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## Cities



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# Spatial advantages of highly educated individuals in Germany: Is sustainable mobility an expression of privilege?

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ARTICLE INFO	A B S T R A C T
Keywords: Sustainability Daily mobility Socio-spatial inequality Education	To effectively combat climate change it is crucial to encourage daily environmentally friendly behaviour across large parts of the population. This includes daily mobility behaviour, since private transport is one of the largest contributors to greenhouse emissions. Previous studies suggest that highly educated individuals exhibit more environmentally friendly mobility behaviour, a fact that is usually explained by their higher environmental awareness. We instead explore the extent to which this behaviour is driven by their socio-spatial advantages. We use comprehensive data on daily mobility: our analytical sample includes 16,419 journeys from 4168 individuals in 2002 and 102,774 journeys from 26,036 individuals in 2017. The data is representative of German residents in large cities aged 18 to 59. We employ multilevel OLS regression, logistic regression, and fractional multinomial logit models to analyse changes in travel patterns among highly educated individuals over time. Our findings reveal that university graduates tend to reside not only more often in large cities but in the most central neighbourhoods within these areas, leading to shorter daily travel distances. Consequently, their daily journeys take less time and they are able to use slower, more sustainable mobility options when commuting, running errands, or engaging in leisure activities without incurring higher travel time costs than other groups. Our results highligh the importance of addressing residential inequalities as a key step in enabling a broader population to adopt sustainable lifestyles.

#### 1. Introduction

I

Climate change is one of the most pressing challenges of our time (IPCC, 2022). The transport sector, along with the energy and industrial sectors, is among the major contributors to climate change (Georgatzi et al., 2019). Particularly in Germany, where the number of registered cars is high and greenhouse gas emissions from cars and motorcycles constitute a substantial portion of the country's total emissions, effective  $CO_2$  reduction efforts require a shift from private cars to sustainable modes of transport (Ivanova et al., 2020). At the same time, daily travel distances per person are increasing worldwide (Odyssee-Mure, 2015). Therefore, to create a more sustainable transport system it is necessary to reduce both overall travel distances and private car use (Banister, 2011).

One social group appears to be at the forefront of these transitions: highly educated individuals. They use sustainable modes of transport more often than other socio-economic groups in Western societies and are more supportive of policies aiming to reduce car use (Hudde, 2022; Kim et al., 2016; Roos et al., 2020). A higher level of educational attainment is positively associated with more environmentally friendly behaviour in general (Al-Nuaimi & Al-Ghamdi, 2022; Meyer, 2015). The link between educational attainment and environmentally friendly behaviour has been the subject of considerable debate. One prominent hypothesis is that individuals with higher levels of education are more aware of the dangers posed by climate change and, as a result, engage in more environmentally friendly behaviours (Kim et al., 2016).

We argue that reducing highly educated people's environmentally friendly behaviour to their greater environmental awareness is an oversimplification. Instead, environmentally friendly behaviour, especially regarding daily mobility choices, requires certain resources and imposes certain costs. For instance, for people to choose bikes over cars, they need suitable roads and reasonably short distances, otherwise cycling becomes dangerous and overly time-consuming. In this paper we aim to explore the extent to which the environmentally friendly daily mobility behaviour of those with higher education can be explained by their socio-spatial advantages. Personal travel needs, preferences, and

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choices are strongly connected with residential location (Bruns & Matthes, 2019). Importantly, research on residential segregation indicates that individuals with higher educational attainment are more prone to reside in large cities, particularly in well-connected inner-city locations (Beckers & Boschman, 2017; López-Gay et al., 2020). Highly educated people's socio-spatial advantages might explain why they can afford to opt for more sustainable modes of transport and why it even might be in their best *personal* interest.

To answer this question, we use uniquely comprehensive mobility data from the *Mobility in Germany* (MiG) surveys in 2002 and 2017. The MiG provides detailed information on daily mobility behaviour – including daily travel distances, travel time, modal choice, travel purposes, etc. – in addition to socio-economic and socio-spatial characteristics, and it is representative of German residents of all ages. We look at large cities due to the significant differences in the availability of transportation options across regions; we aim to examine places where individuals have the freedom to choose between private, public and shared transportation, recognising that smaller cities face numerous challenges and lack the range of sustainable mobility options available in large cities.

Previous research on mobility behaviour has often been limited to the choice of transport mode and does not include travel distance or travel time (Hudde, 2022, 2023). It also generally fails to account for the education of respondents (Ngah et al., 2021). In the following analysis, we link existing literature on socio-spatial inequality to daily mobility behaviour and show how socio-economic and spatial factors affect daily mobility patterns.

#### 2. Research background

Individuals with higher levels of education (A-level or above) demonstrate enhanced environmental awareness, concern for societal welfare (Meyer, 2015), and an understanding of the environmental impact of individual behaviour (Alvarez-Suárez, Vega-Marcote, & Mira, 2014). This fosters environmentally friendly behaviour by people with higher levels of education, especially in the areas of household, food and transport choices (Al-Nuaimi & Al-Ghamdi, 2022; Asiksoy et al., 2020), as well as greater support for sustainability policies (El-Menouar & Unzicker, 2021). These trends extend to mobility behaviour and attitudes towards transport policies: Greater environmental awareness and education positively influence support for policies aimed at reducing motorised individual transport (Kim et al., 2016). Furthermore, highly educated individuals are more likely to use bicycles and public transport (Roos et al., 2020). In German cities, for instance, more highly educated people use bicycles more often than people of lower educational attainment doubled their use of bicycles between 1990 and 2018 (Hudde, 2022).

Overall, environmental awareness significantly influences individual daily mobility behaviour (Hamidi & Zhao, 2020). It explains why highly educated individuals differ from others with a high socio-economic status. While higher-income households rely on private cars (Follmer & Gruschwitz, 2019), the environmentally conscious behaviour among highly educated individuals prompts greater bicycle and public transport usage (Roos et al., 2020). However, sustainable mobility comes at a cost. Mobility-related time costs are higher for users of public transportation or bikes; in fact, evidence from Sweden, Brazil, Australia, and the Netherlands suggests that commuting by public transport often takes twice as long as by private car (Liao et al., 2020). Travel times for public transit in major German cities most recently have been estimated to be approximately three times longer than those for motorised individual transport commuting (Mocanu et al., 2021). The time costs of sustainable mobility are an obstacle to a broader sustainability transformation. High travel time expenditures, furthermore, have a detrimental impact on both mental and physical health (Giurge et al., 2020; Lorenz, 2018; Milner et al., 2017; Xiao et al., 2020), they increase stress (Strazdins et al., 2016), lower productivity (Giurge et al., 2020; Lorenz, 2018;

Milner et al., 2017; Xiao et al., 2020), and limit the time available for healthy eating habits (Senia et al., 2017), physical activity (Brownson et al., 2005) as well as for rest and leisure (Xiao et al., 2020).

More so than socio-economic factors, the residential context shapes mobility behaviour (Gao et al., 2022; Lucas et al., 2018). Urban areas usually offer a denser public transport network and higher accessibility of local services daily such as supermarkets or schools within close distances, than rural areas (Carmo et al., 2017; Holian & Kahn, 2015). Within cities, given their concentric structure, travel distances to points of interest (POI) decrease when people live closer to the city centre (Park et al., 2021). Neighbourhoods with a greater proportion of high-income households offer a more extensive range of transportation alternatives and a closer proximity to essential services. Conversely, disadvantaged neighbourhoods are less well connected to public transportation, employment opportunities, and institutions of higher education (Nicoletti et al., 2023).

Convenient access to essential services often guides residency decisions (Hesse & Scheiner, 2010), likely driving up rents in areas with high accessibility (Gupta et al., 2022; Rennert, 2022). Evidence from Munich (Germany) and other countries suggests that low-income residents are increasingly priced out of more central urban areas (Dohnke et al., 2012; Srinivasan et al., 2020), which has a negative impact on their access to public transportation and other services (Büttner et al., 2013; Hochstenbach & Musterd, 2018). In general, poverty segregation in German cities has increased during the last two decades (Helbig & Jähnen, 2018). Crucially, segregation and gentrification are not driven by income alone. Individuals with higher levels of education prefer to live in central neighbourhoods, as evidences by studies on various European cities (Booi & Boterman, 2020; Dohnke et al., 2012; Hochstenbach & Musterd, 2018; López-Gay et al., 2020; Sterzer, 2017). Their decision is influenced by a desire to gain improved access to public transportation, POIs, cultural offerings and, most notably, knowledge industry employment opportunities in urban areas Florida (2019); Konietzka and Martynovych (2023); Reckwitz (2021); Vos et al. (2016).

Against this background, we are interested in how highly educated individuals' daily mobility in German large cities has changed during the last two decades. We assume that highly educated individuals more often live in large cities and that this trend has increased over the years (1a). In addition, we hypothesise that within large cities, highly educated individuals live in more central areas than other social groups (1b). We further assume that travel distances to POIs for commutes, errands, leisure, and shopping are shorter for highly educated individuals than for other social groups (2a) due to their more central residential location (2b). These shorter distances should allow highly educated individuals to choose sustainable modes of daily mobility more often (3a) without incurring higher travel time expenditures than other social groups (3b).

#### 3. Method and data

The following section introduces the Mobility in Germany (MiG) survey that provides information on daily mobility behaviour, socioeconomic and socio-demographic characteristics of urban residents in 2002 and 2017. We explain the sampling procedure, data collection and weighting, and introduce variables such as travel distance, time and speed. The statistical approach employs multi-level regression models to scrutinise changes in mobility patterns, whereas fractional multinomial logit models are employed to examine the change in transport mode preference.

#### 3.1. Sampling, data, and weighting

We use individual-level data on daily mobility behaviour, the socioeconomic status and socio-demographic background of German residents in large cities from the MiG survey. Conducted by the social research institute *infas* in 2002 and 2017, the MiG survey, commissioned by the *Federal Ministry of Transport and Digital Infrastructure*, is the largest and most comprehensive of its kind in Germany. It is representative of the entire German population across all ages, and we obtained access through the *German Aerospace Centre*.

The sampling of the MiG employs a two-stage approach, starting with household interviews followed by individual interviews. Households were randomly selected across Germany based on population registers as well as, in 2017, random-digit-dialling of both landline and mobile phone numbers (triple-frame design). A questionnaire was administered to each household, requesting information about the household and offering the option of a more detailed follow-up interview with each member. These interviews could be conducted via postal mail, computer-assisted telephone interviews, or online, and were available in multiple languages. All respondents consented to the anonymised use of their data for scientific studies on mobility behaviour (infas ; 2019b). Information about daily journeys were collected via journey logs that respondents were asked to fill out at a randomly selected day within the span of 1.5 years during the field phase of each survey to ensure the data is neither biased by day-of-week nor seasonal biases (infas ; 2019a). The net response rate was 39 % in 2002 (Follmer & Kunert, 2003) and 6 % in 2017 at the individual level (RP3 response rate according to AAPOR 2016 which assumes the proportion of cases of unknown eligibility that are eligible to be equal to the proportion of eligible units among all units in the sample). The decline in response rates in such surveys has been noted by several studies e.g., (Czajka & Beyler, 2016). The triple-frame design employed in 2017 should ensure representativeness despite a decrease in response rates.

Our sample only includes respondents aged 18 to 59, as children, adolescents, and pensioners' daily mobility behaviour differs significantly from those within working-age. (The typical retirement age in Germany, which was 62 years in 2002 and 64 years in 2017, could not be accurately implemented due to the fact that the information on the age of respondents was made available by the German Aerospace Centre as a categorical variable only). We further restrict our sample to large cities in Germany, which are, in accordance with the definition provided by the German Federal Ministry for Digital Affairs and Transport, cities with more than 500,000 inhabitants: Berlin, Hamburg, Bremen, Dortmund, Essen, Duesseldorf, Hannover, Cologne, Bonn, Frankfurt am Main, Mannheim, Nuremberg, Stuttgart, Munich, Leipzig, and Dresden (BMVI;, 2011). Our analytical sample consists of 4168 individuals from 2437 households that recorded 16,419 journeys in 2002, and 26,036 individuals from 15,846 households that went on 102,774 different journeys in 2017. In order to test hypothesis 1a, we have included respondents from outside the 16 cities as well. Gathering information about daily mobility poses significant challenges, particularly in terms of determining exact journey details. To address these challenges, respondents were provided with notebooks or online options for recording their journeys. When respondents recorded their journeys retrospectively, an interviewer was typically present to assist and support was available during the whole data collection period. Journey endpoints were determined by interactive lists or by writing down addresses. Travel distance, duration and speed were later on calculated based on the information provided by respondents.

The data are weighted according to the season and day of the week of the survey, the respondent's place of residence, household size, employment status, education, age, and gender. This redressment adjusts for minor imbalances in the representation of specific social groups or respondents who were surveyed about their daily mobility on a particular weekday or during a specific season. But the data weights also address the different selection probabilities associated with the survey's triple-frame design and adjust for non-response rates among specific sub-populations (Follmer & Gruschwitz, 2019). (For example, young single males are less likely to consent to participate in the survey and are less accessible via telephone.) A non-response survey was utilised to collect preliminary information on initial non-respondents. There were no significant differences in travel patterns between respondents and non-respondents. However, the main survey exhibited a slight underrepresentation of respondents with a high volume of daily journeys (Follmer & Gruschwitz, 2019). Another potential bias could arise from non-mobile survey participants. Table A1 in the Online Appendix compares the education level of mobile and non-mobile urban residents aged 18 to 59. Non-mobile respondents tend to have lower education levels.

#### 3.2. Variables

Our analyses examines three main outcome variables: travel distance, travel time, and travel speed for each journey. To exclude implausible values, we trimmed the top one percentile of each of these variables. As shown in Fig. A1 and A2 in the Appendix, all three outcome variables have a skewed distribution, which is why we chose to logtransform them for analysis (West, 2022). Respondents' journeys were divided into four different purposes: commuting, leisure, errands, and shopping. The main mode of transport indicates the predominant mode of transport used by respondents for an individual journey (by car, cycling/walking, or by public transportation). The distance to the city centre gives the air line distance of the geometric centre of respondents 1 km-by-1 km neighbourhood grid to the geometric centre of the city.

Our statistical estimates of the effects of respondents level of educational attainment are controlled for effects of household income, employment status (employed or not), gender, age, whether or not there are children in the household, and whether or not the household owns cars. Household income was categorised into quantiles based on the equivalised income according to household size. To test hypothesis 1a, we use a variable to distinguish between respondents who live within one of the 16 cities included in our main sample and those who live elsewhere in Germany; all other hypotheses are tested only on respondents who live withing these 16 cities. Table A2 in the Appendix provides more information on the exact definition of each variable while Table 1 provides summary statistics.

#### 3.3. Statistical approach

The data are clustered at different levels (multiple trips per each individual, individuals clustered within households), therefore we applied multi-level approaches that account for this data structure. Beyond that, our dependent variables require different approaches as they are measured at different statistical scales. Two of our main dependent variables - average travel distance and travel time per journey - are metric but highly skewed and where log-transformed to be used in a linear regression analysis which most closely tests our assumptions expressed in hypotheses 2a, 2b, and 3b, without violating statistical model requirements. We estimated linear random intercept fixed slope multilevel models with education as the main explanatory variable and travel distance and travel time as dependent variables, plus various control variables (see below). We specified fixed slopes because we do not test whether the statistical association between, for example, education and travel distance varies between different households. However, we assume that different households differ in terms of the average travel distance of their members, which we account for by specifying random intercepts (and by controlling for some household characteristics, see below). We estimated these models separately for 2002 and 2017 as well as separately for each mobility purpose (commuting, errands, shopping, leisure). The linear multilevel regression models are defined as follows:

$$Y_{ijk,t} = b_{000,t} + b_{0p0,t} X_{pk,t} + b_{00q,t} Z_{q,t} + e_{ijk,t} + u_{0j0,t} + v_{00k,t}$$
(1)

Where  $Y_{ijk}$  are travel distance/time/speed for journey i of individual j who is a member of household k and  $b_{000}$  is the grand across-households intercept. 1â&P are predictors X at the individual level (e.g., educational attainment) and  $b_{0p0}$  each of their slopes fixed across households. 1â&Q are predictors Z at the household level (e.g., household income, distance

#### Table 1

#### Summary Statistics.

	2002		2017				
	N	Mean/ Percent	N	Mean/ Percent			
Data Unit:	Journe	eys					
Travel distance in kilometres	4033	11.17	23,377	13.53			
Travel time in minutes	4131	29.80	25,396	35.54			
Travel speed in km/h	4016	19.57	23,181	19.02			
Distance to the city centre <sup>A</sup>	-	-	24,110	5.85			
Main mode of transport							
1. Car	1808	43.57	8440	35.38			
<ol><li>By bike or by foot</li></ol>	1298	31.29	8480	35.65			
3. Public transport	1043	25.14	6867	28.87			
Travel purpose							
1. Leisure	945	22.82	5900	23.05			
2. Commutes	1717	41.44	11,146	43.54			
3. Errands	635	15.33	4636	18.11			
4. Shopping	790	19.06	3208	12.53			
Data Unit	Individ	Individuals					
Education	marris	iuuis					
1 Elementary school/no	598	16.89	1934	9 1 9			
degree	0,0	10.05	1901	5.15			
2. Secondary school	1005	28.41	4818	22.88			
3 A-level	405	11.43	4412	20.95			
4 University	1531	43.27	9891	46.97			
Gender: Female	2129	51.07	12,758	49.75			
Age groups	2122	01107	12,700	15170			
1, 18–30 years	1072	25.73	7601	29.64			
2. 31–40 years	1337	32.08	6871	26.80			
3. 41–50 years	967	23.20	6045	23.57			
4. 51–67 years	791	18.99	5125	19.99			
Employed	2980	71.64	19,850	77.45			
Linployed	2,000	, 101	19,000	//110			
Data Unit:	Households						
Household income							
1. Very low	195	5.35	1996	7.78			
2. Low	567	15.56	2650	10.34			
3. Middle	1418	38.93	9779	38.13			
4. High	1118	30.71	8708	33.96			
5. Very high	344	9.45	2510	9.79			
Households with kids	1426	34.35	9031	35.38			
Households with cars	1041	25.32	5264	21.04			

Notes. The variables travel distance, travel time and travel speed are presented here in their original form before undergoing log-transformation for our analysis.

<sup>A</sup> The variable for the distance to the city centre is exclusively accessible within the subset of data, the MiD-local data set from 2017. This data set contains individuals who have chosen to document their exact address.

to city centre of place of residency, see below), with each of their slopes  $b_{00q}$ .  $e_{ijk}$  are residual errors at the journey level,  $u_{0j0}$  residual errors at individual level and  $v_{00k}$  residual errors at the household level. Lastly, t stands for the year 2002 or 2017. We estimate multi-level OLS regression models using the MIXED routine of Stata 17. We calculated linear predictive margins of both the average travel distance and average travel time per journey based on the regression models to visually highlight the differences between the four educational groups. As these dependent variables were log-transformed to be included in the regression models, we back-transformed them to provide the travel distance in kilometres and travel time in minutes according to the following formula:

$$Y = Y_{\log} e \tag{2}$$

. .

Where  $\hat{Y}$  is the back-transformed predictive value of the independent variable,  $\hat{Y}_{log}$  the log-transformed predictive value of the independent variable, and *e* is the mathematical constant *e* (Euler's number).

To test hypotheses 3a that examines the main mode of transportation, we employed fractional multinomial logit models to investigate the primary mode of transport chosen by respondents for different travel purposes. For this, we examined the frequency of using specific modes of transport - car, public transport, bike/walking - for all journeys on the day of questioning and calculated a percentage between 0 and 1 for each mode of transport and person. Fractional multinomial logit models are suitable in cases where the dependent variable represents the probability of choosing a specific alternative out of mutual exclusive alternatives. This is true in our case, where choosing a car as the main mode of transport for a trip means deciding against public transport or cycling/walking as the main mode of transport. By estimating fractional multinomial logit models, we are able to examine the relative probabilities of choosing different modes of transport for each travel purpose, while accounting for the interdependencies between transport choices. The full model equation is as follows:

$$q(b) = \sum_{n=1}^{N} \sum_{m=1}^{M} y_{im} log(g_m(x_n, b))$$
(3)

$$g_m(x_n, b) = \begin{cases} \frac{e^{x_n b_m}}{1 + \sum_{k=1}^{M-1} e^{x_n b_k}}, & \text{if } m < M \\ \\ \frac{1}{1 + \sum_{k=1}^{M-1} e^{x_n b_k}}, & \text{if } m = M \end{cases}$$
(4)

Where bj. = (b1m, ..., bpm.) represents a vector of coefficients for individual, household and neighbourhood predictors P and the m,m < M mode of transportation. Standard errors are clustered at the household level. We have calculated these models separately for each mobility purpose (commuting, errands, shopping, leisure) and separate for 2002 and 2017.

Regarding hypotheses 1a and 1b units of analysis are individuals, not trips, and the dependent variables - place of residency in large cities and distance to centre of place or residency - are household level characteristics, which renders multilevel models obsolete. With regard to hypothesis 1b, the distance to the city centre of the respondents' place of residence is highly skewed and was log-transformed. We tested hypotheses 1b by applying linear regression models with distance to the city centre as the dependent variable. Hypotheses 1a required a logistical regression model as the dependent variable is binary (living in large cities or not).

To address potential confounding factors, we introduced several control variables which previous research has identified as influencing daily mobility behaviour and travel time expenditures. This includes household income, employment status (employed or not), gender, age, the presence of children in the household, and whether or not the household owns cars. Higher household income is generally associated with a higher level of educational attainment and also influences travel patterns (Carmo et al., 2017; Delclòs-Alió & Miralles-Guasch, 2018). Women tend to engage in more sustainable and active travel behaviours, leading to increased travel time, while men tend to travel longer distances and use cars more often (Goel et al., 2023; Roos et al., 2020). Age affects travel behaviour through physical mobility and agility (Dedele et al., 2020; García Román & Gracia, 2022). The employment status of individuals, too, is associated with distinct commuting patterns (Roos et al., 2020). Lastly, individuals with children often need to travel longer distances for child-related errands and are more likely to use cars (Dedele et al., 2020; Delclos-Alió & Miralles-Guasch, 2018; Lee et al., 2018).

To test hypotheses 1b and 2b, we require data on the distance to the city centre of respondents' place of residency which the MiG survey only provides for 91 % of our main sample and only for 2017. Therefore, to examine hypothesis 2b, we first replicate the regression model explaining travel distances without the variable 'distance to the city centre' with the reduced sample size and compare the results with the regression model of the full sample. This approach enables us to eliminate the likelihood that variations in the outcomes are due to the altered

sample rather than the explanatory variable of the distance to the city centre of respondents neighbourhoods. Subsequently, we insert the variable 'distance to the city centre' to determine its impact on the variation in these distances between educational groups.

#### 4. Results

This chapter presents the results for our three hypotheses. We begin by examining the place of residence of highly educated individuals. Secondly, we analyse the average travel distance and, thirdly, travel time per journey.

#### 4.1. Educational attainment and residential choice

(1a) Highly educated individuals more often live in large cities and this trend has increased over the years. (1b) Within large cities, highly educated individuals live more central than other social groups.

We computed the linear predictive margins for the binary outcome variable residing in large cities for 2002 and 2017 based on the logistical regression model for hypothesis (1a). Results in Fig. 1 show that individuals with a university degree are more likely to reside in large cities than other groups, and this trend increased between 2002 and 2017. In 2017, individuals with a university degree were three times more likely to live in large cities in Germany than those with elementary school degree. These findings are consistent with those of similar studies conducted in Spain (González-Leonardo et al., 2019) and England (Bridge, 2006).

Regarding hypotheses (1b), we tested if people with higher educational attainment generally live more central within the 16 large cities of our main sample, meaning if their 1 km-by-1 km neighbourhoods are closer to the geographical city centre. Results shown in Fig. 2 support that assumption. In large cities, university graduates live closest to the geographical city centre out of all educational groups, between 0.53 and 1.52 km closer than other educational groups. Individuals with higher education not only more often live in large cities but also most central within these areas.

#### 4.2. Travel distances and residential choice

(2a) travel distances to POIs for commutes, errands, leisure, and shopping, are shorter for highly educated individuals compared to other social groups (2b) due to their more central residential location.

We estimated a series of multilevel OLS regressions with individuals in large cities to analyse the daily travel distances of different educational groups, presented in Table 2. Fig. 3 displays the linear predictive margins of these models for travel distances per journey, separately for each travel purpose for individuals residing in large cities, and independent of the effects of all control variables (employment status, gender, age, children in the household, cars in the household). In 2002, travel distances did not vary significantly among educational groups. In 2017, however, people with university degrees travelled significantly shorter distances per journey for leisure, shopping and errands than individuals without higher education. For example, university graduates travel 20 % fewer kilometres for shopping trips and 15 % fewer kilometres for errands compared to people with a secondary school degree. Regarding commutes to and from work in 2017, we did not find any significant differences between educational groups.

To test hypothesis (2b), whether the proximity to the city centre accounts for the reduced travel distances among the higher educated, we replicated the regression model for hypotheses (2a) but now including the distance to the city centre of individuals' place of residency as an additional independent variable. Since this variable is only available for a subset of our sample from 2017, we first replicated the regression model for hypotheses (2a) to ensure that there are no meaningful differences of this sub-sample compared to our main sample. These Results can be found in Table A5 in the Online Appendix and show no relevant differences compared to the main sample. Next, we repeated the regression model to test hypothesis (2a), including residential distance to the city centre as an independent variable. As expected, centrality has a significant impact on travel distance for different travel purposes (see Fig. 4): Including residential distance to the city centre in the models reduces the differences regarding the average distance per journey between the different educational groups, supporting Hypothesis 2b.



Fig. 1. Probabilities of educational groups living in large cities.

*Notes*.Linear predictive margins derived from the regression models in Table A3 in the Online Appendix. Interpretation: In 2017, individuals with higher education had a 33 % chance to live in a large city (and a 67 % chance to live in other areas of Germany, respectively) whereas individuals with secondary education had a 14 % change to live in large cities, each net of all other effects.



### Fig. 2. Distance to city centres in large cities in 2017.

*Notes.* Linear predictive margins derived from regression models in Table A4 in the Online Appendix. Interpretation: The mean distance between the residence of university graduates in large cities and the geometric city centre (airline distance) is 5.03 km, compared to 6.46 km for individuals with secondary education, net of all other effects.

#### Table 2

ML-OLS regressions: Kilometres per journey.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Year	2002	2017	2002	2017	2002	2017	2002	2017
Variables	Commutes		Leisure		Errands		Shopping	
Elementary school or no degree	-0.064	0.025	0.090	0.048	0.140	0.049	0.062	0.161
	(0.092)	(0.057)	(0.101)	(0.080)	(0.120)	(0.095)	(0.111)	(0.090)
A-levels	-0.026	-0.026	0.277**	-0.055	0.104	-0.080	-0.101	-0.118*
	(0.093)	(0.038)	(0.106)	(0.045)	(0.143)	(0.054)	(0.130)	(0.052)
University	-0.137	0.023	0.104	-0.111**	-0.018	-0.157**	0.050	-0.201***
	(0.073)	(0.034)	(0.085)	(0.042)	(0.103)	(0.049)	(0.093)	(0.046)
Household income: Very low	-0.091	0.125	-0.205	0.079	-0.027	0.185	0.166	-0.038
	(0.187)	(0.078)	(0.178)	(0.087)	(0.256)	(0.100)	(0.189)	(0.103)
Low	-0.066	-0.087	0.181	-0.056	-0.157	0.111	0.073	-0.038
	(0.113)	(0.051)	(0.125)	(0.066)	(0.145)	(0.069)	(0.121)	(0.067)
High	0.027	-0.013	0.102	0.015	0.130	0.002	0.187*	0.031
	(0.071)	(0.027)	(0.093)	(0.037)	(0.106)	(0.044)	(0.095)	(0.040)
Very high	0.354**	-0.008	-0.117	0.074	0.524**	0.026	-0.096	-0.044
	(0.112)	(0.038)	(0.157)	(0.051)	(0.183)	(0.056)	(0.164)	(0.055)
Female	-0.216***	-0.220***	-0.044	-0.058*	-0.187*	-0.084*	-0.093	0.030
	(0.055)	(0.022)	(0.059)	(0.024)	(0.079)	(0.033)	(0.074)	(0.031)
Age Groups: 18-30	0.338***	0.065	0.137	0.025	0.277*	0.079	-0.006	-0.026
	(0.101)	(0.038)	(0.119)	(0.043)	(0.141)	(0.058)	(0.133)	(0.051)
31-40	0.153	0.063	-0.035	-0.030	0.310*	$-0.125^{*}$	0.080	-0.065
	(0.091)	(0.033)	(0.113)	(0.042)	(0.134)	(0.051)	(0.113)	(0.047)
41–50	0.058	0.076*	0.072	-0.029	0.192	-0.068	0.041	-0.039
	(0.095)	(0.033)	(0.106)	(0.040)	(0.126)	(0.050)	(0.108)	(0.043)
Employed	0.240*	0.184***	0.059	0.047	-0.037	0.088	-0.039	0.072
	(0.106)	(0.050)	(0.080)	(0.037)	(0.089)	(0.046)	(0.079)	(0.043)
Household with kids	-0.026	-0.127***	-0.124	$-0.182^{***}$	$-0.215^{*}$	-0.281***	-0.058	0.010
	(0.074)	(0.028)	(0.093)	(0.037)	(0.108)	(0.040)	(0.091)	(0.039)
Household with cars	0.352***	0.374***	0.498***	0.289***	0.315**	0.317***	0.602***	0.426***
	(0.088)	(0.029)	(0.104)	(0.039)	(0.124)	(0.046)	(0.109)	(0.042)
Constant	1.343***	1.486***	0.840***	1.342***	0.646***	1.024***	-0.090	0.146*
	(0.160)	(0.068)	(0.146)	(0.066)	(0.181)	(0.082)	(0.151)	(0.072)
N journeys	2913	21,152	3325	20,863	2203	14,275	2625	12,032
N individuals	1137	8282	1221	8086	770	5297	1068	5505

Notes. Robust standard errors in parentheses.

The variable kilometres per journey was log-transformed; Interpretation: On average, individuals with university education travel 20.1 % shorter distances on journeys to shopping destinations compared to individuals with secondary school degrees (reference category) in 2017, net of all other effects.

\*\*\* p<0.001.

<sup>\*\*</sup> p<0.00

p<0.05 (two-tailed tests).



#### Fig. 3. Travel distance per travel purpose by educational groups.

Notes. Linear predictive margins of travel distances for each travel purpose by educational level, net of all other effects. The margins are based on regression models from Table 2 in the Online Appendix. As the travel distance per journey was log-transformed for incorporation into the regression model, it was back-transformed to kilometres per journey for this figure (see Statistical Approach). Interpretation: University graduates travel, on average, 1.28 km per journey to and from shopping destinations, net of all other effects.



#### Fig. 4. Travel distance per travel purpose by educational groups, controlled for residential distance to the city centre.

*Notes.* Linear predictive margins of average travel distances per journey separated for each travel purpose by educational groups in large cities, including residential distance to the city centre as an independent variable, net of all other effects. The margins are based on regression models from Table A6. As the travel distance per journey was log-transformed for incorporation into the regression model, it was back-transformed to kilometres per journey for this figure (see Statistical Approach). Interpretation: University graduates travel, on average, 1.30 km per journey to and from shopping destinations, net of all other effects including residential distance to the city centre.

#### 4.3. Sustainable travel and time costs

(3a) Shorter travel distances allow highly educated individuals to choose sustainable modes of transport (3b) without incurring higher time costs.

To test hypothesis (3a), we examined the likelihood of individuals with different levels of educational attainment in large cities to choose between three main modes of transport for any given journey: driving by car, public transport, and walking/cycling. We estimated fractional multinomial logit models for each trip purpose and year. We included all control variables except whether the household owns cars, as this is already a perquisite of the category driving by car. The results indicate that university graduates prefer walking/cycling as well as using public transport over driving by car for commutes from and to work. For shopping, they prefer walking/cycling over driving and using public transport. Individuals with higher education do not show a preference for driving by car over walking/cycling or using public transport for any of the travel purposes. Sustainable modes of transport such as public transport, cycling, and walking incur higher travel time expenditures due to their relatively slower travel speed. To ensure that this general assumption applies to our current sample, we calculated the average travel speed per journey in km/h (log-transformed) and applied a multilevel regression model to show the association between more sustainable modes of transport and travel speed (see Table A9 in the Online Appendix). We find that using sustainable modes of transport as main of transport is associated with higher travel time expenditures and that individuals with higher level of educational attainment in large cities indeed travel at slower speed.

We applied a multilevel regression model to test hypotheses (3b) and

found, that those with higher levels of education do not incur higher travel time expenditures for errands, shopping, or leisure activities than other educational groups (see Fig. 5). In fact, they spent on average about 7 % less time per journey for errands and shopping than those of secondary education or lower, about 11 % less time than those with elementary school education on leisure activities in 2017 (see Table A8 in the Online Appendix). However, individuals with higher levels of education spent more time on commuting in 2017, which is to be expected since their commuting distance does not significantly differ from other educational groups. Despite their preference for slower, sustainable modes of transport, people with higher levels of educational attainment that live in large cities do not incur higher travel time expenditures for daily journeys than other educational groups due to their shorter distances to POIs in 2017. We do not find these effects in our sample of 2002 when the level of education was not yet as meaningful in predicting individuals' place of residency (Booi & Boterman, 2020).

#### 5. Discussion

Our results extend current research on sustainable daily mobility in three different areas: First, while we find that within large cities individuals with a higher level of education travel at slower speeds and more often opt for sustainable modes of transport than other educational groups (Hudde, 2022), our results show that they nevertheless do not have to invest more time in their daily mobility. Second, we show that this can be explained by their shorter distances to POIs, which, third, can partly be attributed to them living closer to the geographical centre of large cities. In this regard, people with higher levels of educational attainment differ from people with high household incomes. While the





*Notes.* Linear predictive margins of minutes per journey for each travel purpose by level of educational attainment of residents of large cities, net of all other effects. Margins are based on regression models from Table A8 in the Online Appendix. As the travel time per journey was log-transformed for incorporation into the regression model, it was back-transformed to minutes per journey for this figure (see Statistical Approach). Interpretation: University graduates spent, on average, 11.36 min per journey to and from shopping destinations, net of all other effects.

former tend to travel long distances by car, the opposite is true for people with higher levels of educational attainment. This finding suggests that the changes in daily mobility behaviour observed among highly educated individuals between 2002 and 2017 are specific to their level of education.

We further conclude that the daily mobility of highly educated individuals is linked to their neighbourhood quality: They reside in close proximity to local services, allowing them to save time. In addition to level of education and heightened environmental awareness (Meyer, 2015), place of residency is a key factor in adopting more sustainable behaviour. Individuals with higher educational attainment not only have the financial means to live in large cities, where they have access to better infrastructure and transportation services; they also have the cultural capital to identify neighbourhoods that offer a wide range of activities and services in close vicinity.

Living close to POIs leads to time-efficiency in daily mobility. Given that time is a valuable resource in capitalist societies (Amato et al., 2019), saving time in daily mobility is an advantage. While almost every social group in Germany has experienced an increase in the distances they travel on a daily basis over the last decades, highly educated individuals, due to the socio-spatial advantages of their places of residence, are to some extent insulated from the "faster and further" mobility demands of modern life. Partly due to these socio-spatial advantages, they can escape the stress of modern lifestyles while still actively participating in daily life (Rosa, 2014).

Since reducing daily travel distances helps to reduce private care use and to lower emissions (Banister, 2011; Ivanova et al., 2020), the higher educated are likely to be responsible for fewer emissions from their daily travel behaviour than other social groups. However, our analysis solely focuses on daily mobility. If we were to consider vacations and air travel (e.g., for work trips), we can reasonably expect that the lower emissions in daily mobility by people with higher education are likely to be offset by their non-daily mobility behaviour (Holden & Linnerud, 2011). That means, while higher educated individuals exhibit a sustainable daily mobility behaviour, it might not translate to overall reduced CO<sub>2</sub> emissions compared to other social groups.

#### 6. Limitations

Although we found that highly educated individuals tend to travel shorter distances, we were not able to include information on the spatial distribution of POIs across German large cities due to a lack of sufficient and reliable data. Therefore, we cannot draw any definitive conclusions about the residential proximity of individuals to such destinations.

Furthermore, our analysis does not investigate whether individuals with higher levels of education proactively choose to travel shorter distances, or whether these shorter distances are simply a consequence of where they live. It similarly remains unclear whether highly educated people deliberately choose neighbourhoods close to certain POIs. This aspect can only be inferred through insights drawn from other studies (Hesse & Scheiner, 2010).

Another limitation of our study is its reliance on survey data and respondents' memories, which can introduce inaccuracies, particularly for short-distance trips. While data based on tracking methods can address these problems and contain more detailed information about daily mobility, it comes with its own set of problems (Bock & Schönduwe, 2021). Most importantly, tracking data often is limited to specific geographic areas and fails to provide demographic and socio-economic information on respondents.

#### 7. Conclusion

Effective strategies to reduce daily travel distances and private car use are needed to combat climate change (Banister, 2011; Ivanova et al., 2020). Highly educated individuals have been regarded as front-runners in transitioning towards sustainable modes of transport (Hudde, 2022; Hudde, 2023; Kim et al., 2016; Roos et al., 2020). Research commonly assumes that greater environmental awareness among people with higher educational attainment explains their sustainable daily mobility choices (Kim et al., 2016).

We investigated to the extent to which the environmentally friendly mobility behaviour observed among individuals with higher education can be attributed to their socio-economic and socio-spatial advantages. By analysing the *Mobility in Germany* survey data, encompassing a sample of 27,882 respondents in 2002 and 134,167 respondents in 2017, and utilising multilevel OLS, logistic regressions, and fractional multinomial logit models, we analysed the relationship between educational attainment, place of residency and daily mobility choices while controlling for the influence of various other factors (employment status, gender, age, children in the household, cars in the household).

Our findings indicate that the socio-spatial advantages of highly educated individuals have a pronounced effect on their daily mobility behaviour. Individuals with higher educational attainment are more likely to live in large cities than other educational groups or high-income individuals and, furthermore, reside in more central locations within large cities. We found that their travel distances to POIs such as shopping, errands and leisure activities are shorter than those of other educational groups. For example university graduates travel 20 % fewer kilometres for shopping trips and 15 % fewer kilometres for errands compared to people with a secondary school degree. However, the location of their residence can only account for a proportion of their shorter travel distances. These shorter travel distances allow individuals with higher education to choose more sustainable - but also slower modes of transportation such as cycling and walking without incurring the otherwise associated higher travel time expenditures.

It is crucial to consider the socio-spatial advantages of highly educated individuals when analysing their sustainable daily mobility behaviour. Our findings indicate that sustainable mobility patterns among this group are more likely to reflect privilege rather than sacrifice. While heightened environmental awareness may impact their choices, our study challenges the assumption that environmental awareness alone is sufficient to drive the adoption of sustainable mobility practices. In order to foster sustainability, it is essential to address the socio-spatial disadvantages linked to spatial inequalities (Kadi et al., 2022). Further research is required to ascertain whether highly educated individuals deliberately choose to reside in proximity to points of interest (POIs) with the specific intention of adopting sustainable mobility practices.

Furthermore, it would be advantageous to investigate the manner in which these associations have developed in the context of the global pandemic caused by COVID-19. Individuals with a higher socioeconomic status were more likely to work from home during the pandemic (Knie et al., 2021), and there was a notable reduction in spatial mobility, particularly in regions with a larger population of residents with higher education (Brough et al., 2021). Our analysis revealed that individuals with higher education experienced longer commutes in 2017. However, the pandemic likely reduced their daily commutes, as they have benefited especially from the rise in work-from home policies.

This increasing divergence presents a challenge to our ability to comprehend the issues faced by other social groups in their adaptation to sustainable modes of transport. The 2022 Berlin state elections provide an illustrative case in point, with the transition to sustainable urban transportation emerging as a dominant issue in the electoral discourse. Outer-city districts demonstrated a predominantly conservative voting pattern, thereby rejecting plans for sustainable transport solutions. In contrast, inner-city areas exhibited a predominantly supportive voting pattern with regard to these policies. The proximity of POIs in daily life is likely to exert an influence on voting preferences for climate-friendly transport measures. In order to address these social inequalities and establish a foundation for the acceptance of more sustainable transportation policies, it is imperative to facilitate the construction of social housing and to guarantee that residential options are not unduly influenced by either educational or economic status. Given the current level of residential inequality in German cities (Helbig & Jähnen, 2018), a transition to sustainable transportation will not be feasible for a significant proportion of urban populations.

#### CRediT authorship contribution statement

Sarah George: Writing – review & editing, Writing – original draft, Visualization, Software, Methodology, Formal analysis, Data curation, Conceptualization. Katja Salomo: Writing – review & editing, Supervision, Project administration, Methodology, Investigation, Conceptualization. Marcel Helbig: Writing – review & editing, Resources, Investigation, Conceptualization.

#### Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

#### Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cities.2024.105507.

#### Data availability

Data will be made available on request.

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