Supply from 2004 to 2010? Urban Stud. 50, 1183–1200. https://doi.org/10.1177/0042098012460735.

Hess, D.B., 2001. Effect of Free Parking on Commuter Mode Choice: Evidence from Travel Diary Data. Transp. Res. Rec. J. Transp. Res. Board 1753, 35–42. https://doi.org/10.3141/1753-05.

Johansson, E., Rosendahl, N., 2021. Replacing Parking with Mobility Services?. In: A Study of Gothenburg's Flexible Parking Requirements and Work with Mobility Agreements. Chalmers University of Technology.

Johansson, F., Henriksson, G., Envall, P., 2019. Moving to Private-Car-Restricted and Mobility-Served Neighborhoods: The Unspectacular Workings of a Progressive Mobility Plan. Sustainability 11, 6208. https://doi.org/10.3390/su11226208.

Kimpton, A., Pojani, D., Ryan, C., Ouyang, L., Sipe, N., Corcoran, J., 2021. Contemporary parking policy, practice, and outcomes in three large Australian cities. Prog. Plann. 153, 100506 https://doi.org/10.1016/j.progress.2020.100506.

King, D.A., 2022. Linking off-street parking to local transport and resilience policies. In: Cao, X.J., Ding, C., Yang, J. (Eds.), Urban Transport and Land Use Planning: A Synthesis of Global Knowledge. Academic Press, Cambridge, MA, pp. 163–180. https://doi.org/10.1016/bs.atpp.2021.10.004.

Kirschner, F., Lanzendorf, M., 2020. Parking management for promoting sustainable transport in urban neighbourhoods. A review of existing policies and challenges from a German perspective. Transport Rev. 40, 54–75. https://doi.org/10.1080/01441647.2019.1666929.

Lehe, L., 2018. How minimum parking requirements make housing more expensive. J. Transp. Land Use 11. https://doi.org/10.5198/jtlu.2018.1340.

Li, F., Guo, Z., 2014. Do parking standards matter? Evaluating the London parking reform with a matched-pair approach. Transport. Res. Part A Policy Pract. 67, 352–365. https://doi.org/10.1016/j.tra.2014.08.001.

Li, F., Guo, Z., 2018. Do Parking Maximums Deter Housing Development? J. Plann. Educ. Res. 38, 183–197. https://doi.org/10.1177/0739456X16688768.

Litman, T., 2021. Parking Requirement Impacts on Housing Affordability.

Liu, Q., Wang, J., Chen, P., Xiao, Z., 2017. How does parking interplay with the built environment and affect automobile commuting in high-density cities? A case study in China. Urban Stud. 54, 3299–3317. https://doi.org/10.1177/0042098016667040.

Lundin, P., 2010. Mediators of Modernity: Planning Experts and the Making of the "Car-Friendly" City in Europe. In: Hard, M., Misa, T.J. (Eds.), Urban Machinery: inside Modern European Cities. The MIT Press, Cambridge, MA.

Manville, M., Shoup, D., 2005. Parking, People, and Cities. J. Urban Plann. Dev. 131, 233–245. https://doi.org/10.1061/(ASCE)0733-9488, 2005)131:4(233.

Manville, M., Beata, A., Shoup, D., 2013. Turning Housing Into Driving: Parking Requirements and Density in Los Angeles and New York. Hous. Policy Debate 23, 350–375. https://doi.org/10.1080/10511482.2013.767851.

McCahill, C., Garrick, N., 2012. Automobile use and land consumption: Empirical evidence from 12 cities. Urban Des. Int. 17, 221–227. https://doi.org/10.1057/udi.2012.12.

McCahill, C., Garrick, N., 2014. Parking Supply and Urban Impacts. In: Ison, S., Mulley, C. (Eds.), Parking: Issues and Policies. Emerald Group Publishing Limited, Bingley, UK.

McCahill, C.T., Garrick, N., Atkinson-Palombo, C., Polinski, A., 2016. Effects of Parking Provision on Automobile Use in Cities: Inferring Causality. Transp. Res. Rec. J. Transp. Res. Board 2543, 159–165. https://doi.org/10.3141/2543-19.
Mingardo, G., van Wee, B., Rye, T., 2015. Urban parking policy in Europe: A conceptualization of past and possible future trends. Transport. Res. Part A Policy Pract. 74, 268–281. https://doi.org/10.1016/j.tra.2015.02.005.
Ministry of the Environment. Sweden's Climate Policy Framework. https://www.government.se/articles/2021/03/swedens-climate-policy-framework.
Mukhija, V., Shoup, D., 2006. Quantity versus Quality in Off-Street Parking Requirements. J. Am. Plann. Assoc. 72, 296–308. https://doi.org/10.1080/01944360608976752.
Nieuwenhuijsen, M.J., Khreis, H., 2016. Car free cities: Pathway to healthy urban living. Environ. Int. 94, 251–262. https://doi.org/10.1016/j.envint.2016.05.032.
Ornetzeder, M., Hertwich, E.G., Hubacek, K., Korytarova, K., Haas, W., 2008. The environmental effect of car-free housing: A case in Vienna. Ecol. Econ. 65, 516–530. https://doi.org/10.1016/j.ecolecon.2007.07.022.
Pierce, G., Shoup, D., 2013. Getting the Prices Right. J. Am. Plann. Assoc. 79, 67–81. https://doi.org/10.1080/01944363.2013.787307.
Parking Reform Network, 2021. Parking Mandates Map [WWW Document]. URL. https://parkingreform.org/resources/mandates-map/, 12.20.21.
Richardson, E., 2014. The Importance of Parking Policy for Sustainable Transport and Land Use City Planning. In: AITPM 2014 National Conference.
Rosenblum, J., Hudson, A.W., Ben-Joseph, E., 2020. Parking futures: An international review of trends and speculation. Land Use Pol. 91, 104054 https://doi.org/10.1016/j.landusepol.2019.104054.
Scheiner, J., Holz-Rau, C., 2007. Travel mode choice: affected by objective or subjective determinants? Transportation 34, 487–511. https://doi.org/10.1007/s11116-007-9112-1.
Scheiner, J., Faust, N., Helmer, J., Straub, M., Holz-Rau, C., 2020. What's that garage for? Private parking and on-street parking in a high-density urban residential neighbourhood. J. Transport Geogr. 85, 102714 https://doi.org/10.1016/j.jtrangeo.2020.102714.
Selzer, S., 2021. Car-reduced neighborhoods as blueprints for the transition toward an environmentally friendly urban transport system? A comparison of narratives and mobility-related practices in two case studies. J. Transport Geogr. 96, 103126 https://doi.org/10.1016/j.jtrangeo.2021.103126.
Shoup, D.C., 1999. The trouble with minimum parking requirements. Transport. Res. Part A Policy Pract 33, 549–574. https://doi.org/10.1016/S0965-8564(99)00007-5.
Shoup, D.C., 2011. The High Cost of Free Parking. American Planning Association, Chicago, IL.
Shoup, D., 2014. The High Cost of Minimum Parking Requirements. In: Ison, S., Mulley, C. (Eds.), Parking: Issues and Policies. Emerald Group Publishing Limited, Bingley, UK.
Shoup, D., 2021. Pricing curb parking. Transport. Res. Part A Policy Pract 154, 399–412. https://doi.org/10.1016/j.tra.2021.04.012.
Simma, A., Axhausen, K.W., 2003. Interactions between Travel Behaviour, Accessibility and Personal Characteristics: The Case of Upper Austria. Eur. J. Transport Infrastruct. Res. 3, 179–197. https://doi.org/10.18757/ejtir.2003.3.2.3686.
SKR, 2016. Classification of Swedish Municipalities 2017.
Sprei, F., Hult, C., Hult, Å., Roth, A., 2020. Review of the Effects of Developments with Low Parking Requirements. Sustainability 12, 1744. https://doi.org/10.3390/su12051744.
Statistics Sweden, 2016. Nearly 4.8 million dwellings in Sweden [WWW Document]. URL. https://www.scb.se/en/finding-statistics/statistics-by-subject-area/housing-construction-and-building/housing-construction-and-conversion/dwelling-stock/pong/statistical-news/dwelling-stock-2016-12-31/, 12.7.21.
Statistics Sweden, 2020. The Statistics Database [WWW Document]. URL. https://www.statistikdatabasen.scb.se/pxweb/sv/ssd/.
Taylor, E.J., 2020. Parking policy: The politics and uneven use of residential parking space in Melbourne. Land Use Pol. 91, 103706 https://doi.org/10.1016/j.landusepol.2018.11.011.
Van Acker, V., Witlox, F., 2010. Car ownership as a mediating variable in car travel behaviour research using a structural equation modelling approach to identify its dual relationship. J. Transport Geogr. 18, 65–74. https://doi.org/10.1016/j.jtrangeo.2009.05.006.
Watters, P., O'Mahony, M., Caulfield, B., 2006. Response to cash outs for work place parking and work place parking charges. Transport Pol. 13, 503–510. https://doi.org/10.1016/j.tranpol.2006.05.008.
Weinberger, R., 2012. Death by a thousand curb-cuts: Evidence on the effect of minimum parking requirements on the choice to drive. Transport Pol. 20, 93–102. https://doi.org/10.1016/j.tranpol.2011.08.002.
Weinberger, R.R., 2014. Three Faces of Parking: Emerging Trends in the U.S. In: Ison, S., Mulley, C. (Eds.), Parking: Issues and Policies. Emerald Group Publishing Limited, Bingley, UK.
Weinberger, R.R., Karlin-Resnick, J., 2015. Parking in Mixed-Use U.S. Districts: Oversupplied No Matter How You Slice the Pie. Transp. Res. Rec. J. Transp. Res. Board 2537, 177–184. https://doi.org/10.3141/2537-19.
Weinberger, R., Seaman, M., Johnson, C., 2008a. Suburbanizing the City: How New York City Parking Requirements Lead to More Driving.
Weinberger, R., Seaman, M., Johnson, C., Kaehny, J., 2008b. Guaranteed Parking – Guaranteed Driving.
Yin, C., Shao, C., Wang, X., 2018. Built Environment and Parking Availability: Impacts on Car Ownership and Use. Sustainability 10, 2285. https://doi.org/10.3390/su10072285.