The Journal of Transport and Land Use http://jtlu.org
Vol. 11 No. 1 [2018] pp. 1–18

Different destination, different commuting pattern? Analyzing the influence of the campus location on commuting

David S. Vale (corresponding author)
University of Lisbon
dvale@fa.ulisboa.pt

Mauro Pereira
University of Lisbon
mauro.pereira@fa.ulisboa.pt

Claudia M. Viana
University of Lisbon
claudiaviana@campus.ul.pt

Abstract: There is a vast literature on the relationship between built environment and travel, emphasizing the importance of built environment as a determinant of travel. However, the majority of studies focuses on the characteristics of origins and neglects the influence that the destination might have on travel, despite the already demonstrated importance of destinations to explain travel. In this paper, we test the relationship between residential and workplace built environment and the commuting pattern of staff and students of the University of Lisbon, a multi-campus university. Data was obtained through a dedicated travel survey, containing 1474 georeferenced individuals. Chi-square analyses were developed to analyze differences between staff and students and between different campuses. A logistic regression model was developed to explain car commuting, controlling for socio-demographic data. Two different models were developed for students and staff.

Our results show the built environment and associated multimodal accessibility of the campuses are important explanatory variables of commuting. Free parking at the campus is crucial for car commuting, especially for students. These results emphasize the importance of measuring destinations as explanatory variables and promoting good urban integration of the campus in the city, increasing its multimodal accessibility.

Keywords: University campus, commuting, destination, student, staff

Article history:
Received: October 31, 2016
Received in revised form: June 21, 2017
Accepted: November 10, 2017
Available online: Jan. 5, 2018

1 Introduction

There is a vast literature on the relationship between the built environment and travel, emphasizing the importance of the built environment as a determinant of travel. In general terms, the determinants of

http://dx.doi.org/10.5198/jtlu.2018.893
ISSN: 1938-7849 |

The *Journal of Transport and Land Use* is the official journal of the World Society for Transport and Land Use (WSTLUR) and is published and sponsored by the University of Minnesota Center for Transportation Studies. This paper is also published with additional sponsorship from WSTLUR.

the built environment can be described as the 5Ds (Cervero & Kockelman, 1997; Cervero, Sarmiento, Jacoby, Gomez, & Neiman, 2009; Ewing & Cervero, 2010), better defined as "3Ds+A", i.e., Density, Diversity, Design and Accessibility, the last normally identified as Destination Accessibility and Distance to transit (Vale & Pereira, 2016). However, the focus of the majority of studies is on the characteristics of origins (the location of the home) and they neglect the influence that the destination might have on travel, despite the already demonstrated importance of destinations in explaining travel.

Indeed, the built environment of destinations has been pointed out as more important than the built environment of origins in explaining mobility patterns for several travel modes (Forsyth, Hearst, Oakes, & Schmitz, 2008; McNeil, 2011; Millward, Spinney, & Scott, 2013; Vale & Pereira, 2016), especially if the destination is a regular, consistent destination such as the workplace (Chatman, 2003). Even for active travel, this influence still holds (Manaugh & El-Geneidy, 2011), as although the home to work distance is the major barrier to active commuting, the workplace is an origin for several other daily trips (Dong, Ma, & Broach, 2015), and its built environment features might impede or encourage the making of these trips by walking or cycling (Adams, Bull, & Foster, 2016). The uncertain geographical context problem (Kwan, 2012) gives further support to the importance of destinations in explaining travel behavior, since spatiotemporal variability is extremely important in understanding the real exposure of an individual throughout the day, not only to air pollution and associated health risks (Park & Kwan, 2017), but also to different space-time accessibility conditions (Miller, 2007; Weber & Kwan, 2002), which might exert a strong influence on mode choice and associated travel behavior.

University campuses are special and important destinations in cities. Not only do they constitute important landmarks in cities and exert an important cultural and educational influence, they are also large employers, generating a significant number of trips (Lavery, Páez, & Kanaroglou, 2013; Shannon et al., 2006; Tolley, 1996). Therefore, like other similar places such as hospitals and office and science parks, they can play an important role in promoting sustainable urban mobility for students and staff (Akar & Clifton, 2009; Balsas, 2003) as well as contribute health benefits, such as reduced depression (Field, Diego, & Sanders, 2001) and decreased risk of overweight and obesity (Frank, Andresen, & Schmid, 2004).

Additionally, the complex and distinctive travel behavior of university students who commute for three or more years to the same place, and are potential active commuters given their age and income situation, is well known (Delmelle & Delmelle, 2012; Limanond, Butsingkorn, & Chermkhunthod, 2011; Miralles-Guasch & Domene, 2010; Zhou, 2012). Students participate more in social or recreational activities than the general population, making more daily trips (Khattak, Wang, Son, & Agnello, 2011). In contrast, researchers, professors and administrative staff, like other full-time workers, acquire travel habits that affect their mode choice and frequency (Heinen, van Wee, & Maat, 2010), normally associated with a greater dependency on private vehicles and longer commutes (Shannon et al., 2006; Zhou, 2014).

Previous research studied universities sited at different locations throughout the world (Limanond et al., 2011; Miralles-Guasch & Domene, 2010; Rodríguez & Joo, 2004) and results consistently point out that the built environment in which they are located, together with the parking policy of the campus, can be determinant in promoting active travel (Rodríguez & Joo, 2004; Wang, Akar, & Guldmann, 2015; Whalen, Páez, & Carrasco, 2013; Zhou, 2016).

In this paper, we are revisiting the influence of the university's built environment and accessibility conditions on the travel pattern of students. We have used as case study the University of Lisbon, the largest university of Portugal with nearly 50,000 students distributed over 18 faculties. The university is spread across the Lisbon Metropolitan Area in nine different campuses, located in the city of Lisbon and in the suburbs, offering considerably different built environment and accessibility conditions for the members of each campus. Through a comparison of five urban campuses, we evaluate to what extent the travel behavior of students and staff can be explained by the built environment of the campus, regardless of the built environment of their residence.

2 Hypothesis

In accordance with the existent literature on the relationship between land use and travel, and on the commuting pattern of students, we are establishing two hypotheses:

a) Students and staff have a different commuting pattern, regardless of their residential place or workplace;

b) Students and staff's commuting behavior is influenced by the characteristics of the built environment of their residential location, but also by the built environment features of their university campus.

3 Methodology

3.1 Travel survey

To test our two hypotheses, we conducted a focused travel survey during December 2015, using both an online platform and a face-to-face questionnaire to obtain a significant and representative sample of all faculties of the university. All students and staff (researchers, professors and administrative staff) were invited to participate, and asked to describe their typical mobility pattern from their home to the university. We asked for the location of their house (7-digit postal code), socioeconomic data, and also some data regarding alternative mobility patterns and willingness to change travel mode (see the list of selected variables in the appendix).

We obtained 2037 valid answers, and geocoded the residential location of all individuals with ArcGIS© Online Geocoding Service, supplemented with the Portuguese postal service company website (CTT) for unmatched addresses, which reduced the geocoded sample to 1882 individuals. Finally, as we wanted to evaluate typical commuting patterns of students and staff, we selected only faculties in which we had both students and staff and also only individuals that travel to the university 3 or more times per week, which produced the final sample with 1474 individuals, 1219 students and 255 staff.

3.2 Built environment data

We collected built environment data for both home and workplace locations, based on the known determinants of BE for travel, namely: density, diversity, design (including connectivity), accessibility, and topography (see full list in the appendix). Due to lack of data, topography was only collected for the campuses. All built environment indicators were calculated using a 500-metre floating catchment area (FCA), calculated in ArcGIS© Network Analyst with road centerlines. Through a correlation analysis of variables within each dimension, we selected a final list of 10 variables, as seen in Table 1. With these, we calculated two indexes: walkability index and accessibility index. Inspired by the walkability index of Frank and colleagues (Frank et al., 2006; Frank, Devlin, Johnstone, & van Loon, 2010; Frank, Schmid, Sallis, Chapman, & Saelens, 2005), our walkability index was calculated after standardizing the six built environment variables, giving equal weight to all. Accessibility index was calculated after normalization of the three accessibility variables, also giving equal weight to all, and varies between 0 and 1. Since car parking availability and cost can increase car commuting (Christiansen, Engebretsen, Fearnley, & Usterud Hanssen, 2017), we also calculated a parking index for each campus, by calculating a dummy variable representing the availability of free parking at each campus.

Table 1: Built environment variables used to analyze residential and campus locations

Dimension | Variable code	Description
Built environment	
BE_Walkability	
Density	
N_Resident	Number of resident population (m2)
N_Dwellings	Number of dwellings (m2)
Diversity	
NumPOIS	Number of points of interest (POIs)
VarietyPOIS	Variety of POIs
Design	
Average_Link_Length	Average link length (m)
Pedshed	Pedestrian shed ratio (0 to 1)
BE_Accessibility	
Acc_Metro	Has a metro stop up to 500 metres (Yes=1)
Acc_Train	Has a train stop up to 800 metres (Yes=1)
Count_Stop	Number of transit stops
Parking*	
FreeParking	Free parking spaces (Yes=1)

* only for campuses

3.3 Statistical and spatial analysis

We developed three major analyses to test our hypotheses, using three dependent variables: travel mode, travel time and travel steps. First, to evaluate the differences between students and staff, we developed a chi-square analysis, to compare students' and staff's travel behavior. Second, to test for differences between campuses, we started by developing a spatial analysis of residential locations of students and staff. A kernel density function map was calculated for all campuses and for each of the campus individually, with a 100-meter cell size resolution. To control for eventual errors, we focused our analysis on only five campuses for which we had data for both students and staff. Third, we developed chi-square analyses to evaluate differences between the five campuses, and also a logistic model to explain car commuting, using a dummy variable "CarCommuting." Spatial analysis was developed with ArcGIS© 10.3.1 and statistical analysis was developed with Statistical Package for the Social Sciences (SPSS) version 22.

Due to the known influence of travel distance on commuting, we segmented our sample into four classes of distance, reflecting active travel feasibility. Accordingly, we used "less than 1 km," in which walking is possible, "1 to 4 km," in which besides walking the bicycle is the fastest mode, "4 to 8 km," in which walking is residual but bicycle is still feasible, and "more than 8 km," in which only public transport or SOV are the feasible options.

4 Results

4.1 Students and staff commuting pattern

In our sample, we registered a high car ownership rate, but the ownership rate of staff (94.1%) is higher than that of students (88.5%) - Table 2. Similarly, almost all staff members have a driver's license (93.3%), while only 70.2% of students have one, which is nevertheless quite high for a young population, in which 80.3% are less than 25 years old (undergraduate students). Students depend more on public transport, as can be seen in the 70.4% of public transport monthly ticket holders, in comparison to only 27.1% of staff.

Table 2: Socioeconomic features of the sample of staff and students

	Staff		Student		Total	
	n	Percent	n	Percent	n	Percent
Socio-economic						
SE_Gender						
Female	147	57.6	820	67.3	967	65.6
Male	108	42.4	399	32.7	507	34.4
SE_Age						
Under 25 years	2	0.8	979	80.3	981	66.6
25 to 34	28	11	150	12.3	178	12.1
35 to 44	60	23.5	52	4.3	112	7.6
45 to 54	91	35.7	25	2.1	116	7.9
55 to 64	70	27.5	12	1	82	5.6
65 or more	4	1.6	1	0.1	5	0.3
SE_HasCar						
No	15	5.9	140	11.5	155	10.5
Yes	240	94.1	1079	88.5	1319	89.5
SE_DriversLicense						
Yes	238	93.3	856	70.2	1094	74.2
No	17	6.7	363	29.8	380	25.8
SE_Passe						
Yes	69	27.1	858	70.4	927	62.9
No	186	72.9	361	29.6	547	37.1
Total	255	100.0	1219	100.0	1474	100.0

Table 3: Differences in the commuting pattern of staff and students

	Staff		Student		Total				
	n	Percent	n	Percent	n	Percent	x^2	df	p-values
Commuting									
Com_Mode							239.1	5	0.000
Walk	22	8.6	176	14.4	198	13.4			
Bicycle	1	0.4	10	0.8	11	0.7			
Public Transport	43	16.9	676	55.5	719	48.8			
Car passenger	1	0.4	21	1.7	22	1.5			
SOV	175	68.6	254	20.8	429	29.1			
PT + others	13	5.1	82	6.7	95	6.4			
Com_Time							55.48	5	0.000
=< 5 min	1	0.4	8	0.7	9	0.6			
5 - 15 min	32	12.5	116	9.5	148	10.0			
15 - 30 min	95	37.3	275	22.6	370	25.1			
30 45 min	66	25.9	234	19.2	300	20.4			
45 - 60 min	26	10.2	175	14.4	201	13.6			
> 60 min	35	13.7	411	33.7	446	30.3			
Com_Dteps							112.4	6	0.000
1	175	68.6	419	34.4	594	40.3			
2	30	11.8	195	16	225	15.3			
3	31	12.2	287	23.5	318	21.6			
4	19	7.5	204	16.7	223	15.1			
5	0	0.0	82	6.7	82	5.6			
6	0	0.0	28	2.3	28	1.9			
7 or more	0	0.0	4	0.3	4	0.3			
Total	*255*	*100.0*	*1219*	*100.0*	*1474*	*100.0*			

Overall, the mobility pattern of staff is different from that of students. In terms of travel mode, students show a more evenly distributed pattern in all travel modes, as already pointed out in the literature (Whalen, Páez, & Carrasco, 2013). A significant difference is found in the travel mode of staff and students ($x^2(5)=239.1$, p=.000). Indeed, most of the students use public transport (55.5%) or walk (14.4%) to the university, while the vast majority of staff use SOV (68.6%). Likewise, travel time also differs between the two groups ($x^2(5)=55.48$, p=.000), with students showing a longer travel time than staff. Finally, the number of steps of the commuting trip, used as an indicator of the burden of the commuting, is also significantly different between the two groups ($x^2(6)=112.4$, p=.000), with students needing more steps than staff to reach the university.

4.2 Commuting pattern per class of distance

Despite the difference found in the commuting patterns of students and staff, an additional feature that has a clear influence on commuting is the distance from the residential location to the university, as distance, in itself, reduces the feasibility of certain travel modes once certain thresholds are passed. Our results show that distance is an important explanatory variable for commuting, either in explaining the travel mode of staff ($x^2(6)=33.92$, p=.000) or students ($x^2(6)=395.14$, p=.000), or in explaining travel time ($x^2(15)=113.52$, p=.000, and $x^2(15)=796.12$, p=.000, respectively – Table 4). However, within the same travel distance class, the commuting pattern of students and staff remains different, as in the case of SOV usage by staff, which is zero in the closest travel distance zone (under 1 km), but is similar across all other zones (around 70%), where students' use of SOV increases with distance. In terms of walking however, the pattern is similar in both groups, being dominant in the first zone (92.5% and 100%) and significantly decreasing as distance increases. In terms of travel time, for staff it tends to increase with distance up to the 8-km zone, in which the majorities take up to 30 minutes to commute. After this distance threshold, 30 minute stands as the norm, which suggests that staff members are able to exchange distance for speed, maintaining their commuting within the acceptable isochrones, as already seen in Lisbon (Vale, 2013). On the other hand, students seem not to be able to keep their commuting within the acceptable value, as travel time tends to increase with travel distance, as well as with the number of steps needed to reach the university.

Table 4: Differences in commuting pattern of staff and students according to their distance from the university

	Staff					**Student**				
	Zone 1	Zone 2	Zone 3	Zone 4	Total	Zone 1	Zone 2	Zone 3	Zone 4	Total
	<= 1km	> 1 to <= 4km	> 4 to <= 8km	> 8km		<= 1km	> 1 to <= 4km	> 4 to <= 8km	> 8km	
Commuting										
Com_Mode										
Walk	100.0	14.0	13.9	1.6	8.6	92.5	39.4	11.1	3.0	14.4
Bicycle	0.0	0.0	1.4	0.0	0.4	0.0	2.8	1.3	0.0	0.8
PublicTran-port	0.0	14.0	15.3	19.4	16.9	5.0	44.0	61.4	59.5	55.5
Car pas-senger	0.0	1.8	0.0	0.0	0.4	0.0	1.4	2.3	1.7	1.7
SOV	0.0	70.2	66.7	70.2	68.6	2.5	12.5	22.5	23.9	20.8
PT + others	0.0	0.0	2.8	8.9	5.1	0.0	0.0	1.3	11.9	6.7
x^2 (df) | p**			33.919 (6)	0.000				395.139 (6)	0.000	
Com_Time										
=< 5 min	0.0	1.8	0.0	0.0	0.4	12.5	1.4	0.0	0.0	0.7
5 - 15 min	100.0	40.4	8.3	0.8	12.5	72.5	24.5	9.8	0.6	9.5
15 - 30 min	0.0	42.1	54.2	25.8	37.3	15.0	50.9	24.5	12.8	22.6
30 - 45 min	0.0	14.0	25.0	32.3	25.9	0.0	16.7	35.6	13.5	19.2
45 - 60 min	0.0	0.0	5.6	17.7	10.2	0.0	4.6	19.6	16.0	14.4
> 60 min	0.0	1.8	6.9	23.4	13.7	0.0	1.9	10.5	57.1	33.7
x^2 (df) | p			113.521(15)	0.000						
Com_steps								796.115(15)	0.000	
1	100.0	80.7	70.8	61.3	68.6	97.5	53.2	32.4	25.3	34.4
2	0.0	10.5	15.3	10.5	11.8	2.5	24.5	28.4	8.2	16
3	0.0	7.0	5.6	18.5	12.2	0.0	17.6	25.2	26.2	23.5
4	0.0	1.8	8.3	9.7	7.5	0.0	4.2	12.1	24.0	16.7
5	0.0	0.0	0.0	0.0	0.0	0.0	0.5	2.0	11.4	6.7
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.3	2.3
7 or more	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.3
x^2 (df) | p			15.520(9)	0.780				295.223(18)	0.000	
n	*2*	*57*	*72*	*124*	*255*	*40*	*216*	*306*	*657*	*1219*

* Zone 1 (<= 1km), Zone 2 (> 1km to <= 4km), Zone 3 (> 4km to <= 8km), Zone 4 (> 8km)

** In order to achieve viable result to c2 the travel mode was grouped into 3 modes: Walk/bike, PT (solo or with others) and SOV

4.3 The influence of the campus location

The campuses of the University of Lisbon show different built environment features – see Figure 1. The university is spread across nine campuses, located in three different municipalities: Lisbon, Oeiras and Loures. Through the use of our three indexes (walkability, accessibility, and parking availability), it becomes clear that they constitute four different types of campus. ISEG and IST are examples of an "urban campus," with high walkability and accessibility, and no free parking available outside the campus. Cidade Universitária is the main campus of the University and has good multimodal accessibility. However, due to its very large size (approximately 10 hectares), it shows lower walkability conditions, and we therefore classified it as a "large urban campus." Pólo da Ajuda is the secondary campus of the University, being the location of three faculties. It shows poor walkability and multimodal accessibility, and free parking is available in the campus – we classified it as a "suburban campus." Finally, FMH is a special case of a suburban campus: being the location of the sports science faculty, it is adjacent to the National Stadium of Portugal, and is therefore classified as an "isolated campus." Finally, in terms of parking, it should be said that practically all faculties have private parking for staff and sometimes also for students, available for a small monthly or annual fee, which is a clear example of the subsidization of car commuting by the University (Tolley, 1996).

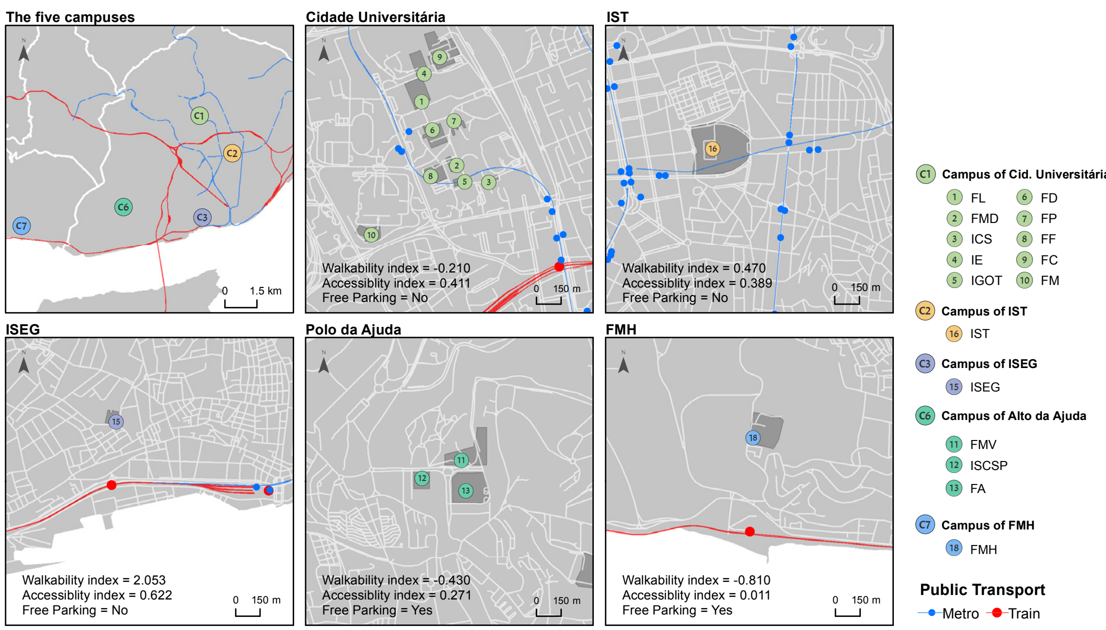

Figure 1: Location of the analyzed campuses

4.3.1 Spatial analysis

The kernel density map of the residential locations of staff and students shows a general location pattern that follows the main public transportation network of Lisbon, namely the metro and train lines, with a clear tendency towards the center of Lisbon as a preferred location (see Figure 2). However, different campuses show different distribution of their staff and students. The urban campuses (IST and ISEG) show a more concentrated pattern, due to the higher availability of housing nearby the campus. On the other hand, the suburban campus (Pólo da Ajuda) has its population spread across the metropolitan area, with a minor tendency towards the nearby locations. The large urban campus (Cidade Universitária) has a similar scattered pattern, although with a higher tendency for individuals to locate across the city of Lisbon, following the metro network. The isolated campus (FMH) is a special case, as several students live on campus, and so the density distribution is clearly focused on the campus itself.

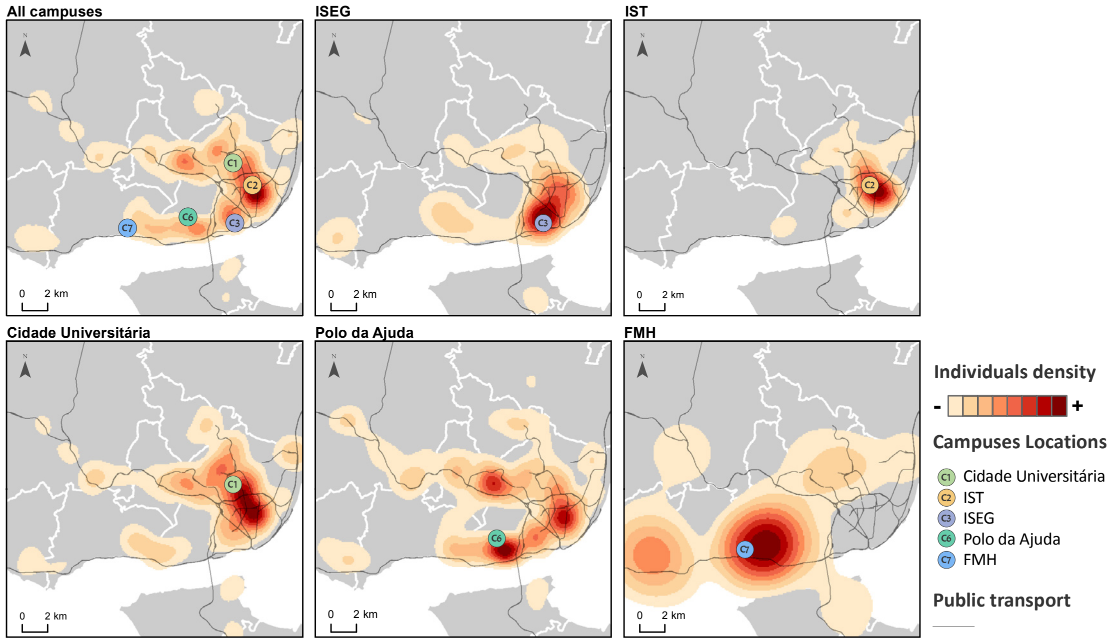

Figure 2: Kernel density maps of the residential location of staff and students of the different campuses

4.3.2 Statistical analysis of the influence of campus location on commuting pattern

Despite a low percentage of staff walking (8.6%), this pattern alters according to the campus. Indeed, as seen in Table 5, the percentage of staff walking to urban campuses (IST and ISEG) is significantly higher than average, between 13.6 and 20.0%. Travel time is not influenced by the location of the campus, again suggesting that staff members exchange distance for speed, choosing faster travel modes to reduce travel time. On the other hand, students are mainly public transport users (55.5%), and only 14.4% walk to campus. Nevertheless, as in the case of staff, students are affected by the location of campus, especially in terms of walking to an urban campus (IST=29.9% and ISEG=21.4%). Commuting to a very large campus (Cidade Universitária = 12.3%) or a suburban campus (Pólo da Ajuda = 11.7%) decreases the number of students walking. The suburban campus, with low multimodal accessibility, shows a significant number of students commuting by car (Pólo da Ajuda = 22.9%). The isolated campus (FMH) is again a special case, showing high walking (21.7%) and also high SOV usage (52.2%), reflecting not only the poor multimodal accessibility, but also the existence of student accommodation on campus, which allows walking to the faculty. Just as with staff, travel time is not affected by the location of the campus.

Table 5: Commuting pattern of staff and students by campus (%)

	Cidade Univ.		Polo Ajuda		ISEG		IST		FMH		Total	
	Staff	**Student**	**Staff**	**Student**	**Staff**	**Student**	**Staff**	**Student**	**Staff**	**Student**	**Staff**	**Student**
Commuting												
Com_Mode												
Walk	11.2	12.3	4.3	11.7	13.6	21.4	20.0	29.9	0.0	21.7	8.6	14.4
Bicycle	1.0	1.8	0.0	0.0	0.0	0.0	0.0	4.1	0.0	0.0	0.4	0.8
Public Transport	19.4	57.7	17.0	59.5	13.6	48.7	15.0	37.1	9.5	21.7	16.9	55.5
Car passenger	0.0	1.5	1.1	1.7	0.0	0.0	0.0	4.1	0.0	4.3	0.4	1.7
SOV	60.2	16.9	76.6	22.9	68.2	16.2	55.0	18.6	85.7	52.2	68.6	20.8
PT + others	8.2	9.8	1.1	4.3	4.5	13.7	10.0	6.2	4.8	0.0	5.1	6.7
Com_Time												
=< 5 min	0.0	0.0	1.1	0.3	0.0	2.6	0.0	3.1	0.0	0.0	0.4	0.7
5 - 15 min	13.3	8.6	11.7	6.6	13.6	12.0	10.0	23.7	14.3	34.8	12.5	9.5
15 - 30 min	36.7	24.5	41.5	21.5	27.3	16.2	45.0	27.8	23.8	34.8	37.3	22.6
30 - 45 min	28.6	22.7	21.3	17.2	31.8	23.9	20.0	17.5	33.3	8.7	25.9	19.2
45 - 60 min	8.2	12.0	9.6	15.2	18.2	14.5	10.0	17.5	14.3	8.7	10.2	14.4
> 60 min	13.3	32.2	14.9	39.2	9.1	30.8	15.0	10.3	14.3	13.0	13.7	33.7
Com_Steps												
1	67.3	29.8	68.1	32.5	72.7	35.0	75.0	52.6	66.7	73.9	68.6	34.4
2	11.2	15.0	11.7	17.8	9.1	12.8	5.0	13.4	23.8	4.3	11.8	16.0
3	14.3	26.1	10.6	22.3	9.1	28.2	20.0	22.7	4.8	4.3	12.2	23.5
4	7.1	18.1	9.6	17.4	9.1	17.1	0.0	8.2	4.8	13.0	7.5	16.7
5	0.0	8.0	0.0	7.2	0.0	4.3	0.0	3.1	0.0	4.3	0.0	6.7
6	0.0	2.1	0.0	2.7	0.0	2.6	0.0	0.0	0.0	0.0	0.0	2.3
7 or more	0.0	0.9	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
n	*98*	*326*	*94*	*656*	*22*	*117*	*20*	*97*	*21*	*23*	*255*	*1219*

4.4 Explaining car commuting to the University of Lisbon

Table 6 shows the logistic models of socioeconomic and built environment variables in car commuting for staff and students. For students, we developed two different models: one for all students and the other for undergraduate students only, as these last represent the vast majority of students and are normally full-time students who do not have any type of income. For all models, the dependent variable is having commuted to the campus by car (Yes=1), either as a driver or as a passenger. All models show reasonable values of R^2 (Nagelkerke): between .414 and .431. As expected, the models for staff and students show different significant predictors. Car commuting by staff is mainly explained by their status, in that being a professor increases the probability of commuting by car in comparison with other staff (B=1.693, p=.000). As expected, the number of cars in the household is also a significant predictor (B=1.564, p=.000). For staff, commuting distance is not a significant variable, which was expected given their modal share per commuting distance class (see Table 4). The built environment of the home is not significant in explaining the commuting patterns of staff, but the accessibility of the campus is the highest significant predictor, reducing the probability of car usage (B=-1,896, p=.042). Therefore, for staff, commuting to a multimodal accessible campus significantly reduces the number of car commuters, which is an important finding for transport policy development.

The commuting pattern of students is also influenced by their socioeconomic status, namely the number of cars in their household (B=1.443, p=.000), the size of their household (B=-.532, p=.000), and their income — in comparison to a student with a monthly income of only €500/month, a student with an income of more than €4000/month is almost twice as likely to commute by car (B=1.970, p=.002). Younger students are less frequently car commuters than older students, probably due to their family composition, which is known to influence car usage (Delmelle & Delmelle, 2012). Unlike staff, students' car commuting is sensitive to commuting distance and to the built environment of the home and campus. Living close to the campus reduces the probability of commuting by car (B=-2.064, p=.076), as does living in a walkable environment (Walkability index at home B=-.251, p=.098). In contrast, studying at a campus with free parking significantly increases their probability of commuting by car (B=1.432, p=.000). The model for undergraduate students shows only similar results to the model for the entire student population. However, in either case, two major differences arise. First, the possession of a driver's license increases the probability of commuting by car (B=2.927, p=.000). Second, the built environment of the home is not significant in explaining car commuting, only the availability of parking at the campus (B=1.444, p=.000).

Table 6: Logistic model of socioeconomic and built environment variables in car commuting

	Staff					Students					Undergraduate students (< 25 years old)				
Variable	**B**	**S.E.**	**Wald**	**Sig.**	**Exp(B)**	**B**	**S.E.**	**Wald**	**Sig.**	**Exp(B)**	**B**	**S.E.**	**Wald**	**Sig.**	**Exp(B)**
Constant	-.350	.570	.376	.540	.705	-4.424	.635	48.564	.000	.012	-6.884	1.060	42.161	.000	.001
Socio-economic															
SE_StaffStatus (Professor = 1)	1.693	.349	23.469	.000	5.436										
SE_Age (less than 25 years)								78.462	.000						
SE_Age (25 to 34)						1.918	.288	44.333	.000	6.809					
SE_Age (35 to 44)						2.949	.410	51.838	.000	19.088					
SE_Age (45 to 54)						2.456	.611	16.155	.000	11.656					
SE_Age (more than 55)						1.908	.741	6.623	.010	6.737					
SE_DriversLicense (Yes=1)											2.927	.609	23.097	.000	18.665
SE_HouseholdSize	-.503	.159	9.965	.002	.605	-.532	.105	25.818	.000	.587	-.371	.127	8.490	.004	.690
SE_NumberCars	1.564	.297	27.771	.000	4.778	1.443	.142	102.998	.000	4.232	1.112	.167	44.282	.000	3.040
SE_Income (less than 500€/month)								16.765	.005				12.860	.025	
SE_Income (500 to 999€/month)						.850	.531	2.560	.110	2.340	1.168	.801	2.127	.145	3.215
SE_Income (1000 to 1499€/month)						.455	.528	.743	.389	1.577	.717	.798	.808	.369	2.049
SE_Income (1500 to 1999€/month)						.794	.551	2.072	.150	2.212	1.102	.814	1.834	.176	3.011
SE_Income (2000 to 3999€/month)						.787	.553	2.023	.155	2.196	.833	.818	1.037	.309	2.300
SE_Income (more than 4000€/month)						1.970	.621	10.050	.002	7.168	2.263	.883	6.573	.010	9.608
Commuting distance															
Com_Dist (MoreThan8km)			.024	.999				7.473	.058				9.399	.024	
Com_Dist (LessThan1km)	-21.480	25034.901	.000	.999	.000	-2.064	1.164	3.148	.076	.127	-1.815	1.105	2.699	.100	.163
Com_Dist (1kmTo4km)	-.062	.449	.019	.890	.940	-.551	.342	2.600	.107	.576	-1.076	.429	6.302	.012	.341
Com_Dist (4kmTo8km)	-.043	.395	.012	.912	.957	.178	.258	.472	.492	1.194	.080	.297	.073	.787	1.084
Built environment - Home															
Home_BE_Walkability						-.251	.151	2.743	.098	.778					
Built environment - Campus															
Campus_BE_Accessibility	-1.896	.934	4.123	.042	.150										
Campus_BE_FreeParking (Yes=1)						1.432	.239	35.763	.000	4.185	1.444	.295	23.949	.000	4.237
R^2 (Cox & Snell)			.294					.282					.251		
R^2 (Nagelkerke)			.414					.431					.428		
Model X^2 (df)			87.48 (7)					290.03 (16)					196.54 (12)		

5 Conclusion

Our results can be instrumental in developing an effective sustainable urban mobility policy for the University of Lisbon. As expected, staff and students present different commuting patterns, and are influenced by different factors, and so different policies should be adopted for each group. Staff members are particular sensitive to the multimodal accessibility conditions of the campus, and so only through an effective "carrots and sticks" package of tools might their commuting be changed to a more sustainable pattern. In this respect, it should be said that the authors know that on a majority of campuses there is affordable parking for staff, although this data is not easily available. We assume that this could be also an influential factor in explaining the commuting behavior of staff, and intend to look deeper into this issue in the future.

Students are more influenced by the built environment of both the home and campus location. In particularly, free parking acts as a magnet for students commuting by car, despite the high financial cost of this travel mode. Parking policies are paramount in this respect, and could be one of the most effective mobility management tools for this population. Additionally, the provision of student accommodation in walkable locations might be paramount in contributing to an increase in walking and cycling to the campus, especially if these locations are close (i.e., up to 4 km) to the campus.

Indeed, the observed difference in commuting patterns in relation to commuting distance supports the promotion of mixed-use development in and around campuses. Both the large urban campus and the suburban campus are good examples, in which student accommodation should be provided, as well as other local facilities. Likewise, the multimodal accessibility conditions of the campus, together with the availability of free parking, are also important policy tools. Therefore, we would recommend reducing or eliminating free parking around campuses, as long as these measures are accompanied by an increase in multimodal accessibility conditions and mixed-use development, allowing walking to be an option. In other words, one could see the campus as a special case of a Transit-oriented Development policy, in which, following Bertolini's node-place model (Bertolini, 1996, 1999; Vale, 2015), there is a significant amount of place-index that should properly be accompanied by a node-index.

We acknowledge some limitations of our work. First, due to lack of data, public transport accessibility was only poorly measured, as the distance to a stop is important, but does not fully represent the accessibility of a location. Indeed, with a better evaluation of public transport accessibility, this could eventually be an important explanatory variable. Secondly, parking was only evaluated as a binary variable representing the availability of free parking. Supported also by our own results, we acknowledge that a better evaluation of parking availability, including supply, cost, and number of places offered at the campus and in the vicinity, would provide a better representation of the real parking conditions. Finally, ideally one should measure the individual multimodal accessibility conditions, considering the home and the campus as space-time anchors. Such an evaluation would be extremely useful as an indicator of the real commuting alternatives for each individual, which again is probably an important explanatory variable.

References

Adams, E. J., Bull, F. C., & Foster, C. E. 2016. Are perceptions of the environment in the workplace neighbourhood associated with commuter walking? *Journal of Transport and Health 3*(4), 479–84. doi:10.1016/j.jth.2016.01.001

Akar, G., & Clifton, K. J. 2009. Influence of individual perceptions and bicycle infrastructure on decision to bike. *Transportation Research Record, 2140*, 165–72. doi:10.3141/2140-18

Balsas, C. 2003. Sustainable transportation planning on college campuses. *Transport Policy, 10*(1), 35–49.

Bertolini, L. 1996. Nodes and places: Complexities of railway station redevelopment. *European Planning Studies, 4*(3), 331–45.

Bertolini, L. 1999. Spatial development patterns and public transport: The application of an analytical model in the Netherlands. *Planning Practice and Research, 14*(2), 199–210.

Cervero, R., & Kockelman, K. 1997. Travel demand and the 3Ds: Density, diversity, and design. *Transportation Research Part D: Transport and Environment, 2*(3), 199–219. doi:10.1016/S1361-9209(97)00009-6

Cervero, R., Sarmiento, O. L., Jacoby, E., Gomez, L. F., & Neiman, A. 2009. Influences of built environments on walking and cycling: Lessons from Bogotá. *International Journal of Sustainable Transportation, 3*(4), 203–226. doi:10.1080/15568310802178314

Chatman, D. G. 2003. How density and mixed uses at the workplace affect personal commercial travel and commute mode choice. *Transportation Research Record, 1831*(1), 193–201.

Christiansen, P., Engebretsen, Ø., Fearnley, N., & Hanssen, J. U. 2017. Parking facilities and the built environment: Impacts on travel behavior. *Transportation Research Part A: Policy and Practice, 95*(January), 198–206. doi:10.1016/j.tra.2016.10.025

Delmelle, E. M., & Delmelle, E. C. 2012. Exploring spatio-temporal commuting patterns in a university environment. *Transport Policy, 21*(0), 1–9. doi:http://dx.doi.org/10.1016/j.tranpol.2011.12.007

Dong, H., Ma, L., & Broach, J. 2015. Promoting sustainable travel modes for commute tours: A comparison of the effects of home and work locations and employer-provided incentives. *International Journal of Sustainable Transportation, 10*(6), 150106050204007. doi:10.1080/15568318.2014.1002027

Ewing, R., & Cervero, R. 2010. Travel and the built environment—A meta-analysis. *Journal of the American Planning Association, 76*(3), 265–94.

Field, T., Diego, M., & Sanders, C. E. 2001. Exercise is positively related to adolescents' relationships and academics. *Adolescence, 36*(141), 104–10.

Forsyth, A., Hearst, M., Oakes, J. M., & Schmitz, K. H. 2008. Design and destinations: Factors influencing walking and total physical activity. *Urban Studies, 45,* 1973–96. doi:10.1177/0042098008093386

Frank, L. D., Andresen, M. A., & Schmid, T. L. 2004. Obesity relationships with community design, physical activity, and time spent in cars. *American Journal of Preventive Medicine, 27*(2), 87–96. doi:10.1016/j.amepre.2004.04.011

Frank, L. D, Devlin, A. Johnstone, S., & van Loon, J. 2010. *Neighborhood design, travel, and health in metro Vancouver: Using a walkability index.* Vancouver: University of British Columbia.

Frank, L. D, Sallis, J. F., Conway, T. L., Chapman, J. E., Saelens, B. E., & Bachman, W. 2006. Many pathways from land use to health: Associations between neighborhood walkability and active transportation, body mass index, and air quality. *Journal of the American Planning Association, 72,* 75–87. doi:10.1080/01944360608976725

Frank, L. D., Schmid, T. L., Sallis, J. F., Chapman, J., & Saelens, B. E. 2005. Linking objectively measured physical activity with objectively measured urban form: Findings from SMARTRAQ. *American Journal of Preventive Medicine, 28*(2S2), 117–25. doi:10.1016/j.amepre.2004.11.001

Heinen, E., van Wee, B., & Maat, K. 2010. Commuting by bicycle: An overview of the literature. *Transport Reviews, 30*(1), 59–96. doi:10.1080/01441640903187001

Khattak, A., Wang, X., Son, S, & Agnello, P. 2011. Travel by university students in Virginia. *Transportation Research Record, 2255*(1), 137–45. doi:10.3141/2255-15

Kwan, M.-P. 2012. The uncertain geographic context problem. *Annals of the Association of American Geographers, 102*(5), 958–68. doi:10.1080/00045608.2012.687349

Lavery, T. A., Páez, A., & Kanaroglou, P. S. 2013. Driving out of choices: An investigation of transport modality in a university sample. *Transportation Research Part A: Policy and Practice, 57*, 37–46. doi:10.1016/j.tra.2013.09.010

Limanond, T., Butsingkorn, T., & Chermkhunthod, C. 2011. Travel behavior of university students who live on campus: A case study of a rural university in Asia. *Transport Policy, 18*(1), 163–71. doi:10.1016/j.tranpol.2010.07.006

Manaugh, K., & El-Geneidy, A. 2011. Validating walkability indices: How do different households respond to the walkability of their neighborhood? *Transportation Research Part D: Transport and Environment, 16*(4), 309–15. doi:10.1016/j.trd.2011.01.009

McNeil, N. 2011. Bikeability and the 20-min neighborhood: How infrastructure and destinations influence bicycle accessibility. *Transportation Research Record, 2247,* 53–63. doi:10.3141/2247-07

Miller, H. J. 2007. Place-based versus people-based geographic information science. *Geography Compass, 1*(3), 503–535.

Millward, H., Spinney, J., & Scott, D. 2013. Active-transport walking behavior: Destinations, durations, distances. *Journal of Transport Geography, 28,* 101–10. doi:10.1016/j.jtrangeo.2012.11.012

Miralles-Guasch, C., & Domene, E. 2010. Sustainable transport challenges in a suburban university: The case of the autonomous University of Barcelona. *Transport Policy, 17*(6), 454–463. doi:10.1016/j.tranpol.2010.04.012

Park, Y. M., & Kwan, M. P. 2017. Individual exposure estimates may be erroneous when spatiotemporal variability of air pollution and human mobility are ignored. *Health and Place, 43*(February), 85–94. doi:10.1016/j.healthplace.2016.10.002

Rodríguez, D. A., & Joo, J. 2004. The relationship between non-motorized mode choice and the local physical environment. *Transportation Research Part D: Transport and Environment, 9*(2), 151–73. doi:10.1016/j.trd.2003.11.001

Shannon, T., Giles-Corti, B., Pikora, T., Bulsara, M., Shilton, T., & Bull, F. 2006. Active commuting in a university setting: Assessing commuting habits and potential for modal change. *Transport Policy, 13*(3), 240–253. doi:10.1016/j.tranpol.2005.11.002

Tolley, R. 1996. Green campuses: Cutting the environmental cost of commuting. *Journal of Transport Geography, 4*(3), 213–217. doi:http://dx.doi.org/10.1016/0966-6923(96)00022-1

Vale, D. S. 2015. Transit-oriented development, integration of land use and transport, and pedestrian accessibility: Combining node-place model with pedestrian shed ratio to evaluate and classify station areas in Lisbon. *Journal of Transport Geography, 45*, 70–80. doi:10.1016/j.jtrangeo.2015.04.009

Vale, D. S. 2013. Does commuting time tolerance impede sustainable urban mobility? Analyzing the impacts on commuting behavior as a result of workplace relocation to a mixed-use center in Lisbon. *Journal of Transport Geography, 32*, 38–48. doi:10.1016/j.jtrangeo.2013.08.003

Vale, D. S., & Pereira, M. 2016. Influence on pedestrian commuting behavior of the built environment surrounding destinations: A structural equations modeling approach. *International Journal of Sustainable Transportation, 10*(8), 730–741. doi:10.1080/15568318.2016.1144836

Wang, C.-H., Akar, G., & Guldmann, J.-M. 2015. Do your neighbors affect your bicycling choice? A spatial probit model for bicycling to The Ohio State University. *Journal of Transport Geography, 42,*(January), 122–130. doi:10.1016/j.jtrangeo.2014.12.003

Weber, J., & Kwan, M.-P. 2002. Bringing time back in: A study on the influence of travel time cariations and facility opening hours on individual accessibility. *Professional Geographer, 54*(2), 226–240.

Whalen, K. E., Páez, A., & Carrasco, J. A. 2013. Mode choice of university students commuting to school and the role of active travel. *Journal of Transport Geography, 31*(0), 132–42. doi:http://dx.doi.org/10.1016/j.jtrangeo.2013.06.008

Zhou, J. 2012. Sustainable commute in a car-dominant city: Factors affecting alternative mode choices among university students. *Transportation Research Part A: Policy and Practice, 46*(7), 1013–1029. doi:10.1016/j.tra.2012.04.001

Zhou, J. 2014. From better understandings to proactive actions: Housing location and commuting mode choices among university students. *Transport Policy, 33,* 166–175. doi:10.1016/j.tranpol.2014.03.004

Zhou, J. 2016. Proactive sustainable university transportation? Marginal effects, intrinsic values and university students' mode choice. *International Journal of Sustainable Transportation, 10*(9), 815–824. doi:10.1080/15568318.2016.1159357

Appendix: List of variables used

Dimension | Variable code	Description
Socio-economic	
SE_Gender	Gender (Female = 1)
SE_Age	Age
SE_HouseholdSize	Household size
SE_YoungChildren10_01	Has children younger than 10 years (yes=1)
SE_StudentDe	Student degree (Undergraduate = 1, Master = 2, PhD = 3)
SE_StaffStatus	Staff type (Professor=1, Other=0)
SE_Income	Income
SE_ULyears	Number of years working/studying at University
SE_NumberCars	Number of cars
SE_HasCar	Has car (Yes=1)
SE_DriversLicense	Drivers licence (Yes=1)
SE_MonthlyTicket	Monthly ticket (Yes = 1)
SE_VivaViagem_01	Rechargable PT card (Yes=1)
SE_PasseCost	Cost with monthly ticket
SE_CarCost	Cost with car usage (fuel + parking)
Commuting	
Com_Mode	Commuting mode (Walk, Bicycle, Public Transport (PT), Single occupant vehicle (SOV), car passenger, PT and other)
Com_Dist	Travel distance from home to the university (km)
Tr_Steps	Number of travel steps of the commuting trip
Tr_Time	Commuting time (minutes)

Dimension | Variable code	Description
Built environment	
BE_Walkability	
Density	
N_Resident	Number of residents per area (Ha)
N_Buildings	Number of buildings (Ha)
N_Dwellings	Number of dwellings (Ha)
N_Exc_Res_Buildings	Number of exclusive residential buildings (Ha)
Diversity	
NumPOIS	Number of points of interest (POIs) per area (Ha)
VarietyPOIS	Variety of POIs
Design	
Average_Link_Length	Average link length (m)
Node_Density	Node density (node/ha)
Straightness	Straightness (ratio)
Pedshed	Pedestrian shed ratio (0 to 1)
RouteLengthFCA	Route length (m)
Count_Green*	Number of green spaces
Area_Green*	Area of green spaces (m2)
Length_CycleLanes*	Length of bike paths (m)
BE_Accessibility	
Min_DistanceToStop	Distance to the closest transit stop (m)
DistanceToStop_Type	Type of closest transit stop (BUS, metro, train)
Acc_Metro	Has a metro stop up to 500 metres (Yes=1)
Acc_Train	Has a train stop up to 800 metres (Yes=1)
Acc_Bus	Has a bus stop up to 500 metres (Yes=1)
Count_Stop	Number of transit stops
Count_Stop_Variety	Variety of transit stops (1 to 3)
Parking*	
N_Parking	Number of parking spaces
Paid_Parking	Paid parking spaces (Yes=1)
FreeParking	Free parking spaces (Yes=1)
Topography*	
Mean_slope	Mean streat slope (%)
Max_slope	Maximum street slope (%)
Min_slope	Minimum street slope (%)

* only for campuses