

## **Where to park your car at home? How district parking garages can complement existing parking options in dense urban neighborhoods.**

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### **Extended Abstract**

#### **1. Context and research questions**

Car ownership rates are decreasing in many European cities, especially in dense urban neighborhoods. However, many of these neighborhoods have been developed before mass motorization. The costs for residential parking permits are often rather low and do not reflect the variations of supply and demand of parking in different neighborhoods. Therefore, there is a shortage of on-street parking in those neighborhoods which results in parking search traffic. At the same time, city governments want to reduce the space allocated for on-street parking to free up space to expand urban greenery as a climate mitigation measure. In addition, road space currently allocated for cars is needed to expand bicycle tracks and provide more space for sojourning activities of the local population. Cities have different options to enable such a transformation of urban road space. They can i) increase the price of residential on-street parking permits, ii) support the development of district parking facilities either through adapted regulations with regards to parking requirements or their own initiatives, iii) collaborate car sharing companies in order to increase the availability of shared cars or iv) offer discounts for people to abolish their cars to further reduce car ownership rates.

Different to private parking facilities, district parking facilities are operated by the government or other organisations on their behalf. Users cannot rent specific parking lots but are only provided with access to the parking facility against a fee. Furthermore, the usage of district parking facilities for long term parking is restricted to local residents. In this way, the provision of district parking can help governments to directly reduce parking demand for

on street parking. However, due to the high construction cost, such facilities cannot usually not operated in a way that covers costs and therefore need subsidies, which for example can raised by increasing the cost for on-street resident parking permits.

There is a research gap with regards how car owners decide where to park their cars at their residence in dense urban neighborhoods. Therefore it remains unclear which of those strategies is suitable and financially efficient to reduce the demand for on street parking which opens opportunities to reallocate urban road space for a more sustainable transport system. In this context, this research addresses the following research questions:

- What is willingness to pay for the different types of parking spaces?
- How do different factors such a cost, distance and type of parking facility as well as the availability of car sharing options influence parking preference at their residence and car ownership? What role does the intensity of car use and the current type of parking play in this?
- Which implication do those preferences have with regards to the management and provision of car parking options and alternatives for cities that aim to transform urban road space?

## **2. Literature**

Parking policy has been considered as a key element of transport policy in many countries for several decades and therefore also has been the subject of academic research. The work by (Axhausen & Polak, 1991) is one of the earliest works that applied a stated preference approach to separately quantify the perception of different components of the parking activity , e.g., general in-vehicle time, parking search time, egress time. Since then, many researchers have applied similar approaches and sometimes combined it with revealed preference data to analysis parking choice behaviour. While the bulk of that work focuses on non-residential parking, e.g. in a town center (Rodríguez et al., 2023), at the workplace (Christiansen et al., 2017; Tchervenkov et al., 2021) or at park and ride facilities (Bos et al., 2004), there are surprisingly few studies that focus on parking choice at the residence, e.g. (Ostermeijer et al., 2019) despite the fact that cars are being parked at those locations for the longest time periods and the huge potential that a reduction of on street parking lots would provide to reallocate road space (Croeser et al., 2022). This paper addresses this research gap.

## **3. Methodology and data collection**

The preference structure of residential parking choice cannot be reliably described only on revealed preference data. On the one hand, certain attributes do not show any variation within a city, e.g. the costs for a residents' on street parking permits. On the other hand, public district parking facilities are not available in most cities and if so are limited to certain neighborhoods. Therefore, a stated choice experiment is used to determine the preference

structure. Respondents were asked to select the most preferred alternative among the following four options:

1. On-street parking with residential parking permit
2. Public district parking facility
3. Privat parking lot
4. Giving up the car

The survey is has been designed for car owners who live in a dense or very dense district in the cities of Basel, Geneva and Zurich where there is a shortage in on-street parking lots for residents. Here, the creation of distric parking facilities promises to be an appropriate measure to reduce the amount of space required for on-street parking spaces and to reduce parking search traffic. The prices of residential parking permits vary in those cities between 200 CHF in Geneva, 284 CHF in Basel, 300 CHF in Zurich and relevant amounts of district parking facilites are currently only available in Geneva.

### **3.1.Experiment design**

Each of the first three alternatives is described by the monthly costs and location of the parking space in relation to the place of residence. Since most residents' parking permits are purchased for one year, the annual costs were also displayed for the “on-street” alternative on the questionnaire. The location of the parking area is described by distance in metres and walking time in minutes. Since the distance between the place of residence and the parking space in the blue zone varies, ranges of walking distances are indicated for this alternative. For the alternatives “district parking” and “private parking”, the parking lot type is also described. In the case of district parking, a distinction is made between a free choice of parking space and a fixed parking lot that is permanently allocated to a car; in the case of private parking space, a distinction is made between an uncovered outdoor parking space, a fixed lot in a parking garage and an individual garage which would additional allow to safely store personal items such as spare tyres or bulky sport equipment. The alternative “givin up the car” has no specific characteristics as it mainly serves as a option in case the respondent considers the other parking options as too expensive. However, it is expected that the availability of car sharing vehicles near the place of residence has an influence on the willingness to give up the car. Therefore, the information on the distance to the nearest car sharing location and the number of vehicles stationed there are described as part of the alternative "giving up the car".

The attributes and attribute levels used for the different alternatives are presented in Table 1. For the costs of parking spaces in neighbourhood parking areas and private parking spaces, different attribute levels are taken into account depending on the city and density class of the

postcode zone of the place of residence as well as the respective parking space type. This ensures that the costs in the decision experiments are within a credible range of values depending on the place of residence of the participant and the type of parking space specified in each case.

*Table 1: Attributes and attribute levels of the decision experiment*

		On-street parking (cost per year)	Distric parking (cost per month)	Private parking lot (cost per month)	Giving up the car
Cost	Dense neighborhood	Basel (alle post codes)	300   480   780   1200	65 <sup>a</sup>   90 <sup>b</sup>   110 <sup>b</sup>   120 <sup>b</sup>   145 <sup>c</sup>	90 <sup>d</sup>   120 <sup>e</sup>   150 <sup>e</sup>   165 <sup>e</sup>   195 <sup>f</sup>
		Genf (post codes 1203,1206,1227)	360   600   900   1320	80 <sup>a</sup>   105 <sup>b</sup>   130 <sup>b</sup>   140 <sup>b</sup>   170 <sup>c</sup>	120 <sup>d</sup>   160 <sup>e</sup>   200 <sup>e</sup>   220 <sup>e</sup>   260 <sup>f</sup>
		Zürich (post codes 8006,8008,8037)	360   600   900   1320	65 <sup>a</sup>   90 <sup>b</sup>   110 <sup>b</sup>   120 <sup>b</sup>   140 <sup>c</sup>	110 <sup>d</sup>   145 <sup>e</sup>   180 <sup>e</sup>   200 <sup>e</sup>   235 <sup>f</sup>
	Very dense neighborhood	Genf (post codes 1201,1205,1207)	360   600   900   1320	85 <sup>a</sup>   110 <sup>b</sup>   140 <sup>b</sup>   150 <sup>b</sup>   180 <sup>c</sup>	150 <sup>d</sup>   200 <sup>e</sup>   250 <sup>e</sup>   275 <sup>e</sup>   325 <sup>f</sup>
		Zürich (post codes 8003,8004,8005)	360   600   900   1320	80 <sup>a</sup>   105 <sup>b</sup>   130 <sup>b</sup>   140 <sup>b</sup>   170 <sup>c</sup>	130 <sup>d</sup>   175 <sup>e</sup>   220 <sup>e</sup>   240 <sup>e</sup>   285 <sup>f</sup>
			-	Free choice <sup>a,b</sup>   fixed parking lot <sup>b,c</sup>	outdoor <sup>d,e</sup>   in parking garage <sup>e,f</sup>   individual garage <sub>e,f</sub>
Type of parking lot					
Walking duration between residence and parking lot (min)		1   2-3   3-5   5-8	3   6   9   12	0   2   5   8	
Number of vehicles stationed at car sharing location					1   2   4
Walking duration to the nearest car sharing location (min)					1   3   6   12

The experimental designs of the decision experiment were implemented with NGene, which allows the generation of choice sets according to the principles of efficient design (Rose et al., 2008). By defining constraints, it was ensured that trade-offs arise between the alternatives neighbourhood parking and private parking, i.e. that the closer alternative is at least as expensive as the alternative further away. For each combination of city and density class, 25 different blocks were generated, each with 7 choice situations per questionnaire. The assignment of a block to individual participants was done through a random process.

The survey was implemented as a web-based questionnaire with the software Qualtrics. Figure 1 shows an example of a choice situation. The accompanying text above the choice situation remained the same throughout the experiment and ensured that respondents were

clear which car is meant and that the decision is not being influenced by the (changing) expectations with regards to the availability of charging facilities among the different options. In case a person owned more than one car In case a person owned more than one car, the choice experiment was specified for the most frequently used car. In order to easily distinguish between the alternatives, the columns were coloured differently.

Imagine that **only the following options are available for parking** your Audi A2 at your place of residence.

Charging stations for electric cars are available everywhere

	On street parking	District parking garage	Private parking lot	Giving up the car
<b>Cost per month</b>	30 CHF (360 CHF per year)	100 CHF	250 CHF	-
<b>Type of parking lot</b>	-	Free choice	Outdoor	-
<b>Walking distance to residence</b>	5 - 8 min (400– 600 meter)	3 min (250 meter)	On the same plot	-
<b>Nearest carsharing location</b>	-	-	-	3 min (200 Meter) 2 shared cars
<b>Your choice</b>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Figure 1: Visual display of a choice situation in the web-based questionnaire.

### 3.2. Sample

The participants were recruited in cooperation with the motor vehicle registration authority of each city. Invitation letters to participate in the survey were sent to randomly selected individuals who had at least one car registered in their name in one of the selected postcode zones. The letter briefly described the context of the study and included a shortened URL and a QR-code which directed the recipient to the web-based questionnaire. In order to increase the response rate and to obtain a representative sample, that e.g. also covers people with lower incomes or lower education levels, taking part in a prize draw of 5x 100 Swiss Francs was offered as an incentive to all respondents who completed the questionnaire. A pretest was conducted in the city of Zurich. Since neither special patterns with regards to the response behaviour or none a need to improve the questionnaire were identified, recruitment in Basel and Geneva was carried out without a pretest. In Zurich, the survey has been conducted in February 2023 and in Geneva and Basel in March 2023.

Table 2 lists the response rates for the three cities. For respondents who own a parking lot or can use one at no additional cost, the stated choice experiment seems pretty abstract. Therefore only respondents who rent a parking lot or pay for a resident parking permit have been asked to fill the choice experiment.

*Table 2: Response rates by city*

	Basel	Geneva	Zurich	Total
Letters sent	1152	2000	2000	5152
Questionnaire started	233	540	594	1367
Answering rate	20%	27%	30%	27%
Questionnaire completed with stated choice experiment	154	301	420	875
Number of respondents who currently use on-street parking	67	126	212	406
Number of respondents who currently use private parking	86	140	196	428
Number of respondents who currently use district parking	1	35	12	48
Net response rate	13%	15%	21%	17%

Basel has the lowest gross response rate at 20%, while Zurich has the highest at 30%. These differences can be read as an indication of how important the topic of parking space planning is to the population in the various cities due to the existing problem pressure. This hypothesis is supported by the fact that residential parking supply is scarcer in the selected postcode zone in Zurich and Geneva as compared to Basel.

The representativeness of the sample has been checked by comparing the proportions of socio-demographic characteristics with the Microcensus Mobility and Transport 2015 whose sample includes 914 car owners living in the considered postcode zones and has been reweighted to be representative for the Swiss resident population. The comparison revealed that lower income groups, persons with lower education levels and living in single households are underrepresented in our sample. Therefore, we reweighted our sample to fit the control totals as given by the Microcensus for the selected postcode areas. We used the R-library “anesrake” for this task and restricted the maximum person weight to not exceed a value of five. In this way, a match within a range of +/- 1% was reached for all attribute levels except for the variable “highest completed education”. Here, our reweighted sample still

exceeds the expected share by 18 percentage points. We used the computed weights for all analyses presented in this paper.

### 3. Results

The stated choice experiment was analysed using the R-library Apollo (Hess & Palma, 2019). First, a basic model was estimated in which the utility of an alternative is described as a linear combination of the respective alternative-specific attributes. As the descriptive analysis of the data showed strong inertia effects, i.e. a preference for those alternatives that represent the type of parking which is currently used, inertia variables were added to the utility function. In addition, various formulations of nested logit models were tested to determine whether correlations exist between the alternatives that cannot be depicted by the alternative-specific attributes and the inertia variables. It turned out that the cross-nested model structure shown in Figure 2 corresponds best to the data. This model structure describes that people who currently park their car in a private parking space tend more towards the alternative "district parking" than towards the "blue zone" or "car abandonment". Conversely, people who currently use the blue zone are more inclined to give up their car or to use a neighbourhood parking facility than to rent a private parking space.

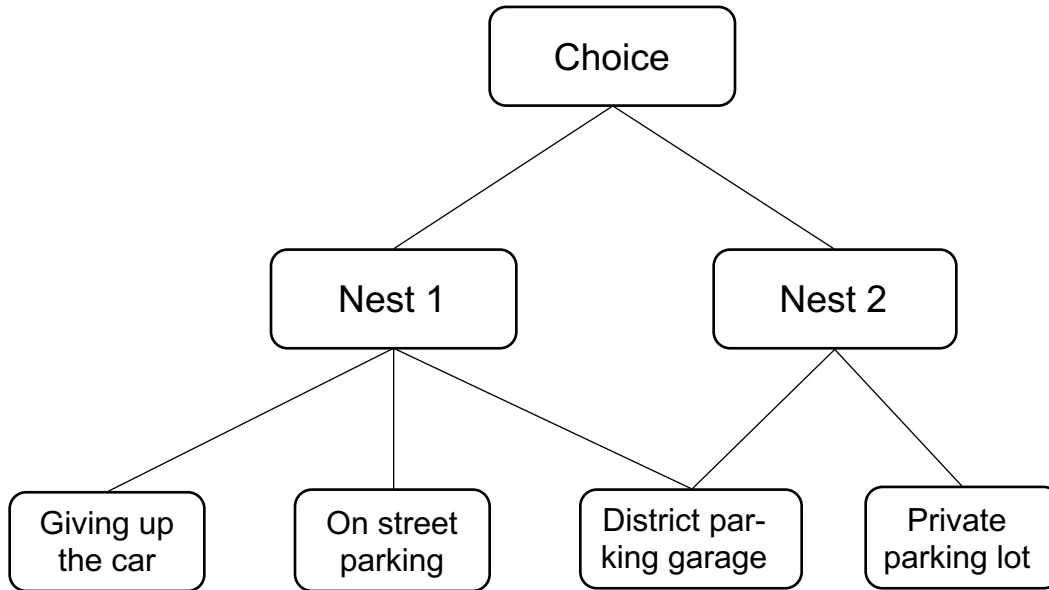


Figure 2: Cross-nested logit model structure that best describes the observed decisions.

In further steps of the model development, interaction terms were used to investigate whether there are systematic perception differences with regard to costs and walking time. With regard to costs, an interaction term as described in equation 1 was employed.

$$f(c, y) = \beta_c \cdot \left(\frac{y}{\bar{y}}\right)^\lambda \cdot c \quad (1)$$

In equation 1,  $c$  stands for cost,  $\beta_c$  is the linear cost parameter,  $y$  the respondent's household income and  $\bar{y}$  the average household income across the whole sample. Accordingly, a negative parameter value of  $\lambda$  describes that costs are perceived less strongly with increasing income.

Furthermore, interaction terms as indicated in equation 2 were used to test whether distances are systematically perceived differently among different groups of respondents.

$$f(d, x) = \beta_d \cdot (1 + \beta_{d,x} \cdot x) \cdot d \quad (2)$$

In equation 2,  $d$  stands for walking duration,  $\beta_d$  is the linear walking duration parameter and  $x$  a dummy variable that takes the value of 1 if a variable fulfills a certain requirement. Hence,  $\beta_{d,x}$  describes to what extent this subgroups' perception of distance is different to the control group.

Finally, it was investigated to what extent the various person-specific attributes have a statistically significant influence on the perceived utility and thus the probability of selecting the different alternatives: age, sex, personal assessment of the availability of on-street parking lots on a scale from 1 (very bad) to 5 (very good), car usage frequency (number of used days over the last seven days), residual value of the car, membership in car sharing organization, income, population and job density within a radius of 400m (excluding parks and waterbodies).

The results of the statistical model are presented in Table 3. The attractiveness of an alternative decreases with rising costs and longer distances from the place of residence to the parking lot. People who currently use on-street parking with a residents' permit react much more sensitively to changes in parking costs. With regard to the assessment of the alternative "on street parking", these people have a 3.2 times stronger perception of costs than other people. With regard to the costs for the alternatives "private parking area" and "neighbourhood parking", a higher cost sensitivity by a factor of 1.5 is determined.

The exponent of the income elasticity indicates that the willingness to pay increases slightly with rising income. Persons with an monthly household income of CHF 16,000 per month have a 6% higher willingness to pay as compared to the average income of CHF 9,000. A person with a household income of CHF 9,000 is willing to pay an extra CHF 17.4 per months if a private parking space is located 100 metres closer to the place of residence.

The alternative "on street parking" is considered significantly more attractive by people who already use a residents' parking permit as compared to by people who currently use a private parking space.

The better the availability of on street parking spaces at the place of residence is assessed, the more likely the alternative "on street parking" is chosen. Interestingly, the willingness to choose the alternative "on street parking" also increases with the number of days on which the car was used during the last seven days before the survey. This neither applies for the alternative "private parking lot" nor "district parking". It might be caused by the fact that respondents who use on-street parking in areas with good on-street parking availability use their cars much more frequently as persons living in areas with low availability.

Respondents from Geneva, where many district parking facilities are already in operation, did not systematically choose the alternative "neighbourhood parking" more often than respondents from other cities.

*Table 3: Model results*

Alternative	Parameter	Parameter	Std. error	t-value
All alternatives with parking option	Cost (1/CHF)	-0.008	0.00	-13.00
	Income elasticity $\lambda$	-0.100	0.03	-2.99
	Distance (1/100m)	-0.148	0.01	-11.87
On-street parking permit	Inertia (today's choice)	1.351	0.25	5.31
	Stronger cost perception for respondents who use on street parking today	3.223	0.31	7.16
	Assesment of the availability of on-street parking lots (per step)	0.497	0.07	7.49
	Numbers of days with car usage among the last seven days	0.052	0.01	3.57
	Residual car value (1/1000 CHF)	0.008	0.00	3.47
Private parking lot	Alternative specific constant	1.070	0.24	4.50
	Inertia (today's choice)	0.449	0.22	2.01
	Additional inertia for respondents from Geneva	0.109	0.05	2.02
	Stronger cost perception for respondents who use on street parking today	1.445	0.14	3.20
	Parking garage (as compared to outdoor parking)	0.304	0.06	4.68
	Individual parking garage (as compared to outdoor parking)	0.330	0.06	5.18
	Numbers of days with car usage among the last seven days male	0.012	0.01	1.09
	Residual car value (1/1000 CHF)	0.142	0.05	2.81
District parking	Alternative specific constant	0.011	0.00	6.30
	Stronger cost perception for respondents who use on street parking today	1.843	0.11	16.08
	Increased perception of distance	1.582	0.21	2.77
	Fixed parking lot (as compare to free choice)	0.338	0.13	2.62
Giving up the car	Alternative specific constant	0.124	0.05	2.40
	Respondents from Geneva	-1.482	0.24	-6.12
	Respondent who uses on street parking today	0.423	0.12	3.57
	Reduced perception of distance (to car sharing station)	0.624	0.22	2.81
	Number of car sharing vehicles at the station	-0.823	0.16	-4.99
	Assesment of the availability of on-street parking lots (per step)	0.090	0.04	2.20
	Income (linear)	-0.078	0.03	-2.86
	Existing car sharing membership	-0.046	0.01	-3.41
$\lambda$ -Parameter Nested Logit	Additional term for users of on-street parking in areas with low availability	0.603	0.16	3.78
	Nest 1: district parking, on-street parking and giving up car	-0.882	0.14	-6.28
	Nest 2: district parking and private parking lot	0.866	0.10	8.58
	Affiliation of district parking: Nest 2	0.608	0.07	8.70
	$\rho^2$	0.881	0.21	4.24
	Log-Likelihood (0) / (final)			0.29
				-8006 / -5667

For people who already use a private parking space, a private parking space in a parking garage offers an additional benefit on average, which corresponds to a value of CHF 214 per month in Zurich and Basel and CHF 227 per month in Geneva. The willingness to pay for private parking spaces determined with the stated choice experiment are slightly higher than the prices paid according to the sample in the three study areas. This is in line with expectations, as the willingness to pay must be higher than the market price for a person to consider renting such a parking space and demonstrates the validity of the results.

In the case of the alternative "giving up the car", the strongly negative constant describes that this alternative is perceived negatively and is therefore chosen comparatively rarely. However, respondents who use a resident parking permit are significantly more likely to chose this alternative. This also applies to respondents living in Geneva. The walking time to the nearest car sharing location has 86% less effect on the choice of this alternative as compare to the walking time to a parking lot for one's own car. This alternative, on the other hand, is systematically chosen more often the more car sharing vehicles are stationed at the next location. For an additional stationed vehicle, an additional walk of 350 metres to the car sharing station is accepted on average.

#### **4. Discussion**

The decision experiment reveals that the preference structures for the choice of parking at the place of residence differ greatly between different groups of people. People who currently use a residents' parking card react much more sensitively to changes in costs, especially with regard to the fees for the residents' parking card. Likewise, these people are more likely to consider giving up the car and are more sensitive to improvements in car sharing.

People who currently use a private parking space consider neighbourhood parking as an equal alternative, especially if no parking space is available directly at their place of residence. This means that district parking is more likely to compete with the private parking spaces than with on street parking. Accordingly, regulatory measures are required if district parkings should target a reduction of the demand for on street parking.

Increased fees for residents' parking permits and improvements of car sharing availability will cause a small share of people who currently use on street parking to give up their car. This is especially true for people who are already members of a car sharing organisation. However, in areas with as surplus demand for on street parking, the willingness to forego owning a car is less, possibly because in these areas people with a low need to own a car have already refrained from owning a car. This indicates that in such areas, a substantial reduction of demand for on street parking can only be achieved through increased fees for residents' parking permits and the provision of alternative parking lots, e.g. in district parkings.

## **5. Conclusion**

The development of district parking garages is a suitable measure to reduce the space required for on street parking. This is especially true for areas which are characterized by a surplus demand for on street parking and at low vacancy rates of private parking spaces.

When introducing district parking garages, various control measures are needed to prevent it from being used primarily by people who would otherwise have used a private parking space. For example, access could be restricted to people who live in an area with surplus demand for on street parking and who do not have the possibility to use a private parking space at their place of residence. In addition, access to district parking garages could be limited to one car per household, or people who have previously obtained a residents' parking permit could be given priority on a waiting list.

In dense urban neighborhoods, the creation of district parking facilities is challenging due to the lack of available space and is therefore expensive to build. The funds required for this could, however, be at least partly covered by increasing the costs for residents' parking permits. This would also motivate some residents who use on street parking to give up their cars. This effect would also enhance the impact of district parkings and thus allow for a more dedicated reallocation of road space for climate change mitigation measures, cycling facilities and more space for sojourning activities.

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## **Note with regards to this abstract**

A more extensive literature review and case studies where the impact of various pricing scenarios is simulated are omitted due to space constraints. However, such content will be presented at the conference and be included in a full paper if the abstract is selected for special issue publication.

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