ACE 34

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Cómo citar este artículo: SORIA-LARA, J. A.; MIRALLES-GUASCH, C. & MARQUET, O. *The influence of lifestyle and built environment factors on transport CO_2 emissions: the case study of Autonomous University of Barcelona* [en línea] Fecha de consulta: dd-mm-aa. En: ACE: Architecture, City and Environment = Arquitectura, Ciudad y Entorno, 12 (34): 11-28, 2017. DOI: 10.5821/ace.12.34.4756. ISSN: 1886-4805.

ACE Architecture, City, and Environment Arquitectura, Ciudad y Entorno

Journal of the Centre of Land Policy and Valuations | Polytechnic University of Catalonia and of The Thematic Network Architecture, City and Environment

THE INFLUENCE OF LIFESTYLE AND BUILT ENVIRONMENT FACTORS ON TRANSPORT CO_2 EMISSIONS: THE CASE STUDY OF AUTONOMOUS UNIVERSITY OF BARCELONA

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Remisión inicial: 24-03-2016 **Remisión final:** 14-06-2017

Key words: Survey; greenhouse emissions; sustainability; Climate Change

Structured abstract

Transport is a major user of carbon-based fuels and is seen as crucial intervention sector for meeting CO_2 emission reduction targets. While the academic literature has traditionally focused more on correlating built environment factors (i.e. urban density, trip distance, etc.) and production of CO_2 in the transport sector, only limited attention has been paid to the influence of lifestyle factors. This paper examines the effects of lifestyle and built environments factors on transport CO_2 emissions generated by the daily commutes to and from the Autonomous University of Barcelona (UAB) in Greater Barcelona (Spain). The analysis revealed that lifestyle choices were as relevant as the built environment for understanding the emitting sources and CO_2 volume. Accordingly, the study provides insights how the design of efficient transport policy packages can integrate lifestyle factors as a central focal point.

1. Introduction

Climate change is a very serious and urgent issue. The concentration of atmospheric CO_2 has increased significantly, representing around 78% of total anthropogenic greenhouse gas (GHG) emissions since 2004. Academia and institutions agree that the transport sector is a major source of GHG and has the fastest growth in CO_2 emission of any sector (Berrittella et al., 2008; Dulal et al., 2011). Carbon dioxide is not directly toxic to most plants and animals, but it has other negative impacts on the environment, which ultimately results in global warming. Due to the fact that the most significant GHG are the product of the oxidation of carbon through the combustion of carbon-based fuels, part of the response for achieving low-carbon cities should be based on reducing CO_2 emissions from the transport sector (Aamaas et al., 2013; Abid, 2015; Hickman et al., 2010; 2011; Hysing, 2009).

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A more in-depth understanding about the causes behind transport CO_2 emissions is crucial for designing transport policy packages that further low-carbon cities and regions. While there is growing interest in combining personal behaviour, technology, land use and fuel quality to achieve significant reductions in the CO_2 production from the transport sector (Ahanchian and Biona, 2013; Begg and Gray, 2004; Dulal and Akbar, 2013; Meggers et al., 2012), the literature has paid more attention to exploring the correlation between built environments and transport CO_2 emissions. Only limited attention has been paid to understanding the production of CO_2 in a more comprehensive way, including the impact of individual lifestyle choices and socio-demographic factors (Miralles-Guasch, 2012).

Under the assumption “planning more to travel less” (Banister, 1999; Bertolini et al., 2008), scholars have come to realize that integrated built environment and transport planning at the city level can deliver a significant contribution to meeting sustainable planning goals (Banister, 2008; Silva and Pinho, 2011; Soria-Lara et al., 2015; Switzer et al., 2013). This view is also reflects a long-standing body of theory on the relationship between the built environment and the transport sector (Cervero and Kockelman, 1997; Ewing and Cervero, 2010). Specifically, Banister (2005) identified six groups of key factors that interconnect the built environment and transport: settlement size (Hickman and Banister, 2007; Naess, 2009); urban density (Oakes et al., 2007; Liu et al., 2014; Soria-Lara and Valenzuela-Montes, 2014); land use diversity (Pitombo et al., 2010; Song and Knaap, 2004; Soria-Lara et al., 2014); urban design; local accessibility (Cervero et al., 2009); and finally the provision of parking (Albert and Mahalel, 2006). Supported by the abovementioned issues, there has been a proliferation of studies based on correlating transport CO_2 emissions and built environment factors as an initial step to designing transport policy packages for CO_2 mitigation (Bart, 2010). Despite the strong correlations between the built environment and transport CO_2 emissions (Bart, 2010), it is unclear whether land use planning strategies alone are sufficient for meeting the desired CO_2 reduction targets.

Accordingly, many researchers find that for a better understanding of daily travel behaviour the existing connections between the built environment and transport need to be further explored (Thøgersen, 2006). The academic literature has identified a number of issues that underlie this challenge: Bhat and Guo (2007) discussed the non-existence of a true causality in the connection between built environment and transport; typical demographic variables are significantly affecting to modal transport choice providing decision-makers useful insights for design transport policies (Choo and Mokhtarian, 2004); the distinction between planned, habitual and impulsive travels is crucial in forecasting travel behaviour (Gärling et al., 1998); studying socio-demographic factors of mobile populations is key for understanding the daily use of transport modes (Marquet & Miralles-Guasch, 2014; Miralles-Guasch et al., 2014); the effects of a direct connection between residential neighbourhood on car availability are small compared to the influence of other variables, such as age and travel attitude. Extending the previous argument to transport CO_2 emissions, certain scholars highlight the need to assess the impact of lifestyle and socio-demographic factors (Ma et al., 2014; Nicolas and David, 2009).

This paper aims to contribute to the abovementioned discussion by exploring the following central research question: *How do lifestyle and built environment factors affect transport CO_2 emissions in the case study of Autonomous University of Barcelona?* As previously said, the travel demand created by Autonomous University of Barcelona (UAB) within Greater Barcelona provides the empirical focus. For the year 2020, the government of Catalonia has set a CO_2 reduction target of 20%, based on 1990 emission levels, which is in line with Spanish targets under the European 2020 strategy. We explored the indicated research question using a personal travel demand survey disseminated in 2013 among UAB members (*n=5,814*). First, the transport CO_2 daily emissions were estimated (in kilograms CO_2 passenger^{-1}day^{-1}), followed by a non-parametric Mann–Whitney U test (U-test) to correlate the CO_2 emission estimates with lifestyle and built environment factors. The selected lifestyle factors were (i) car availability; (ii) weekly attendance at the UAB campus; (iii) role at UAB; (iv) daily stay at UAB. The built environment factors included (i) trip distance; (ii) public transport accessibility to UAB; (iii) urban density; (iv) settlement size.

After the review of recent academic insights on transport CO_2 emissions outlined above, Section 2 describes the research method, including an in-depth description of the study case. In Section 3 the main results of our research are presented including a discussion on potential transport policy packages in the case study. The paper closes with several concluding remarks and recommendations for further inquiries.

2. Research design

2.1 The UAB campus in the Greater Barcelona and travel demand database

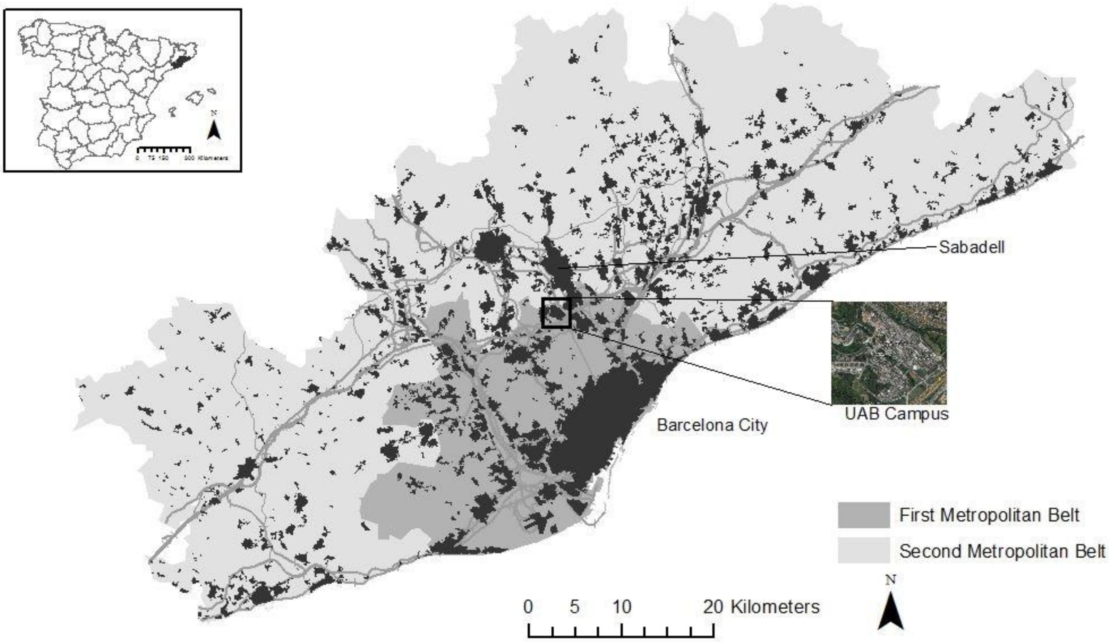
UAB campus provides the empirical focus of our research. It is located in a suburban area within Greater Barcelona, a region that covers an area of 3,242 km^2, including approximately 5 million inhabitants and 164 municipalities. Greater Barcelona is made up of two metropolitan belts that extend from the city outwards. The first belt has both high residential density and high land use diversity. However, the second belt is characterized by low residential density and a poor dotation of public transport systems (Miralles-Guasch and Domene, 2010; Miralles-Guasch et al., 201; Soria-Lara et al., 2017). The UAB campus is located some 15 km from the city centre and shares some of urban characteristics from the second metropolitan belt, like low urban densities and scattered urban developments. It is situated at the intersection between two major motorways, the AP-7 and the C-58 (see Figure 1). Parking at the campus is free for all. Despite its suburban setting, it is worth noting that the UAB campus has high public transport accessibility; three train stations, with direct connections to Barcelona and other surrounding cities, as well as several metropolitan bus stations have been built. The price of a single ticket either by bus or train from Barcelona to the University is 2.15 euros and the expected travel time can range from 25 to 40 minutes.

The UAB community numbers approximately 47,866 (86.2% students, 8.6% teaching/research staff and 5.2% others, including administrative staff). As a consequence of the suburban location of the UAB campus, most of them live in the surrounding municipalities. With a quarter of all residences, Barcelona has the highest concentration (25.7%). The percentages for other major municipalities are as follows: Sabadell (10.5%), Cerdanyola del Vallès (9.3%), Terrassa (6.3%) and Sant Cugat del Vallès (3.8%). It should be noted that there is also some on-campus accommodation for students and visiting lecturers (2.7%).

In 2013 the UAB community was asked to participate in a personal, travel demand survey online. The survey was hosted in the university intranet and was available to be answered online for the whole university community for several weeks. An informative banner was set in the University webpage to encourage participation. In total 5,814 respondents filled out the form, a 12.5% response ratio and a low margin error of ±1.29%. Results were weighted according to its distribution by gender and role at the university, in order to balance the sample to the universe of study. This travel demand survey has been carried out six times since 2001. It provides valuable information, not only because it is a faithful reflection of movement patterns in a unique area such as the UAB campus, but also because it is a longitudinal study over a 13-year period.[4] The survey was structured in four main blocks: (i) general socio-demographic questions, such as age, gender and car availability; (ii) daily mobility habits, such as number of trips or number of hours at the UAB; (iii) usual transport modes and modal choice; and (iv) other questions. For the evaluation of the received enquiries, respondents were required to provide details about their professional activity, such as residential location, role at the university (student, academic staff, administrative staff) etc.

Overall, the suburban location makes it difficult to commute to the campus by no motorized transports (5.8%). The majority of the university community get to the campus either by Public Transport, which represents 59.7% of the travels, or by private modes of transport that represent the remaining 34.5%.

Figure 1. **The UAB campus within the Greater Barcelona, Spain**



Source: Authors.

2.2 Calculation of transport CO2 emissions

[4] More information about the survey in Spanish and Catalan can be found here: http://www.uab.cat/web/la-mobilitat-a-la-uab/enquesta-de-mobilitat-1255501888126.html.

All of the calculations of transport CO_2 emissions were based on regular inventories, made at national and European level, to assess the production of CO_2 and its allocation per specific sector (EU, 2010; Soria-Lara and Valenzuela-Montes, 2014). Carbon dioxide emission coefficients for each transport mode can be consulted in table 1. Given that respondents indicated the transport modes used to travel to the UAB Campus as well as the amount of kilometres covered, the calculations of transport emissions in kg CO_2 passenger^{-1}day^{-1} were directly obtained according to next equation, Estimate of transport CO2 emissions.

$$Transport\ CO_2 Emissions = Distance * CO_2 Coef_j$$

Where distance is the total of kilometres daily covered by UAB members and $CO_2 Coef_j$ is the CO_2 emission coefficient per each transport mode j (table 1). The case of car emissions coefficient was corrected taken into consideration that the 43% of car in the region used diesel fuel according to regional statistics in 2013.

Table 1. **Carbon dioxide emissions coefficient according to transport mode**

Transport modes	kg CO_2*Km^{-1}*passenger^{-1}
Bus	0.052
Car	0.132
Metro	0.019
Motorcycle	0.130
Train	0.030

Source: European Commission, 2010.

2.3 Statistical analysis and selection of lifestyle and built environment factors

The second part analysed how lifestyle and built environment factors affect the production of CO_2 from the transport sector. Each lifestyle and built environment factor was divided in subgroups of discrete variables (see table 2). The Mann–Whitney U test (U-test) was conducted to analyse statistically significant differences at p-level 0.05. It is a non-parametric test of the null hypothesis that two populations (in our case factors of lifestyle and built environment) are the same against an alternative hypothesis especially that a particular population tends to have larger values than the other. The test involves the calculation of a statistic, usually called *U*, whose distribution under the null hypothesis is known. Significant differences at p-level 0.05 for each subgroup of analysed variables would indicate stronger influence on transport CO_2 emissions and vice versa.

As previously indicated, The U-test was used because of the sample's non-parametric characteristics. The production of CO_2 will be presented in Section 3 as the interval of emissions formed by 25th percentile and 75th percentile (50% of representative CO_2 emissions).

Table 2. **Lifestyle and built environment factors**

LIFESTYLE		BUILT ENVIRONMENT	
Factors	**Subgroup of variables**	**Factors**	**Subgroup of variables**
Car availability	1) Yes 2) Not	**Trip distance**	1) <7.5 km 2) Between 7.5 – 15 km 3) Between 15 – 30 km 4) >30 km
Attendance at UAB	1) 1 day 2) 2 days 3) 3 days 4) 4 days 5) 5 days 6) 6 days 7) 7 days	**Public transport accessibility**	1) Direct 2) 1 transfer 3) 2 transfers 4) >2 transfers
Role at UAB	1) Student (<2 years) 2) Student (>2 years) 3) PhD students 4) Research staff 5) Teaching staff 6) Others	**Urban density**	1) <5,000 pop/km^2 2) 5,000 – 10,000 pop/km^2 3) 10,000 – 15,000 pop/km^2 4) 15,000 – 20,000 pop/km^2 5) >20,000 pop/km^2
Daily stay at UAB	1) <4 h 2) Between 4h – 8h 3) >8h	**Settlement size**	1) <1,000 pop 2) 1,000 – 5,000 pop 3) 5,000 – 1,0000 pop 4) 10,000 – 50,000 pop 5) 50,000 – 100,000 pop 6) 100,000 – 200,000 pop 7) > 200,000 pop

Source: Autonomous University of Barcelona.

In the selection of lifestyle and built environment factors two relevant issues were considered. First, lessons from the academic literature about the connection travel demand-lifestyle-built environment. Second, the availability of information from travel demand survey (see Section 2.1). It is worth to emphasize that the travel demand survey used during the research was not specifically designed for the study; its scope was wider and orientated towards the management of daily mobility created by the UAB campus in the Greater Barcelona.

The studied lifestyle factors included (i) car availability; (ii) weekly attendance of the UAB; (iii) role at UAB; and (iv) daily stay at UAB. The source of data was the travel demand survey discussed in Section 2.1. First, “car availability” permits the examination of how CO2 emissions were affected when UAB members could travel daily to and from the UAB campus by car. Almost half (47%) of the respondents had access to a car (figure 2). Second, “weekly attendance of the UAB” shows whether more/less frequent attendance at the UAB campus affects the choice of transport mode, and in turn CO2 emissions. Most of respondents came to the UAB campus 5 days a week (65%) (Figure 2). The third factor was the “personal role at UAB”, which was directly associated with income levels. As can be seen in figure 2, most of respondents were students (61%).

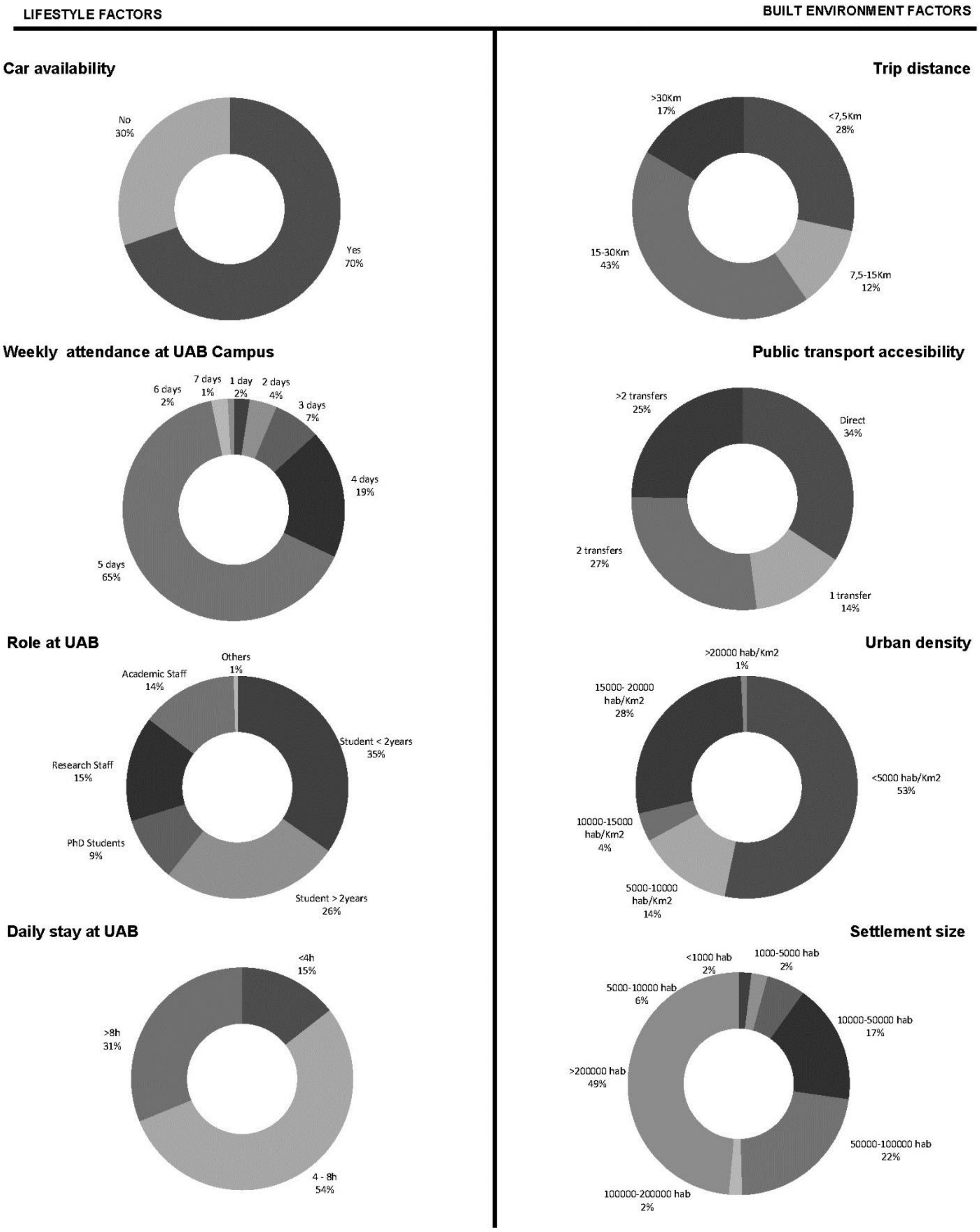
Finally, the consideration of hours spent per visit (“daily stay at UAB”) would indicate how CO2 emissions were affected by the fact that UAB members daily stayed at the UAB campus longer or shorter period of daily time. Specifically, 15% of participants spent 4h per day (15%), 54% indicated 4–8h per day and 31% indicated more than 8h per day (figure 2).

Regarding the built environment, four factors were explored: (i) trip distance; (ii) public transport accessibility; (iii) urban density; and (iv) settlement size. The source of these data was both the travel demand survey described in Section 1 and the statistics office from government of Catalonia.[5] The first factor to be studied was “trip distance”, considered in the academic literature as one of the most important factors for understanding the relationship between mobility and urban form. The largest segment of respondents lived between 15 and 30 km (43%) away from the campus (also coinciding to the distance of the city of Barcelona), while the smallest portion (12%) lived between 7.5 and 12 km (figure 2). Second, “public transport accessibility” to the UAB campus was another important factor (as indicated in other studies, see Cervero et al. (2009) for Bogotá, Colombia). In our study, 34% had a direct public transport connection with the UAB campus; 14% had 1 transfer, 27% had 2 transfers and a total of 24% respondents had more than 2 transfers (figure 2). The last two selected factors were “urban density” and “settlement size”. Both factors are considered crucial for understanding the link between the built environment and transport (Oakes et al., 2007).

Regarding “settlement size”, most of respondents lived in municipalities with more than 200,000 inhabitants, including the city of Barcelona (48%), while “urban density” was more compact as most respondents lived in communities with population densities between 15,000 and 20,000 pop/km2.

[5] Insitut d’Estadística de Catalunya (www.idescat.cat) and Diputació de Barcelona (http://www.diba.cat/hg2/menu.asp?mnid=4).

Figure 2. **Distribution of respondents according to lifestyle and built environment factors**



Source: Autonomous University of Barcelona.

3. Results

3.1 Lifestyle factors and transport CO_2 emissions

Car availability was the first factor to be studied. UAB members with car access had clearly higher CO_2 emissions (see figure 3). Specifically, 50% of the transport CO_2 emissions from the population with car access were estimated between 0.79 and 7.16 kg CO_2 passenger^{-1}day^{-1}. On the other hand, 50% of transport CO_2 emissions from persons without car access were estimated between 0.24 and 0.79 kg CO_2 passenger^{-1}day^{-1}. U-test showed major significant differences at p-level 0.05 between the two groups (table 3). It is worth highlighting that the survey indicated higher car ownership rates (0.69 vehicles UAB member^{-1}) compared to the other Spanish regions (0.41 vehicles habitant^{-1}).

The location of the UAB campus could be responsible for this situation. Despite the fact that the UAB campus is apparently well-connected by public transport, its location at the heart of Greater Barcelona seem subjectively to instigate an increase in car availability for persons who work or study at UAB. Accordingly, car availability should play a crucial role in designing transport policy packages that help mitigate the production of carbon dioxide. In this sense, the promotion of a car-free UAB campus could be fostered through regulatory policies (e.g. limiting car access to the UAB campus for several days a week), economic policies (e.g. implementing parking taxes at the UAB campus) or positive discrimination measures (i.e. prioritizing parking facilities for electric cars or free parking for carpooling).

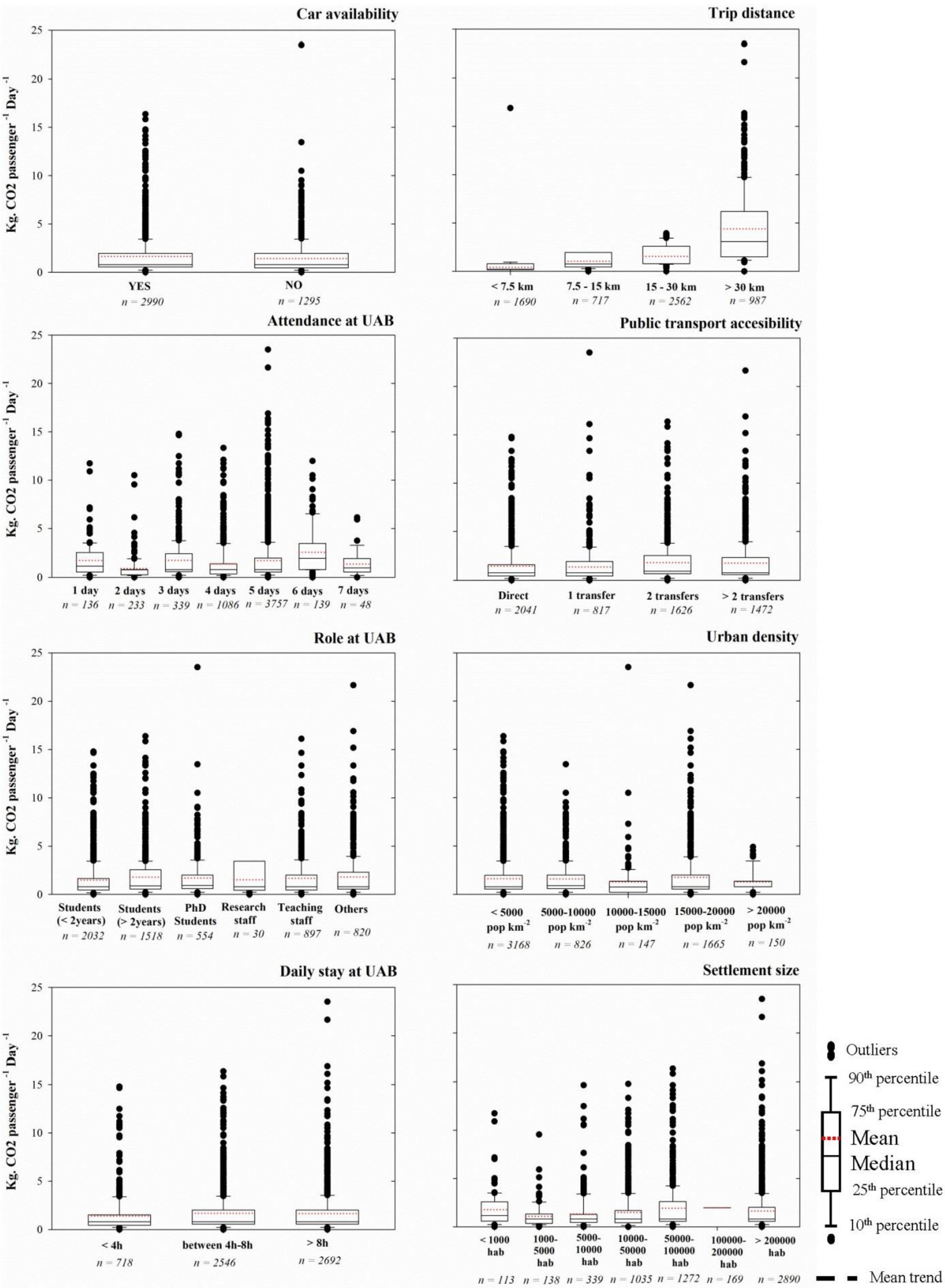
The second lifestyle factor to be studied was *weekly attendance at the UAB campus*. With the exception of UAB members who attended 7 days per week (a limited group of people associated with security staff and a few researchers), the results showed that UAB members with attendance levels of 3 days or less emitted higher kg CO_2 passenger^{-1}day^{-1}values than UAB members who came 4, 5 and 6 days per week (figure 3). Actually, the U-test showed major significant differences at p-level 0.05 between these two weekly attendance patterns (table 3). For attendance levels of 3 days or less, 50% of emissions were between 0.793 and 2.61 kg CO_2 passenger^{-1}day^{-1} (1 day), 3.44 kg CO_2 passenger^{-1}day^{-1} (2 days) and 3.07 kg CO_2 passenger^{-1}day^{-1} (3 days). For the group that attended 4 days or more, CO_2 production ranged from 0.46 (4 days), 0.54 (5 days) and 0.29 (6 days) to maximum of 1.96 kg CO_2 passenger^{-1}day^{-1}. It was highlighted that UAB members with attendance levels of 3 days or less had higher car ownership rates than their colleagues who visited the campus 4 days or more. The conclusion is that those members with occasional trips to UAB were less worried about car use costs and other associated negative externalities.

However, with more frequent attendance, UAB members took car costs more into consideration and opted for public transport. Similar to car availability, frequency of attendance at the UAB campus is also a relevant factor for reducing transport CO_2 emissions. Transport policy packages should carefully consider attendance patterns, especially of less frequent travellers. Public transport bonuses or/and limitation of parking facilities for those who visit the campus up to 3 days a week could be part of zero emission strategies.

Income levels were represented in the survey through *role at UAB* variable. This was the third factor to be analysed. Research staff had the highest levels; 50% of their transport CO_2 emissions ranged from 0.79 to 3.39 kg CO_2 passenger^{-1}day^{-1}. The second group was teaching staff; 50% of their CO_2 emissions were between 0.55 and 2.57 kg CO_2 passenger^{-1}day^{-1} (figure 3). On the other hand, the group of UAB members with the lowest CO_2 production was students with less than 2 years of experience; 50% of their emissions ranged from 0.45 to 1.50 kg CO_2 passenger^{-1}day^{-1}. These results seem to follow a logical sequence in the Spanish context, with the highest income levels (research and teaching staff) using mainly private transport modes and correspondingly higher CO_2 emissions. The U-test verified a significant difference at p-level 0.05 between students with less than 2 years of experience and the other groups (table 3). Two relevant factors could explain these findings. First, students with less than 2 years of experience lived in municipalities closer to the UAB campus, thus leading to shorter trip distance and consequently lower production of carbon dioxide. Second, car availability rates of research and teaching staff were the lowest among the rest of UAB members. Statistically significant differences were also noted between the production of CO_2 from teaching/research staff and students with more than 2 years of experience (including PhD students) (table 3). The location of the homes of teaching and research staff seemed to be crucial in understanding their higher CO_2 emissions rates compared to the other groups. An optimization of the public transport network and promotion of electric transport modes could contribute to reduce transport emissions due to role differences at UAB.

Finally, *daily stay at UAB* was the fourth and last lifestyle factor to be studied. The group of UAB members that stayed at the UAB campus 4-8h per day had the highest transport CO_2 emissions; 50% of their emissions ranged from 0.55 to 23.51 kg CO_2 passenger^{-1}day^{-1}. Respondents who stayed at UAB less than 4h showed the lowest CO_2 production; 50% of such emissions were between 0.45 and 14.78 kg CO_2 passenger^{-1}day^{-1} (figure 3). Several reasons could explain this particular finding. First, respondents in the less than 4h per day group had lower car ownership rates than respondents in the 4h–8h per day group. Second, those who stayed less than 4h also had generally better public transport access to the UAB campus than the other UAB members. Third, they also frequently lived closer to the UAB campus than the other respondents. Accordingly, the U-test results demonstrated significant differences at p-level 0.05 between respondents who stayed at UAB less than 4h per day and the rest (table 3). As can be seen from the obtained results, transport policy packages focused on reducing the production of carbon dioxide should take into account daily stay patterns.

Figure 3. **Emission of Kilograms CO2 passenger-1day-1**



Source: Autonomous University of Barcelona

3.2 Built environment factors and transport CO_2 emissions

The second group of factors regarding transport CO_2 emissions is related to the built environment in Greater Barcelona. *Trip distance* was the first factor to be studied. Results showed that higher trip distances to the UAB campus meant higher CO_2 values. As can be seen in figure 3, 50% of CO_2 emissions in cases of trip distances >30 km were from 1.5 to 3.2 kg CO_2 passenger^{-1}day^{-1}, followed by 15–30 km, which were between 0.79 and 2.6 kg CO_2 passenger^{-1}day^{-1}. The lowest CO_2 production was found in trip distances <7.5 km, between 0.45 and 0.72 kg CO_2 passenger^{-1}day^{-1}. The U-test showed statistically significant differences at 0.05 p-level between the four subgroups (table 3). Research and teaching staff had higher trip distance than other UAB members. Taking into consideration that transport emissions from research and teaching staff were also higher than other UAB members, this could be one of the key reasons behind the higher emissions. Therefore, we propose similar measures for designing transport policy packages: the optimization of the public transport network as well as the promotion of electric transport modes among members of this group.

The second factor was *public transport accessibility to UAB*. The results indicate that UAB members who enjoyed direct connections to the UAB campus by public transport showed lowest CO_2 values. Specifically, 50% of CO_2 emissions from persons who lived in municipalities with direct public transport connection to the UAB campus ranged from 0.79 to 0.84 kg CO_2 passenger^{-1}day^{-1}, while 50% of CO_2 emissions from those with at least 2 public transport transfers were between 0.88 and 3.57 kg CO_2 passenger^{-1}day^{-1} (figure 3). The U-test showed strong correlations, showing statistically significant differences between the four subgroups of variables: direct connection, 1 transfer, 2 transfers, >2 transfers. Similar to the trip distance factor, public transport accessibility seemed to be very relevant for transport CO_2 (table 3). Transport policy packages should focus on optimizing the public transport network, especially in those municipalities where most UAB members currently reside.

The third factor to be studied was *urban density* (pop/km^2). The analysis showed that municipalities with lower urban densities had a higher production of CO_2 (see figure 3); 50% CO_2 transport emissions of municipalities with urban densities lower than 15,000 pop/km^2 were from 0.69 to 2.51 kg CO_2 passenger^{-1}day^{-1}, meanwhile 50% CO_2 transport emissions from municipalities with urban densities higher than 15,000 pop/km^2 were from 0.79 to 1.35 kg CO_2 passenger^{-1}day^{-1}. Differences in transport CO_2 emissions were significant at p-level 0.05 according to the U-test in most urban density subgroups (Table 2). The main explanation behind the difference seems to follow the problem with weaker public transport services in municipalities with lower urban densities.

Settlement size within the Greater Barcelona was the fourth and last built environment factor analysed. In general, the obtained pattern indicated that smaller municipalities produced higher kg CO_2 passenger^{-1}day^{-1} than bigger municipalities, with the exception of municipalities between 100,000 and 200,000 inhabitants. As can be seen in figure 3, 50% of CO_2 emissions from people who lived in municipalities with less than 50,000 inhabitants were between 2.4 and 10.5 kg CO_2 passenger^{-1}day^{-1}, while UAB members living in municipalities with more than 50,000 inhabitants had 0.18 to 8.8 kg CO_2 passenger^{-1}day^{-1}. The U-test also showed statistically significant differences at p-level 0.05 between most subgroups (see Table 3). The main reason seems to be related to better public transport services in bigger municipalities. The recommendations for decision-makers follow the argumentation that reinforcing public transport connections between the UAB campus and smaller municipalities with many UAB residents would sink CO_2 emissions.

Table 3. **Statistical analysis (Mann-Whitney U-test)**

LIFESTYLE FACTORS

Car availability

	Yes	Not
Yes		
Not	2.22E-221*	

Attendance at UAB

	1 day	2 days	3 days	4 days	5 days	6 days	7 days
1 day							
2 days	0.1691						
3 days	0.69	0.2202					
4 days	0.008391*	8.95E-08*	1.29E-06*				
5 days	0.01333*	7.06E-08*	7.53E-07*	0.4603			
6 days	0.005296*	3.40E-06*	7.46E-05*	0.2479	0.1259		
7 days	0.1357	0.00106	0.01088	0.5588	0.7807	0.164	

Role at UAB

	Student <2 years	Student <2 years	Student <2 years	Student <2 years	Student <2 years	Others
Student <2 years						
Student <2 years	0.0003475*					
Student <2 years	0.01668*	0.9038				
Student <2 years	3.76E-19*	4.57E-08*	1.61E-05*			
Student <2 years	1.95E-16*	1.06E-06*	2.30E-05*	0.6146		
Others	0.02881*	0.1639	0.167	0.9223	0.8538	

Daily stay at UAB

	<4h	4h – 8h	>8h
<4h			
4h – 8h	0.0006494*		
>8h	0.005106*	0.451	

BUILT ENVIRONMENT FACTORS

Trip distance

	<7.5 km	7.5 – 15 km	15 – 30 km	>30 km
<7.5 km				
7.5 – 15 km	1.48E-116*			
15 – 30 km	0*	1.31E-146*		
>30 km	0*	3.28E-151*	4.24E-217*	

Public transport accessibility

	Direct	1 transfer	2 transfers	>2 transfers
Direct				
1 transfer	2.33E-11*			
2 transfers	1.20E-18*	8.18E-15*		
>2 transfers	2.81E-98*	7.37E-178*	6.54E-99*	

Settlement size

	<1000	1000-5000	5000-10000	10000-50000	50000-100000	100000-200000	>200000
<1000 pop							
1000-5000 pop	6.74E-10*						
5000-10000 pop	1.22E-14*	0.2429					
10000-50000 pop	5.22E-31*	6.70E-16*	1.89E-18*				
50000-100000 pop	4.98E-54*	4.36E-52*	4.69E-100*	1.20E-112*			
100000-200000 pop	1.40E-15*	0.6581	1	2.78E-06*	3.99E-46*		
>200000 pop	1.59E-53*	5.65E-49*	3.31E-79*	8.79E-43*	6.32E-130*	3.92E-34*	

Urban density

	<5000	5000-10000	10000-15000	15000-20000	>20,000
<5,000 pop/km^2					
5000-10000 pop/km^2	1.48E-21*				
10000-15000pop/km^2	1.00E+00	1.04E-05*			
15000-20000pop/km^2	2.92E-04*	6.94E-13*	8.94E-15*		
>20,000 pop/km^2	1.00E+00	0.5349	1.55E-15*	2.71E-318	

** Statistically significant correlations at p-level 0.05*

Source: Autonomous University of Barcelona

4. Conclusions and discussion

We can now answer the question at the beginning of this paper: *How do lifestyle and built environment factors affect transport CO_2 emissions in the case study of Autonomous University of Barcelona?* The question will be answered in the context of daily commutes to and from the UAB campus in Greater Barcelona (Spain). The obtained results demonstrate two interesting tiers of findings. First, lifestyle factors are as relevant as built environment factors in understanding transport CO_2 emissions. Second, a combined analysis of lifestyle and built environment factors can provide decision-makers with the required knowledge for integrated transport policy planning for CO_2 mitigation.

A shift in how transport CO_2 emissions are traditionally studied seems to be needed. Several authors – for example Ma et al. (2014) and Nicolas and David (2009) – have already indicated that socio-demographic and lifestyle issues are crucial for understanding the patterns of CO_2 transport emissions. Our findings confirm this assertion for the lifestyle factors car availability, weekly attendance at UAB, role at UAB and daily stay at UAB. The U-test revealed the existence of statistically significant differences in CO_2 emissions at p-level 0.05 between the variables car access and no car access as well as between attending UAB 3 days a week or less and attending 4 days or more: they strongly affected the choice of transport mode and consequently the production of CO_2. Higher income levels were correlated to higher CO_2 transport emissions, specifically distinguishing between students and UAB permanent staff. Although strong correlations were also found between built environment factors (trip distance, public transport dotation, settlement size and urban density) and transport CO_2 emissions, as also indicated by previous research, such correlations should be only contemplated as one part in understanding the production of CO_2 from the transport sector.

The second tier of findings was based on the possibilities to design integrated transport policy packages for CO_2 mitigation. As can be seen in this research, studying simultaneously the influence of lifestyle choices and the built environment on CO_2 production provide decision-makers with a more comprehensive view on the driving forces behind motorized personal transport. The results show that UAB members with higher income levels (permanent staff) covered longer trip distances than those with lower income levels (mostly students), who also lived closer to the UAB campus. Therefore, combined policy packages linking income levels and trip distance would be more effective than other types of partial packages. Another relevant finding was the connection between settlement size and car availability. UAB members who lived in smaller settlement had higher car availability and vice versa. In conclusion, the effectiveness of CO_2 mitigation policies should be based on integrated and combined strategies based on the connection between lifestyle and built environment factors.

It is worth to note that both the methodological design of the paper and the identification of transport CO_2 emissions patterns in the specific context of the UAB campus within Greater Barcelona is an initial step in this research field. Main limitations in this research are associated to the use of CO_2 emissions coefficients, which are highly related to trip distance. The use of other indicators such as carbon footprint can help to overcome these limitations in further research. Moreover, qualitative researches based on how university community perceive the modal choice can also help to gain more insights into the problem of carbon emissions. In this respect, future efforts could focus on the use of multivariate statistics to gain more insight into the existing correlations between lifestyle and built environment as well as on the design of backcasting scenarios on CO_2 mitigation for application in Greater Barcelona.

Acknowledgements

This research was carried out whithin the framework of the research project *Movilidad cotidiana activa y saludable en entornos urbanos de proximidad. enfoques multimetodológicos: tracking living labs, encuestas de movilidad y estudios cualitativos*, funded by Ministerio de Economía y Competitividad, Subdirección General de Proyectos de Investigación. Ref: CSO2016-74904-R.

References

AAMAAS, B.; BORKEN-KLEEFELD, J. & PETERS, G. P. *The climate impact of travel behavior: A German case study with illustrative mitigation options*. In: Environmental Science & Policy, 33: 273-282. November 2013. DOI: https://doi.org/10.1016/j.envsci.2013.06.009

ABID, M. *The close relationship between informal economic growth and carbon emissions in Tunisia since 1980: The (ir) relevance of structural breaks*. In: Sustainable Cities and Society, 15: 11-21. July 2015. DOI: https://doi.org/10.1016/j.scs.2014.11.001

AHANCHIAN, M, & MANUEL BIONA, J. B. *Energy demand, emissions forecasts and mitigation strategies modeled over a medium-range horizon: The case of the land transportation sector in Metro Manila*. In: Energy Policy 66: 615-629. 2014

ALBERT, G. & D. MAHALEL. *Congestion tolls and parking fees: A comparison of the potential effect on travel behaviour*. In: Transport Policy, 13 (6): 496-502. November 2006. DOI: https://doi.org/10.1016/j.tranpol.2006.05.007

BANISTER, D. *Planning more to travel less: Land use and transport*. In: Town Planning Review, *70* (3), 313-319. 1999. DOI: http://dx.doi.org/10.3828/tpr.70.3.e7p3837505516833

BANISTER, D. *Unsustainable transport: City transport in the new century*. London, Routledge. 2005. 304 p.

BANISTER, D. *The sustainable mobility paradigm*. In: Transport policy, 15 (2): 73-80. March 2008. DOI: https://doi.org/10.1016/j.tranpol.2007.10.005

BART, IE. *Urban sprawl and climate change: A statistical exploration of cause and effect, with policy options for the EU.* In: Land Use Policy 27 (2): 283-292. April 2010. DOI: https://doi.org/10.1016/j.landusepol.2009.03.003

BEGG, D. & GRAY, D. *Transport policy and vehicle emission objectives in the UK: is the marriage between transport and environment policy over?* In: Environmental Science & Policy, *7* (3): 155-163. June 2004. DOI: https://doi.org/10.1016/j.envsci.2004.02.001

BERRITTELLA, M.; CERTA, A.; ENEA, M. & ZITO, P. *Transport policy and climate change: How to decide when experts disagree*. In: Environmental science & policy, 11 (4): 307-314. June 2008. DOI: https://doi.org/10.1016/j.envsci.2008.01.008

BERTOLINI, L.; CLERCQ, F. L. & STRAATEMEIER, T. *Urban transportation planning in transition*. In: Transport Policy, 15 (2): 69-72. March 2008. DOI: https://doi.org/10.1016/j.tranpol.2007.11.002

BHAT, C. R., & GUO, J. Y. *A comprehensive analysis of built environment characteristics on household residential choice and auto ownership levels*. In: Transportation Research Part B: Methodological, 41 (5): 506-526. June 2007. DOI: https://doi.org/10.1016/j.trb.2005.12.005

CERVERO, R. & KOCKELMAN, K. *Travel demand and the 3Ds: Density, diversity and design*. In: Transportation Research, 2 (3): 199-219. September 1997. DOI: https://doi.org/10.1016/S1361-9209(97)00009-6

CERVERO, R.; SARMIENTO, O. L.; JACOBY, E.; GOMEZ, L. F. & NEIMAN, A. *Influences of built environments on walking and cycling: lessons from Bogotá*. In: International Journal of Sustainable Transportation, 3 (4): 203-226. June 2009. DOI: http://dx.doi.org/10.1080/15568310802178314

CHOO, S. & MOKHTARIAN, P. L. *What type of vehicle do people drive? The role of attitude and lifestyle in influencing vehicle type choice*. In: Transportation Research Part A: Policy and Practice, 38 (3): 201-222. March 2004. DOI: https://doi.org/10.1016/j.tra.2003.10.005

DULAL, H.B.; BRODNIG, G. & ONORIOSE, C.G. *Climate change mitigation in the transport sector through urban planning: A review.* In: Habitat International, 35 (3): 494-500. July 2011. DOI: https://doi.org/10.1016/j.habitatint.2011.02.001

DULAL, H.B. & AKBAR, S. *Greenhouse gas emission reduction options for cities: Finding the "Coincidence of Agendas" between local priorities and climate change mitigation objectives*. In: Habitat International, 38: 100-105. April 2013. DOI: https://doi.org/10.1016/j.habitatint.2012.05.001

EWING, R. & CERVERO, R. *Travel and built environment*. In: Journal of the American Planning Association, 76: 265-294. May 2010. DOI: http://dx.doi.org/10.1080/01944361003766766

GÄRLING, T.; GILLHOLM, R. & GÄRLING, A. *Reintroducing attitude theory in travel behavior research: The validity of an interactive interview procedure to predict car use*. In: Transportation, 25 (2): 129-146. May 1998.

HICKMAN, R. & BANISTER, D. *Looking over the horizon: Transport and reduced CO2 emissions in the UK by 2030*. In: Transport Policy, 14 (5): 377-387. September 2007. DOI: https://doi.org/10.1016/j.tranpol.2007.04.005

HICKMAN, R.; ASHIRU, O. & BANISTER, D., *Transport and climate change: Simulating the options for carbon reduction in London*. In: Transport Policy 17 (2): 110-125. March 2010. DOI: https://doi.org/10.1016/j.tranpol.2009.12.002

HICKMAN, R.; ASHIRU, O. & BANISTER, D. *Transitions to low carbon transport futures: strategic conversations from London and Delhi*. In: Journal of Transport Geography, 19 (6): 1553-1562. November 2011. DOI: https://doi.org/10.1016/j.jtrangeo.2011.03.013

HYSING, E. *Greening transport-explaining urban transport policy change*. In: Journal of Environmental Policy & Planning, 11 (3): 243-261. August 2009. DOI: http://dx.doi.org/10.1080/15239080903056417

LIU, Y.; SONG, Y. & SONG, X., *An empirical study on the relationship between urban compactness and CO2 efficiency in China*. In: Habitat International, 41: 92-98. January 2014. DOI: https://doi.org/10.1016/j.habitatint.2013.07.005

MA, J.; HEPPENSTALL, A.; HARLAND, K. & MITCHELL, G. *Synthesising carbon emission for mega-cities: A static spatial microsimulation of transport CO2 from urban travel in Beijing*. In: Computers, Environment and Urban Systems, 45: 78-88. May 2014. DOI: https://doi.org/10.1016/j.compenvurbsys.2014.02.006

MEGGERS, F.; LEIBUNDGUT, H.; KENNEDY, S.; QIN, M.; SCHLAICH, M.; SOBEK, W. & SHUKUYA, M. *Reduce CO_2 from buildings with technology to zero emissions*. In: Sustainable Cities and Society, 2 (1): 29-36. February 2012. DOI: https://doi.org/10.1016/j.scs.2011.10.001

MARQUET, O. & MIRALLES-GUASCH, C. *Walking short distances. The socioeconomic drivers for the use of proximity in everyday mobility in Barcelona*. In: Transportation Research Part A: Policy and Practice, 70: 210-222. December 2014. DOI: https://doi.org/10.1016/j.tra.2014.10.007

MIRALLES-GUASCH, C. *Las encuestas de movilidad y los referentes ambientales de los transportes*. In: EURE. Revista Latinoamericana de Estudios Urbano Regionales, 38 (115), 33-45. September 2012.

MIRALLES-GUASCH, C., & DOMENE, E. Sustainable transport challenges in a suburban university: The case of the Autonomous University of Barcelona. *Transport policy*, *17*(6), 454-463. 2010

MIRALLES-GUASCH, C.; MARTINEZ MELO, M. & MARQUET SARDA, O. *On user perception of private transport in Barcelona Metropolitan area: an experience in an academic suburban space*. In: Journal of Transport Geography, 36: 24-31. April 2014. DOI: https://doi.org/10.1016/j.jtrangeo.2014.02.009. 2014

NAESS, P. *Residential self selection and appropriate control variables in land use: travel studies*. *Transport Reviews*, 29 (3): 293-324. 2009

NICOLAS, J. P. & DAVID, D. *Passenger transport and CO2 emissions: What does the French transport survey tell us?*. In: Atmospheric Environment, 43 (5): 1015-1020. February 2009. DOI: https://doi.org/10.1016/j.atmosenv.2008.10.030

OAKES, J. M.; FORSYTH, A. & SCHMITZ, K.A. *The effects of neighborhood density and street connectivity on walking behavior: The Twin Cities walking study*. In: Epidemiologic Perspectives & Innovations, 4 (16): 113-224. 2007.

PITOMBO, C.S.; KAWAMOTO, E. & SOUSA. A.J. *An exploration analysis of relationships between socioeconomic, land use, activity participation variables and travel patterns*. Transport Policy, 18 (2): 347-357. 2010.

SILVA, C. & PINHO, P. *The Structural Accessibility Layer (SAL): Revealing how urban structures constrains travel choice*. In: Environment and Planning A, 42 (11): 2735-2752. November 2010.

SONG, Y. & KNAAP, G. *Measuring urban form*. In: Journal of American Planning Association, 70 (2): 2220-2225. 2004.

SORIA-LARA J.A. & VALENZUELA-MONTES L.M. *Diseño de un sistema de evaluación del rendimiento ambiental en corredores de movilidad urbana*. In: ACE, Architecture, City and Environment, 9 (25): June 2014. DOI: http://dx.doi.org/10.5821/ace.9.25.3621

SORIA-LARA, J. A., MARQUET, O., & MIRALLES-GUASCH, C. The influence of location, socioeconomics, and behaviour on travel-demand by car in metropolitan university campuses. *Transportation Research Part D: Transport and Environment*, *53*, 149-160. 2017

SORIA-LARA, J.A.; LÓPEZ, A. A. & BENAVENTE, F. A. *Explorando el uso de métricas espaciales para identificar "entornos de movilidad" urbanos*. Anales de Geografía de la Universidad Complutense, 34 (2): 185-208. 2014

SORIA-LARA, J.A.; VALENZUELA-MONTES, L.M. & PINHO, P. *Using 'Mobility Environments' in Practice: Lessons from a Metropolitan Transit Corridor in Spain*. In: Journal of Environmental Policy & Planning, 17 (5): 553-572. December 2015. DOI: http://dx.doi.org/10.1080/1523908X.2014.991779

SWITZER, A.; BERTOLINI, L. & GRIN, J. *Transitions of mobility systems in urban regions: A heuristic framework*. In: Journal of Environmental Policy & Planning, 15 (2): 141-160. January 2013. DOI: http://dx.doi.org/10.1080/1523908X.2012.746182

THØGERSEN, J. *Understanding repetitive travel mode choices in a stable context: A panel study approach*. In: Transportation Research Part A: Policy and Practice, 40 (8): 621-638. October 2006. DOI: https://doi.org/10.1016/j.tra.2005.11.004