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Investigating people's preferences for car-free city centers: A discrete choice experiment

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ABSTRACT

In the face of climate change and growing health hazards due to air pollution in urban centers, private car use is being increasingly criticized. At the same time, research suggests that there is an unsatisfied demand for modes of transportation other than private cars. In fact, many cities all over Europe have already established car-restricted or car-free areas. This paper uses a discrete choice experiment to learn more about people's preferences regarding a car-free city center in Berlin, Germany. We find that, given the current infrastructure, around 60% of our respondents are willing to accept a car-free city center. By improving infrastructure for cyclists, willingness to accept a car-free city center strongly increases. Similarly, improving the network of bus stops and train stations as well as rededicating released streets to recreational uses would contribute to a higher acceptance of a car-free city center. Using a random parameters logit model, we have also identified observed and unobserved sources of heterogeneity.

1. Introduction

In September 2015 the American Environmental Protection Agency discovered that many Volkswagen cars with diesel engines had a software which was able to manipulate tests to measure carbon dioxide emissions levels. In the following months, it turned out that not only Volkswagen but several European carmakers used similar software to bypass emission rules (EPA, 2017). The "diesel dupe", as the scandal was nicknamed in the media (BBC, 2015), brought the problem of air pollution in city centers back on the political agenda. Whereas there is a likelihood that the car industry will be able to find technical solutions to reduce air pollution from diesel engines, environmental organizations call for the ban of cars with diesel engines in cities (Deutsche Umwelthilfe, 2017). However, neither better filters for diesel engines nor the replacement of diesel cars by petrol-driven or electric cars can solve all of the urgent problems of urban centers caused in large parts by individual motorized traffic. Apart from high concentrations of particulate matter and poor air quality, motorized traffic leads to high noise levels, causing, among other problems, sleep disturbances. Additionally, some authors claim a rapid increase in lifestyle-related health problems such as heart disease, caused by the sedentary aspect of driving (Dora and Philips, 2000). On a global level, motorized traffic substantially contributes to CO_2 emissions and thus to

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climate change (Kent, 2014).

Balancing the need for mobility with environmental and health concerns is one of the most pressing issues for the sustainability of urban centers (European Commission, 2004). Still, motorized traffic is rapidly growing. In 2011, the number of cars in the world was estimated at around one billion (OECD/ITF, 2012). Taking into account increasing incomes and population growth, researchers project that the number of vehicles could pass two billion by 2050 (OECD/ITF, 2012). In recent years, decision makers have drawn more attention to these problems, most prominently to health problems caused by insufficient physical activity and poor air quality. In addition, the fact that emissions from private cars significantly contribute towards climate change has led to a more critical view on car usage. Scholars, government agencies and health organizations have shown growing interest in identifying strategies to convince people to abstain from using their cars (Stradling, 2003) and have started to become actively engaged in developing transportation systems that promote new modes of transportation.

One possible solution to the problems caused by private car use is the establishment of car-free city centers. Since the 1990s, several European cities have introduced measures to restricting car use, ranging from car-free city centers, as in Vienna, to restricting car access in new residential areas, where parking is no longer adjacent to housing but rather organized in concentrated parking facilities (Borgers et al., 2008). Crawford (2002) was among the first to approach the topic of car-free cities theoretically. Without ignoring the health and environmental problems mentioned above, he proposes that the most convincing reasons to establish car-free cities are actually social and aesthetic in nature. In line with others such as Urry (2004), Crawford (2002) argues that the omnipresence of cars in urban areas has caused public spaces to decay and will ultimately lead to a disturbance of urban social systems. He suggests entirely car-free urban designs for new cities but also provides solutions regarding how existing cities can substantially reduce car use. As a result, cycling and walking will become faster, safer and ultimately much more desired modes of transportation. Melia (2014, p. 213) defines car-free areas rather broadly as “residential or mixed use developments which provide a traffic free or nearly traffic free immediate environment (1), are designed to facilitate movement by non-car means (2), and offer no parking for residents or limited parking separated from the dwellings (3)”. Related to this differentiation, Melia et al. (2012) distinguish three types of car-free development. The first type is the Vauban model, which is not per se car-free but does not allow parking adjacent to housing. The second type is limited access, which is similar to the Vauban model but features “less peripheral parking than Vauban” and “varying arrangements to physically control the access of motor vehicles to the residential areas” (Melia et al., 2012, p. 136). The third type of car-free development covers pedestrianized centers which, unlike the first two types, are not set in new residential areas but rather in existing urban spaces that have been retrospectively transformed into car-free city centers.

Citizens’ attitudes and preferences towards car-free city centers are largely unknown, yet crucial for the design of policies. Some studies have focused on preferences for switching from cars to alternative modes of transport. Handy et al. (2005) find that a substantial number of people drive out of necessity rather than actually preferring it to other modes of transportation. Therefore, they suggest, “policies that provide alternatives to driving or that reduce the length of driving trips would help. Such policies might include improved transit services and improved bicycle and pedestrian infrastructure” (Handy et al., 2005, p. 18). This finding is echoed by Ruiz and Barnabe (2014), who identified an unsatisfied demand for non-motorized modes of transportation. Their results suggest that, among those travelling 30 minutes or less, a significant number of people are “willing to change to cycling” (Ruiz and Barnabe, 2014, p. 209). In addition, they find that willingness to cycle to and from work/school depends on the educational level of respondents, distance and bike availability. Similarly Hayden et al. (2017) find that even highly car dependent individuals are willing to reduce car use if alternative transportation strategies are put in place. In contrast, Skov-Petersen et al. (2017), using observed data on bicycle rides before and after an infrastructural improvement in Copenhagen, find that improved bicycle infrastructure does not lead to people shifting transportation mode. Carse et al. (2013) investigate why people prefer using cars for various trip purposes, finding that for work trips “commuting distance and workplace car parking availability were strongly associated with using the car to travel to work” (Carse et al., 2013, p. 69). While they acknowledge that it might be difficult to influence commuting distances in established cities, they point out that these factors and their influence on travel behavior ought to be taken into consideration when planning the location and type of new residential areas. Qin et al. (2013) analyze car-owners’ choice behavior using a discrete choice experiment. They concluded that people are most sensitive to changes in fuel cost and parking fees. Borgers et al. (2008) conducted a discrete choice experiment in four Dutch cities to investigate how residents can be compensated for having to park at some distance from their homes. Their findings suggest that even though residents prefer to park their cars adjacent to their home, safe parking facilities and improved public transport facilities significantly affect their perceptions of concentrated parking areas. They conclude that these factors must be taken into account when designing new car-restricted residential areas. Da Silva Borges and Goldner (2015) investigated which socio-economic variables influence people's willingness to reside in a car-free neighborhood. Drawing on a standardized questionnaire they found that age, children and mode of transport influence the willingness to reside in a car-free zone. Younger people and parents are more likely to accept car-free zones than the elderly and people without children. Respondents who predominantly travel by bike or walk are more likely to live in car-free zones than people who use public transport or cars and motorbikes.

The present paper adds to this literature by investigating preferences and willingness to pay values for a completely car-free city center in one of the largest cities in Europe. To our knowledge, this is the first study to measure the potential of car-free city centers quantitatively. Our study explicitly formulates strategies for car-free city centers and asks people to choose their preferred strategy using a discrete choice experiment. The method allows us to identify drivers – urban green space, and improvements in the public transportation and bicycle infrastructure – that facilitate the acceptance of a car-free city. We analyze how these drivers affect the probability to opt for a car-free city center and to what extent people are willing to pay for different scenarios of car-free city centers.

We have chosen Berlin as a case study as there are ongoing debates on topics related to car-free city centers: Berlin is among those cities in Germany most affected by high concentrations of particulate matter (UBA, 2014). Following a change of government and a citizen's initiative for more infrastructure for cyclists the regional government in Berlin is planning to adopt a new law aiming to provide a safe, healthy and climate friendly transport system (Senatsverwaltung für Umwelt,Verkehr u.Klimaschutz, 2017). For the first time, there will be a legal basis for a comprehensive traffic planning including not only public transport but also bicycles (Senatsverwaltung für Umwelt,Verkehr u.Klimaschutz, 2017). Whereas the goal of the law is set – providing a better infrastructure for those who walk, cycle or take public transport – the exact design of these improvements is still unclear. A key question in the ongoing debate is which measures make other modes of transport more pleasant than driving. Besides our contributions to research on car-free city centers in general, our study produces useful information for the design of new policies in Berlin and can thus be used directly by local policy makers and politicians.

Our study is explorative in nature and relies on a student sample with approximately 300 respondents. The results are thus not representative for Berlin citizens. Still, we can identify important drivers for car-free city centers, which can be used in policymaking. We also show that the discrete choice experiment method is applicable for studying preferences for similar topics and thereby aim to encourage further research in this area. A key contribution of this paper is thus a methodical outline for future research on car-free city centers and similar measures to limit the use of cars in city centers – a topic that will most likely become or remain relevant in nearly all countries in the world (Vedel et al., 2017; Crawford, 2002).

2. Discrete choice experiments to investigate preferences for car-free city centers

Human behavior is, in part, an ongoing process of choosing between different alternatives. According to rational choice theory, humans compare alternatives and choose the one that offers the highest expected net benefit. The value given to the outcome of the decision by the individual is usually referred to as its utility (Jackson, 2005). Economic theory of consumer behavior builds upon this: An individual will choose from a set of alternatives the alternative that maximizes her utility, given her preferences and the prices of goods under constraints. A variation of this framework had been developed by Lancaster (1966), who suggested that consumer preferences for goods do not depend on the good itself but on attributes of that good. Discrete choice experiments are based on Lancaster's model and now commonly used in transportation research (e.g. Borgers et al., 2008; Hensher, 2001), health economics (e.g. Ryan and Gerard, 2003; Scott, 2002), environmental economics (e.g. Birol et al., 2007; Carlsson and Martinsson, 2001; Hanley and Roberts., 2002) and energy research (e.g. Goett et al., 2000; Sagebiel et al., 2014).

Similar to other economic valuation methods, discrete choice experiments have limitations. First, as a direct valuation method, discrete choice experiments are based on hypothetical scenarios and not on observed behavior (Carson and Groves, 2007). Second, in comparison with contingent valuation, discrete choice experiments are rather difficult to process by respondents; this complexity increases the risk that respondents answer according to simple rules of thumb (Hensher and Collins, 2011; Hanley and Roberts, 2002). Furthermore, there is a risk of strategic behavior, leading to either overstatement or understatement of welfare estimates (Perman, 2003).

The main advantage of discrete choice experiments is their consistency with consumer theory, enabling determination of willingness to pay values for each attribute (Alpízar et al., 2001). Discrete choice experiments are, therefore, particularly helpful for the valuation of complex non-market goods and the design of policies aiming to provide such goods.

In this study, we assume that the introduction of a car-free city center has an impact on people's utility U. Additionally, attributes regarding mobility in the city center affect U. Thus, utility is a function of whether the city center is car-free and the levels of the attributes regarding mobility. As preferences differ between different people, socio-demographic variables can be included in the utility function as interaction terms to explain differences in preferences (observed preference heterogeneity). We assume the following utility function.

$$\mathrm{U} = \beta_0\mathrm{CF} + \gamma_1\mathrm{CFx_1} + \gamma_2\mathrm{CFx_2} + \gamma_\mathrm{N}\mathrm{CFx_N} + \beta_1\mathrm{a_1} + \beta_2\mathrm{a_2} + \cdots + \beta_\mathrm{K}\mathrm{a_K} + \epsilon \tag{1}$$

where $(\mathrm{a_1}, \mathrm{a_2}, \cdots, \mathrm{a_K})$ are the levels of the attributes of the scenario and $(\mathrm{x_1}, \mathrm{x_2}, \cdots, \mathrm{x_N})$ the values of socio-demographic variables. CF is a binary variable indicating whether the city is car-free ($CF = 1$) or not, and ϵ is an error term that captures unobserved parts of utility.γ and β are unknown parameters that indicate the impact of the variables on utility. The socio-demographic variables x are multiplied by CF. This allows to investigating the differences in preferences for car-free city centers between people. In all models, we have demeaned the x variables so that the mean value of the variables takes the value zero, i.e. $\dot{x} = x - x_{mean}$. This eases the interpretation of the CF variable, as its parameter value represents the average effect on utility, rather than the effect where all values of the socio-demographic variables are set to zero.

In the discrete choice experiment, respondents can choose between different alternatives i. Each alternative is characterized by different levels of the attributes a_k. Specifically, the respondents can choose between three alternatives, of which two alternatives (Alt1, Alt2) describe situations in a car-free city center ($CF = 1$) and one alternative describes the status quo ($CF = 0$). In the status quo alternative, all levels of the attributes take the value zero. For alternatives Alt1 and Alt2 utility is

$$\mathrm{U_{1,2}} = \beta_0\mathrm{CF} + \gamma_1\mathrm{CFx_1} + \gamma_2\mathrm{CFx_2} + \gamma_\mathrm{N}\mathrm{CFx_N} + \beta_1\mathrm{a_1} + \beta_2\mathrm{a_2} + \cdots\beta_\mathrm{K}\mathrm{a_K} + \epsilon_{1,2} \tag{2}$$

and for the status quo alternative

$$\mathrm{U_3} = \epsilon_3 \tag{3}$$

To model choices, the conditional logit model (McFadden, 1974) can be applied. The logit formula calculates the probability to choose alternative i, conditional on the values of CF, x and a, so that

$$Prob_i = \frac{\exp(U_i)}{\sum_{i=1}^{3}(\exp U_i)} \tag{4}$$

The unknown parameters γ and β can be estimated with the maximum likelihood method, where the dependent variable is the choice made by the respondent. It takes the value 1 for the chosen alternative and zero otherwise. The conditional logit model is limited by the assumption that the error terms for each respondent and each alternative are independently and identically distributed (iid). The iid assumption implies that all respondents have identical preferences. Consequently, the model does not account for unobserved heterogeneity in preferences. Advanced choice models address this restriction. The random parameters logit model, for example, contains additional stochastic elements which can be heteroscedastic and correlated across alternatives (Hensher et al., 2014). The β parameters are treated as random parameters, allowing for different individuals having different parameter values. Each parameter is described by a probability density function and the moments of this distribution (mean, standard deviation) are estimated. The unconditional probability of person q to choose alternative i is given by the integral of the logit choice probability (Eq. (4)), weighted by the density f ofβ:

$$Prob_{qi} = \int \frac{\exp(\mathrm{U_i})}{\sum_{i=1}^{3}(\exp(U_i))} f(\beta)d\beta \tag{5}$$

For the distribution of β, the researcher can choose from any continuous probability density function. The model can be estimated using the maximum simulated likelihood method. A detailed description of the conditional logit and the random parameters logit model in the context of transportation choice experiments can be found, for example, in Hensher et al. (2014).

3. Survey and experimental setup

3.1. Questionnaire and attribute selection

The questionnaire consisted of a brief introduction to the topic; some general questions on age, gender, and frequently used modes of transportation. The second part comprised the discrete choice experiment. The last part of the survey contained additional questions, including income, political party voted for in the last elections and willingness to get involved in creating a car-free city.

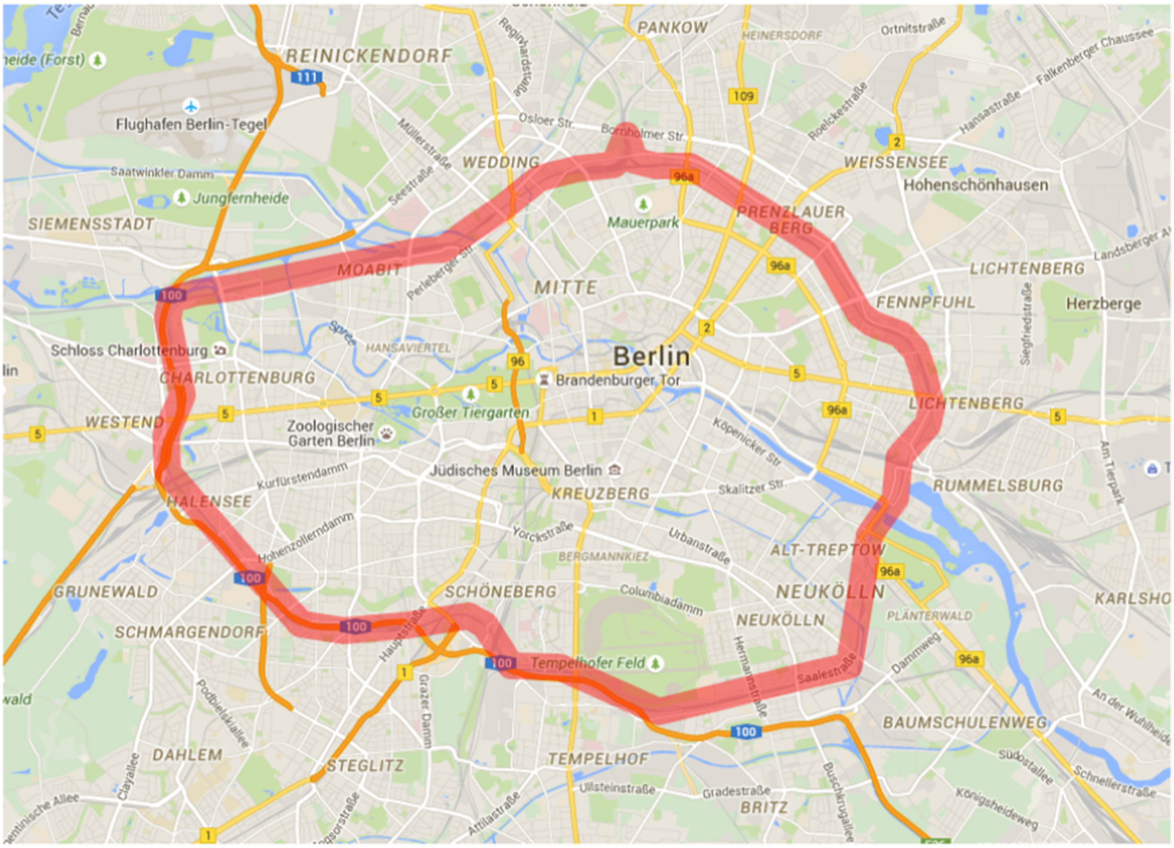

Fig. 1. The area within the *Ringbahn* as a car-free city center.
Source: https://www.google.com/maps/d/viewer?mid=zuVbzNCvXGOk.kpgaotPFBBTE&hl=en (2015, August 17).

Table 1
Attributes, levels and their expected effects within the discrete choice experiment.

Attribute/interaction	Levels	Expected effects
Road network for cyclists (ROAD)	1. As today 2. Bikeways next to every road (BIKELANE) 3. Separate road network for cyclists (BIKESEP)	$\beta > 0$
Walking distance to closest public transport stops (DIST)	1. As today 2. 6 min (DIST6MIN) 3. 3 min (DIST3MIN)	$\beta > 0$
Frequency of public transport (FREQ)	1. As today 2. More frequent (FREQ_HIGHER) 3. Much more frequent (FREQ_HIGHEST)	$\beta > 0$
Park and ride facilities at public transport stops bordering the car-free city center (PARKING)	1. As today 2. Unguarded parking lot available (UNGUARDED) 3. Guarded parking lot available (GUARDED)	$\beta > 0$
Additional recreation areas (RECRE)	1. As today 2. 20% more 3. 40% more	$\beta > 0$
Price for public transport (PRICE)	Free of charge 75% less than today 50% less 25% less As today 25% more	$\beta < 0$
CF x car		$\beta < 0$
CF x Residing within the Ring		$\beta > 0$
CF x public transport		$\beta > 0$
CF x age		$\beta \neq 0$
CF x male		$\beta \neq 0$

The good to be valued in the discrete choice experiment was a car-free city center in Berlin, the capital of Germany. We defined the parameters of the car-free city center to fit exactly within the inner ring of the *Ringbahn*, a 37 km long public train line (Fig. 1). Car-free was defined as the absence of private cars. Taxis, buses used for public transport, and trucks used for delivering goods are still allowed to use the existing road network.

At the start of the discrete choice experiment there was a description of the car-free city, the attributes and finally the valuation scenario. The respondents then chose repeatedly between different alternative concepts for car-free city centers. The alternatives were described solely by the levels of the attributes. Each choice comprised two car-free alternatives and a status quo alternative labeled “no car-free city”, with all attribute levels set to “as today”.

By drawing on existing literature, we identified six attributes, which would presumably affect people’s preferences. Additionally, we conducted a pre-test with ten students completing the discrete choice experiment. Based on the feedback of the students we redefined some of the attributes. Table 1 presents the attributes and levels included in the final version of the discrete choice experiment. The last column contains our hypothesis concerning the sign of the main effect of a change in each attribute on the probability of choosing a car-free city.

Apart from PRICE, all attributes had three levels. For each attribute, there was one reference level called “as today”, referring to the present situation in Berlin.

ROAD, the first attribute, refers to the road network for cyclists, and we hypothesized that better facilities for cyclists would positively affect preferences for a car-free city. DIST refers to the average distance from any point in the car-free city center to the next public transport stop, measured in walking minutes. FREQ is defined as the frequency of the public transportation service. People’s perceptions concerning this attribute would also depend on the availability of public transport at their current residence. Therefore, the frequency attribute has the levels “as today”, “more frequent than today” (FREQ_HIGHER) and “much more frequent than today” (FREQ_HIGHEST). This leaves room for individual interpretation, and avoids cases where a share of respondents would consider one specific level to be a higher frequency compared to their present situation while others considered the same level to be a lower frequency. We expected that a shorter distance to the next public transport stop and a higher frequency of public transport would increase the likelihood that respondents would choose a car-free city. PARKING refers to parking facilities at public transport stops bordering the car-free city center. We expect that providing park-and-ride opportunities would increase the likelihood to choose a car-free city center, especially if the parking is guarded. RECRE refers to additional recreational areas such as parks as space, formerly needed for roads and parking, would become vacant. We expect that using this space for recreation increases the likelihood of people to choose a car-free city. PRICE is defined as the price of tickets for public transportation relative to the current price. It has six levels, varying in 25 percentage-point increments, between 100% less (free of charge) and 25% more expensive than today. The framing of the price attribute as an increase in public transportation requires further explanation. At the two sampled universities, students pay a fixed tuition fee. This fee includes public transportation and is compulsory for all students, regardless if they use public transport or not. Thus, the changes in public transportation costs affect all sampled respondents equally. Even if a student does not use public transportation at all, she will be affected by a price change proposed in the choice experiment. We thereby assure that each

Table 2
Example of a choice set.

	Concept A	Concept B	No car-free city
Road network for cyclists	There are bikeways next to every road	Cyclists and cars share the same road	As today
Walking distance to closest public transport stops	6 min	3 min	As today
Frequency of public transport	As today	More frequently	As today
Park and ride facilities at *Ringbahn* stations	Guarded parking site available	As today	As today
Additional recreation area	20% more recreation area	20% more recreation area	As today
Price for public transport	25% less	Free of charge	As today

respondent is similarly affected by the price attribute and avoid a situation where those who do not use public transport do not pay attention to this attribute. As some students are not registered in Berlin, live in Berlin only temporary for the length of their study, and often do not pay taxes in Berlin, other commonly used framings such as an increase in taxes are not appropriate. Another important criterium for the framing of the price attribute is the credibility of this attribute itself (Johnston et al., 2017). A change in public transportation fees has a direct link to changes in our attributes. The local public transportation company in Berlin is publicly owned and non-profit orientated, which makes a financing of increased ticket prices for better infrastructure reasonable for the respondents.

The last row of Table 1 contains interaction effects between the alternative specific constant CF and selected socio-demographic characteristics to capture observed heterogeneity (see Section 2). We hypothesized that car ownership would have a negative effect on the probability of choosing a car-free city center and that residency within the *Ringbahn* area and frequent use of public transport would positively affect the likelihood of choosing a car-free city center. We included age and gender as additional control variables.

In an ideal situation, a discrete choice experiment would include all possible combinations of attributes, levels and alternatives (full factorial design). In practice, however, given the large amount of possible combinations, this number has to be reduced. Here, we chose to use an orthogonal array, a design intended to ensure that all attributes are independent from each other (orthogonal) and that all levels will occur with the same frequency (Rose and Bliemer, 2009). We used the software package NGene (ChoiceMetrics, 2014) to obtain an orthogonal design with 27 choice sets, which we blocked to three different versions, each containing nine choice sets, i.e. each respondent was responding to nine different choice sets. Table 2 displays an example of a choice set.

3.2. Data collection and sample

The discrete choice experiment was conducted in July 2014 as a web-based survey, and programmed with the software limeSurvey.[1] We sent the link of the survey to student distribution lists from Humboldt-Universität in Berlin and the University for Sustainable Development in Eberswalde, which is located approximately 50 km northeast of Berlin. Using a student sample to investigate the preferences of Berlin inhabitants likely leads to bias. Still, such a convenience sample bears several advantages. First, a convenience sample enables researchers to collect a relatively high amount of data at low cost in a short period. Moreover, even though we cannot easily generalize findings from student samples, they can still provide us with important insights in terms of what attributes affect people's preferences. There is a high chance that effects that have been found to be significant in a convenience sample will also be significant in a random sample. Leiner (2016), in a study about descriptive findings from experiments using convenience sampling, finds that in most cases the effects will only differ in size. In our student sample with only 19% of respondents owning a car, the general preference for a car-free city will most probably be higher than in a random sample. However, we can assume that the main effects of the attributes on the willingness to accept a car-free city will hold for a random sample. Moreover, we can investigate the effects of single socio-demographic variables on preferences. For instance, if gender turns out to have a significant effect in the student sample, it is likely that the variable will also be significant in a random sample. Thus, while findings from student samples do not allow us to make statistical generalizations and aggregation of willingness to pay, they may enable us to draw logical conclusions. Second, by questioning people enrolled in higher education, we increased the chance that respondents would understand the survey. Given the rather complex design of the survey method, a student sample may even give more reliable results than a random sample drawn from the Berlin population. Finally, it is likely that students are more willing to accept car-free city centers than the general population. Hence, the results of our study can be regarded as an upper bound. While we can expect that the general population is less willing to accept car-free city centers, we can conclude with high confidence that the acceptance will not be larger than what we have estimated. This upper bound is a key information for policy makers as it shows the limits of acceptance of car-free city centers. In sum, for our explorative research, the benefits of student sampling — collecting a high amount of high-quality data, fairly quickly and at low cost — outweighed the limitation of not being able to draw statistical conclusions for the general population of Berlin.

In total, 334 students completed the survey. On average, students have less income than the German population (in our sample 61.3% indicated a monthly income below 800 Euros) and less frequently own a car. In Germany, 76.7% of households own a car (Federal Statistical Office, 2013) compared to only 19% of our respondents. 56% of the respondents were female. With an average age of 25 years, our respondents were comparatively young. The majority had been living in Berlin for less than ten years. 54% of respondents lived inside the *Ringbahn* area and, thus, within the hypothetical car-free city center. 61% of respondents stated that they

[1] LimeService is a survey service platform to prepare, run and evaluate online surveys: https://www.limeservice.com/en/.

Table 3
Summary of key variables.

Name	Description		Obs.	Mean	SD	Min	Max
Male	= 1 if male, = 0 if not		310	0.44	0.50	0	1
Age	Age in years		324	25.36	4.86	18	56
Residence duration	Number of years lived in Berlin		331	9.90	10.22	0	51
Income	Monthly income in Euros, *categorical variable*		318	n.a.	n.a.	n.a.	n.a
	Group	Share in %					
	– < 800	61.3					
	– 800–1500	35.5					
	– 1500–3000	2.8					
	– > 3000	0.3					
Car	If respondent owns a car = 0 if "no", =1 if "yes"		334	0.19	0.39	0	1
Residing within the Ring	= 1 if living "within the Ring", = 0 if living "outside the Ring"		332	0.54	0.50	0	1
Public transport	Frequency of using public transport, *categorical variable*		333	n.a.	n.a.	n.a.	n.a
	Group	Share in %					
	– Never	0.9					
	– Several times per year	3.3					
	– Several times per month	8.4					
	– Several times per week	33.3					
	– Every day	54.1					
Willingness to support a car-free city	= 0 if "no", = 1 if "yes"		334	0.61	0.49	0	1

n.a.: not applicable.

would be willing to support a car-free city. Table 3 summarizes some key variables. The number of observations varies across variables because not all respondents answered all questions.

4. Results

4.1. Model fit and estimated parameters

This section reports results from three slightly different logit models. All models included the attributes as explanatory variables and two models additionally included selected socio-demographic variables as interaction terms with the alternative specific constant (CF). Except for RECRE and PRICE, the attributes were dummy-coded to account for non-linear effects on utility.[2] The first model (Logit) is a basic conditional logit model not including observed or unobserved preference heterogeneity. In this model, we used only CF and the attributes as explanatory variables. The second model (Logit Interactions) integrates gender, car ownership, age, location, and usage of public transportation as further explanatory variables. These variables are interacted with CF. The interaction terms show the effect of the socio-demographic variables on choosing a car-free city center. A positive sign means that a higher value of the variable increases the probability to choose a car-free city center. The third model (Random Parameters Logit) is a random parameters logit model accounting for observed and unobserved preference heterogeneity. This model is similar to the second model but with all attributes except PRICE specified as normally distributed random parameters. As we assume that people always prefer lower prices over larger prices we used a log-normal distribution for PRICE. The log-normal distribution assures parameter estimates to be positive.[3] The parameters of the interaction terms remained as non-random. The model was estimated in Stata with the user-written package *mixlogit* (Hole, 2007) with 1000 Halton draws for the simulation of the random parameters.[4]

Table 4 reports the estimation results. The χ^2 values indicate that all models are highly significant. The goodness-of-fit of the models can be compared through information criteria such as the Akaike information criterion (AIC) and the Bayesian information criterion (BIC). These are relative values and a smaller value represents a better fit. Both AIC and BIC are smaller in model 2 than in model 1 and smallest in model 3, indicating that model 3 has the best fit. This result is not surprising as standard deviations of nearly all random parameters are significantly different from zero, i.e. the random parameter logit model includes additional coefficients that contribute significantly to explaining the data. Across models, all coefficients have the same signs and in many cases the same level of significance. This indicates that our results are robust.

In a first step, we investigate the impact of the explanatory variables on utility and choices. A positive (negative) sign of an attribute coefficient means that an increase in this attribute (1) increases (reduces) the overall utility of the respondent, and (2)

[2] We used Wald tests to test for linearity H0: $\beta_1 = 0.5*\beta_2$.

[3] As the coefficient for PRICE is negative, we multiplied PRICE with -1 and then estimated the model.

[4] We estimated additional models including a random parameters logit model with an error component to account for unobserved status quo effects (i.e. different variances of the unobserved part between the hypothetical scenarios and the status quo, Scarpa 2005). However, this model seems to overfit the data, producing unrealistic values for CF. We therefore decided to go for the more parsimonious random parameters logit model. We thereby follow Train's (2003, Ch. 6.3) advice to choose a model that captures unobserved effects that are of key interest in the analysis, which is, in this case, the heterogeneity in preferences.

Table 4
Estimation results for logit, logit with interactions and random parameters logit.

	Logit	Logit with interactions	Random parameters logit
Mean			
CF	0.0419	0.177	0.440**
BIKELANE	0.784***	0.868***	2.169***
BIKESEP	0.971***	1.006***	2.717***
DIST6MIN	−0.152**	−0.128	−0.665***
DIST3MIN	0.342***	0.385***	0.449**
FREQ_HIGHER	0.183***	0.140*	0.309
FREQ_HIGHEST	0.111	0.0913	0.216
UNGUARDED	−0.0685	−0.0829	0.00331
GUARDED	−0.278***	−0.266***	−0.502***
RECRE	0.174***	0.184***	0.466***
PRICE	−0.0186***	−0.0185***	−3.401***
CF x Male		−0.593***	−0.795**
CF x Car		−1.680***	−2.441***
CF x Age		0.0210	0.0134
CF x ResidingWithinRing		0.0257	0.341
CF x PublicTransport		−0.229***	−0.687***
Standard deviation			
BIKELANE			1.981***
BIKESEP			4.187***
DIST6MIN			0.820**
DIST3MIN			0.824**
FREQ_HIGHER			1.606***
FREQ_HIGHEST			0.459
UNGUARDED			1.079***
GUARDED			1.538***
RECRE			1.306***
PRICE			1.303***
Observations	3006	2691	2691
Respondents	334	299	299
AIC	5089.6	4410.9	3534.6
BIC	5167.8	4522.8	3716.5
χ^2	1537.2	1533.9	896.3
Log Likelihood(Null)	−3302.4	−2956.4	−2956.4
Log Likelihood	−2533.8	−2189.4	−1741.3

* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

reduces (increases) the probability to choose the status quo option. Similarly, a positive coefficient of the interaction terms (CFx) means that an increase in the respective x variable increases the probability to choose a car-free city center. The parameter for CF is positive and significantly different from zero at a 5% level in the random parameters model (model 3). In the other models, CF is positive but not significantly different from zero. This means that the probability to choose a car-free city center is approximately 50% in these models while it is above 50% in the random parameters model. CFxMale is significantly different from zero on a 5% level and negative in both models that incorporate observed preference heterogeneity, i.e. men are less likely to choose a car-free city center alternative than women are. CFxCar and CFxPublicTransport are negative and significantly different from zero on a 1% level in both models; owning a car and using public transport reduces the probability to choose a car-free city center. This is only partly in line with our hypotheses. While we expected that car owners do not like to give up driving in the city center, we expected that those who use public transport benefit from a car-free city center. However, this result might be explained by expected inconvenience through over-crowded trains and buses in a car-free city. The interactions CFxAge and CFxResidingWithinRing are not significantly different from zero. Thus, neither the participants' age nor their residence location (within or outside the car-free city center) influence preferences.

Most of our attributes are significantly different from zero and show similar effects across the three models. The first attribute (ROAD) describes the bicycle infrastructure. The coefficients of the two dummy variables BIKELANE and BIKESEP are significantly different from zero at a 1% significance level and have positive signs. The slightly larger coefficient of BIKESEP compared to BIKELANE means that a change from the status quo to a separate road network for cyclists is slightly preferred over a change to bikeways next to every road. This is consistent with our hypotheses (see Table 1). Note that the large standard deviation parameters compared to the mean parameters indicate preference heterogeneity in this attribute.

The next two attributes describe the public transportation infrastructure. The attribute regarding distance to the next station (DIST) has ambiguous signs. While an average walking distance of three minutes (DIST3MIN) is significantly different from zero at a 1% level and positive in all models, a walking distance of six minutes (DIST6MIN) has a negative sign and is statistically different

Table 5
Marginal willingness to pay values in Euro.

	Logit	Logit with interactions	Random parameters logit
BIKELANE	42.15***	46.82***	65.04***
BIKESEP	52.21***	54.26***	81.48***
DIST6MIN	−8.167**	n.a.	−19.93***
DIST3MIN	18.34***	20.76***	13.47**
FREQ_HIGHER	9.825***	7.55*	n.a.
FREQ_HIGHEST	n.a.	n.a.	n.a.
UNGUARDED	n.a.	n.a.	n.a.
GUARDED	−14.96***	−14.36***	−15.06***
RECRE	9.345***	9.92***	13.97***

Standard errors and p-values calculated with the delta method; willingness to pay values were calculated only for significant attribute coefficients (n.a. not applicable).

* $p < 0.1$.

** $p < 0.05$.

*** $p < 0.01$.

from zero only in the conditional logit models (models 1 and 2). A walking distance of six minutes, thus, does not increase the probability to choose a car-free city center. A possible explanation is that 84% of the survey participants stated that the next stop from their home was already less than six minutes walking distance. Therefore, a distance of six minutes might have actually been perceived as an individual deterioration compared to the current situation by these participants. A distance of three minutes, however, is clearly increasing the probability to choose a car-free city center. The attribute describing the frequency of busses and trains (FREQ) seems not to affect preferences. In model 3, both dummy variables (FREQ_HIGHER and FREQ_HIGHEST) are not significantly different from zero. Only FREQ_HIGHER is significantly different from zero at a 1% and 10% level in models 1 and 2, respectively. The limited impact of this attribute is not in line with our hypothesis. A possible explanation is that the current frequency of public transportation is already perceived as high in Berlin. Therefore, benefits from an increase in frequency may be limited for most respondents. The standard deviations for both public transportation attributes are comparatively smaller than for the bicycle infrastructure improvements. Still the values indicate preference heterogeneity in these attributes.

Improved parking opportunities do not increase the probability to choose a car-free city center. In all models, UNGUARDED is not significantly different from zero, and GUARDED is significantly different from zero at 1% level and negative. This result implies that most respondents do not want additional parking opportunities. It may be explained by the small share of car owners in our sample (19%). The large standard deviations compared to the mean estimates indicate heterogeneous preferences.

More recreational areas seem to positively impact the probability to choose a car-free city center. In all models, RECRE is significantly different from zero at the 1% level and positive in all three models. This result is in line with our hypothesis that more recreational areas increase the probability to choose a car-free city center. The PRICE attribute is significantly negative in all three models at the 1% level, which is consistent with standard consumer theory, suggesting that a price increase for public transportation is perceived negatively. Also, RECRE and PRICE show large standard deviations, i.e. preferences for these attributes are heterogeneous.

4.2. Willingness to pay values and choice probabilities

In this section we report marginal willingness to pay values for each of the attributes, and total willingness to pay values for selected policy alternatives. We also investigate choice probabilities for these policy alternatives, i.e. the probability to choose a car-free city center changes, given pre-specified levels of attributes. Marginal willingness to pay values are calculated as the ratio of the attribute coefficient and the price coefficient and can be interpreted as the marginal rate of substitution between an attribute and price. These values represent the increase or decrease in price a person is willing to pay (accept) for a one-unit increase (decrease) in the regarded attribute, keeping utility constant. In our setting, willingness to pay is calculated as absolute Euro values and represents the additional monthly expenses on the compulsory public transportation ticket (see Section 3). The current price students in our sample pay is 78 Euros per month. Table 5 summarizes the marginal willingness to pay values for the significant attributes.[5]

We can see from the results in Table 5 that, by far, the marginal willingness to pay is highest for the cyclist network, meaning that this attribute is the most critical one in our sample. For "bikeways next to every road", the values range from 42 Euro in model 1–65 Euro in model 3. The marginal willingness to pay for "separate road networks for cyclists" lies between 52 and 81 Euro. The second most important attribute appears to be walking distance to the next public transportation stop (DIST). For the second level, representing a 3 min walking time to the next public transportation stop, the willingness to pay ranges between 13 and 21 Euro. For an

[5] As the price attribute is log-normally distributed, the estimated parameter has to be transformed before it can be used to calculate marginal willingness to pay. We used the median value from the log-normal distribution as it is more resistant to outlier values. The median value is calculated as $\exp(\beta) = \exp(-3.401) = 0.033$. Note that the value is positive because we have multiplied the attribute by −1. Therefore we have to multiply the willingness to pay values with −1 again to make them consistent with the willingness to pay values from the other models.

Table 6
Choice probabilities and total willingness to pay values for selected policy alternatives based on results of the random parameters logit model.

Description of policy alternatives	Probability to choose a car-free city center (willingness to pay)
No change: All attributes are "as today"	60.8% 13.2 Euro
Free ticket: All attributes are "as today" but public transportation becomes free	90.2% n.a.
Improved bicycle lanes: All attributes are "as today" except that bikeways are next to roads (level 1)	83.8% 78.23 Euro
Moderate improvements (bikeways next to road, six minutes walking distance, more frequent busses and trains, 20% more recreational area) and current public transportation fees	78.2% 81.5 Euro
Strong improvements (Separate bike lanes, three minutes walking distance, much more frequent busses and trains, 40% more recreational area and higher fees (97 Euro)	73% n.a.
Strong improvements (Separate bike lanes, three minutes walking distance, much more frequent busses and trains, 40% more recreational area and free public transportation	91.6% n.a.

Note: Calculating willingness to pay values is only meaningful in alternatives where the price is not changed (n.a.: not applicable).

additional 20% of areas devoted to recreational areas, arising from unused streets in a car-free city center, the sample participants were willing to pay approximately nine to 14 Euro. In contrast, the willingness to pay values for guarded parking lots are negative. Thus, additional parking lots are not suitable to justify ticket price increases.

Table 6 provides willingness to pay values for various policy alternatives. These policy alternatives were gradually developed. The first alternative (the no-change scenario) simply describes a switch to a car-free city center without any further improvements in the attributes (i.e. all attributes are set to "as today"). According to our model, the probability that a respondent (keeping all socio-demographic interactions at the sample average) chooses a car-free city center is 60.8%. The corresponding willingness to pay is 13.2 Euro. This means that, on average, our respondents prefer a car-free city center and would even accept an increase in public transportation fees. This result corresponds to the 60% of respondents who stated that they are willing to support a car-free city center in general (see Section 2). The second policy alternative is similar to the first one, yet public transportation is free of charge. The corresponding choice probability is 90.2%. This means that most people are willing to accept car-free city centers if public transportation is free. The third policy alternative improves only the bicycle infrastructure with bike lanes next to roads (level 1) and keeps all other attributes including the cost attribute "as today". The corresponding choice probability is 83.8% and the willingness to pay is 78.3 Euros. The fourth policy alternative includes improvements of all attributes except parking to level 1 but keeps the public transportation fees constant. This alternative considers the negative sign of the coefficient for a 6 minutes waiting time, which leads to a lower choice probability than in the alternative above of 78.2%. Still, willingness to pay is comparatively large with 81.5 Euros. The fifth policy scenario comprises strong improvements of all attributes except parking and comes with an increase in public transportation fees to 97 Euros. This price increase is responsible for a comparatively low choice probability of 73%. The last policy alternative can be seen as the best possible option from the respondents' point of view. Here, all attribute levels are set to level 2, and public transportation is free. In other words, this is the best alternative our choice experiment offers. This alternative comes with a choice probability of 91.6%. Note that this value is only slightly higher than the choice probability in second scenario where only bike lanes were improved.

All choice probabilities in the six policy alternatives are above 50%, indicating a relatively high acceptance of the idea of car-free city centers. Reductions in public transportation fees and improvements in the bicycle infrastructure are the most important drivers for the acceptance of car-free city centers. These two attributes can increase the choice probability to above 90%. In contrast, the other attributes that we have included in the discrete choice experiment seem less important. Especially the increase in parking facilities seems not to increase the choice probability.

5. Discussion and conclusions

Given the severely negative external effects of car use on the environment and on human health, introducing regulations and incentives to limit car use appears to be indispensable. Knowledge on which attributes contribute to an increased acceptance of car-free city centers helps to translate claims of reduced motorized traffic in urban areas into policy alternatives. The case study presented here demonstrates that a discrete choice experiment can be an appropriate method for gaining such information. Our results indicate a general acceptance of car-free city centers. Keeping the current infrastructural services constant, approximately 60% of our respondents would choose a car-free city center. This probability increases to above 90% once the bicycle infrastructure is improved and public transportation fees are reduced. Additionally, densifying the network of bus stops and train stations contributes to a higher acceptance of a car-free city center. These findings are in line with previous studies which have found that the development of alternative modes of transportation — specifically non-motorized ones, such as bicycle facilities — are of significant importance to reduce car use (Handy et al., 2005; Borgers et al., 2008; Ruiz and Barnabe, 2014). Moreover, our results suggest that the willingness to accept a car-free city center in Berlin increases by dedicating streets to recreational areas. Interestingly, building parking facilities at train stations bordering the car-free city center would not increase participants' willingness to accept a car-free city center, which contrasts with finding from other studies (e.g. Qin et al., 2013; Borgers et al., 2008). This divergence can be explained by less than

20% of the survey respondents actually owning a car. Our results have also shown that car owners are less likely to accept a car-free city center. Further, we found that men and people using public transportation on a regular basis are less likely to choose a car-free city center. The latter is line with the findings of Da Silva Borges and Goldner (2015) who found that cyclists are more likely to accept car-free zones than people who use public transport. Despite the fact that our models are highly significant and allow us to calculate statistically valid willingness to pay values and choice probabilities, the results should be seen as explorative and used with care. Our sample consists of university students only, and is thus not representative for the general population. It is likely that students are more open towards new concepts such as car-free city centers and set priorities differently compared to the general population. As the average age of our participants is relatively low they are more likely to accept a car-free city center than a representative sample (compare Da Silva Borges and Goldner, 2015). Also, a recent study about the impact of income on willingness to pay for environmental protection indicates that the middle class has the highest willingness to pay for the environment compared to other income groups (Shao et al., 2018). Even though most students have a low income the majority of them will belong to the middle class once they will have finished their studies. As limiting car use is a form of environmental protection it is likely that academics have a higher average willingness to pay for a car-free city center than other social groups. Moreover, most students do not require a car to commute. This might be different for people working in non-academic sectors and older people. In addition, habits and ideologies may strongly influence preferences. People from different social groups may have diverging preferences and would prioritize the attributes differently. We therefore argue that the relatively high choice probabilities for car-free city centers represent an upper bound. Still, it cannot be concluded that willingness to pay of students is in general higher than willingness to pay from the general population. The fact that students often move to another city after their studies might decrease their willingness to pay for infrastructure improvements. The willingness to pay values should thus be interpreted as a broad indication on what attributes of car-free city centers are valued highest and what ranges of payments (either as increases in public transportation fees or as more general increases in taxes of local fees) could be accepted by the general population. We can conclude with a relatively high certainty that people are not objecting car-free city centers and that the concrete design of these city centers as well as compensations (e.g. more recreational areas) have an effect of people’s acceptance.

To validate our willingness to pay values further, it is useful to compare them to values estimated from other studies focusing on urban green. For example, Bertram et al. (2017) find willingness to pay values for visiting urban parks for single attributes of up to 100 Euros. Brander and Koetse (2011) find in a meta-analysis the average value of green space estimated from stated preferences contingent valuation studies to be around 1500 $ per ha. Giergiczny and Kronenberg (2014) found willingness to pay values for increasing street green of between 0.5 and 1.6 Euros per kilometer. Against this background, our values seem plausible given that the scope of our study covers more about 8.800 ha, of which 1000 ha are green spaces and 1000 km of streets[6], and takes into account several large-scale improvements in public transportation, bicycling infrastructure and urban green.

To determine the importance of the different attributes more accurately, more research with a larger and more representative sample is necessary. Most importantly, the sample should comprise a representative share of car owners, since they are less likely to accept a car-free city center. Hence, convincing car owners appears to be more difficult and, therefore, finding out which infrastructure improvements would make them accept a car-free city center is crucial to design policies.

Taking the limitations of our study into account, the results still have important implications for policy makers. Due the low number of car owners and the hypothetical nature of our survey questions, our estimates likely overstate the acceptance of car-free city centers (Johnston et al., 2017, Carson and Groves, 2007). In turn it is unlikely that the actual choice probabilities and willingness to pay values are larger than they would be in the real world. Conclusions such as that the acceptance of car-free city centers is not above 60% may still be valid, given the assumptions above. Considering that there a several cities in Germany with a share of students of between 30 and 50% of the total population, our sample group is an important stakeholder group and the results may be of additional use for cities with a high share of students.

Given the willingness to support a car-free city center of at least a share of the urban population, urban planners and policy makers should consider establishing more car-free city centers, especially as it is likely to be an effective way to respond to people's demands for higher air quality in cities (The European Commission, 2013) and safer roads (VCD, 2014). Meanwhile, improving the network for cyclists, increasing the density of public transportation and using public space currently needed for cars to create additional recreation areas appear to be measures that can reduce car use and increase acceptance of a car-free city center. Further research on people’s preferences should be encouraged and supported by policy makers. Ideally, research should be multidisciplinary and linked to actual or potentially planned policy option.

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[6] These figures are calculated with GIS data from FIS Broker (http://fbinter.stadt-berlin.de/fb/wfs/data/senstadt/s_gruenanlagenbestand) and ESRI (https://opendata-esri-de.opendata.arcgis.com/datasets/bahnstrecke-1).

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