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Energy consumption in university commuting: Barriers, policies and reduction scenarios in León (Spain)

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ABSTRACT

There is a growing interest in university commuting that aims at identifying patterns of behavior, as well as the main barriers limiting the advances in sustainable mobility on campus. This work analyzes, on the basis of an online survey conducted at the University of Leon (ULE), the following issues: a) the behavior of ULE users in their weekly commuting; b) the environmental implications of such behavior in terms of non-renewable cumulative energy demand (NR CED), and c) the main barriers/disincentives to implementing a modal shift as declared by the respondents, according to their work status (students or workers) and gender. The data reveal differences in habits, especially in relation to the users' work status, while differences by gender are not so significant. Still, this case study shows how men students use bicycles and motorcycles slightly more often than women, while the car is the main transportation mode for women workers. Car use is in fact the main hotspot of university commuting to the ULE (approximately 95% of the NR CED). Unsafe cycle paths, thefts at university, bus fares and frequency of service were the main barriers to a greater use of bicycle and bus identified by the survey respondents, with some differences by gender and work status. Measures aimed at minimizing these barriers could achieve maximum reductions of the NR CED ranging between 18.1% and 35.0%. This article discusses measures and policies that could be implemented to improve sustainable mobility at university.

1. Introduction

High education institutions are starting to redirect their education, research and community dissemination activities towards sustainability (Wals 2014). Thus, university students may be taken as a reference group for future leadership in relation to this issue (Lozano et al., 2013; Zilahy and Huisingh 2009). They are one of the main population groups capable of acquiring the technical and specialized knowledge required to implement sustainability and sustainable mobility promotion policies (Leon et al., 2018; Coutts et al., 2018). Previous research works have observed how students and also university staff are more prone to using active and healthier transportation modes, such as walking or cycling, than other population groups (Whalen et al., 2013). Some authors suggest that the consolidation of this mobility model among students could have a repercussion and continuity in their adult life (Shannon et al., 2006). In this sense, university campuses are privileged spaces to explore and promote measures that reinforce sustainable mobility (Balsas 2003; Llurda et al., 2016; Thigpen 2019), even if, later on, the students will adjust their commuting behavior to the demands of their work life (Buch-Geertsema and Lanzendorf 2017; Muromachi 2017).

In this sense, although there is greater awareness of the social and environmental dimensions of transportation, there are still significant gaps in academic work regarding the analysis of the differential impact of travel behavior and transportation policy and provision by gender (Mejía-Dorantes 2018). According to Anfinsen et al. (2019), differences in mobility between men and women are not only related to habits and practices, but also to cognitive, symbolic and material aspects. In this sense, it is essential to understand how gender and its expectations (Zelezny et al., 2000; Fu and Juan, 2017) have a complex relation with other cultural dimensions that create differences in behavior, which implies the need to establish specific measures and policies (Scheiner 2016). Previous studies have revealed how psycho-social factors such as risk perception, security or fear are connected to gender socialization and directly influence the choice and use of transportation modes and their environmental impact (Stark and Meschik 2018). Sovacool (2014) underlines the need to deepen and expand research on the gender implications of transportation and, particularly, energy consumption. These debates are especially relevant within the university context,

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where many high education institutions are planned as car-oriented environments and are facing parking, pollution and other difficulties (Dell'Olio et al., 2018).

In the university context, traveling styles, and the potential of cycling and walking have been widely studied. Recently, some papers have started to include assessments of energy consumption and other sustainability indicators, such as the carbon footprint (Davison et al., 2015; Pérez-Neira et al., 2020; Pérez-López et al., 2021; Sobrino. and Arce-Ruíz, 2021). However, differentiating behaviors by gender is much less frequent in academic works (Li et al., 2015). Most literature has in fact focused on the environmental impact of transportation when this is an item in the campus budget (Larsen et al., 2013; Nunes et al., 2013; Li et al., 2015; Arias et al., 2021; Valls-Val and Bobea, 2021). Thus, analyzing the environmental impact associated with travel choices, and identifying the factors that encourage pro-environmental behaviors at universities by gender are essential to improve the effectiveness of university and public measures and policies (Vicente Molina et al., 2018). Considering all these precedents and the specific reality of the ULE—a higher education institution with two campuses in two Spanish small cities (León and Ponferrada)—, this work has a triple objective: a) to analyze the modal distribution of weekly commuting by ULE users, and the time employed in those travels from a gender perspective; b) to estimate the non-renewable cumulative energy demand (NR CED) of this mobility and to identify its main hotspots; and c) to evaluate the willingness to modify commuting behaviors in relation to the barriers to change declared by the survey respondents and, based on it, to assess different energy consumption reduction scenarios, with a special focus on gender differences. For this purpose, quantitative and qualitative primary information was gathered from a survey of the entire ULE population conducted during the 2016–2017 academic year, and an energy analysis methodology was implemented and applied to university commuting.

2. Literature review

2.1. University commuting

Previous research works point to travel time, distance and institutional factors such as class schedules or the monetary cost of transportation as important determinants of the mode choice of students (Shannon et al., 2006; Zhou 2016; Gurrutxaga et al., 2017). Thus, students demand near-campus housing to be able to walk or cycle to university (Wang et al., 2015; Zhou 2014); on the other hand, their behaviors change depending on the season (Mahdizadeh et al., 2019). Some studies highlight that men are more likely to walk to university than women and, most especially, to use the bicycle or the motorcycle to get there (Delmelle and Delmelle 2012; Akar et al., 2013; Lundberg and Weber 2014). In the other modes, Zhou (2012) and Whalen et al. (2013) find no significant differences, while Lundberg and Weber (2014) and Davison et al. (2015) report that women are the ones most likely to drive a car to the campus. Delmelle and Delmelle (2012) show how students tend to use the car more often when commuting this way is relatively cheap, when they have a vehicle they can use and/or when they have a driving license (Nurul-Habib 2018; Saria-Lara et al., 2017), even if this mode is one of the worst contributors to the ecological footprint of the university (Larsen et al., 2013; Moniruzzaman and Farber 2018).

Other authors point to the price reduction and quality improvement of public transportation as an incentive to increase the use of collective modes such as the bus (Zhou 2014). The low frequency of service of public transportation, travel times and time schedules are also mentioned as barriers to bus use to commute to campus (Sisiopiku 2018; Zhou 2016). Delmelle and Delmelle (2012) and Zhan et al. (2016) indicate that it is mostly women who mention topography, security and infrastructures as the main reasons determining their mode choice, while men are more willing to change the car for other transportation modes throughout the year. In this sense, the development of appropriate and safe cycling and walking infrastructures from the cities to the campuses has been identified as a key factor to encourage active commuting among students and staff (Rybarczyk, 2014; Mrkajic et al., 2015; Sousa-Vale et al., 2021). Success in the promotion of active modes, especially cycling and walking, will have multiple benefits in terms of health, economy and environmental protection (WHO 2017).

2.2. Mobility and gender

Gender has been described as an important predictor of travel patterns in adult life (Law, 1999). There are studies that show that, in general, women travel shorter distances than men. This can be related to such factors as gender differences in household responsibilities, labor market segregation, and/or a mode choice characterized by car use (Hjorthol 2008; Schwanen 2011; Gil-Solá 2016). In fact, the above-mentioned behavior is directly related to the sexual division of labor according to which women take on most household and care responsibilities, and which implies different spatial-temporal organization and mobility for women and for men (Houston 2018). Different studies evidence how women often assume a disproportionate workload in taking their children to school (Scheiner and Kasper 2003; Simons et al., 2017) and make more multipurpose trips related to non-work issues, so they tend to choose more flexible transportation modes (Mahadevia 2017; Craig and Van Tienoven 2019). Polk (2004) and Mahadevia (2017) find that women use public transportation more than men do, and men commute more often by bicycle (Paleti et al., 2013; Prati 2018). In addition, men and women experience waiting times, adaptation to the environment and infrastructures differently in their travel choices and in fact, report different barriers or restrictions to active transportation modes and show more positive attitudes towards change (Fan et al., 2016; Prati et al., 2019).

In relation to car use and walking, the results are divergent. Simons et al. (2017) find that Belgian young women are more prone to using the car to go to work or school, and Paleti et al. (2013) obtain similar results for the employed population in the United States. However, the findings of Gil-Solá and Vilhelmson (2012) or Vance et al. (2005) prove the contrary for Sweden. On the other hand, Mahadevia et al. (2012) and Srinivasa (2008) conclude that women travel shorter distances and walk more than men do, and therefore spend more time traveling and suffer from greater time poverty (Anand and Tiwari 2006; Monzón and De la Hoz 2009). Behaviors and mode choices are closely linked to environmental impacts. Recent research works argue that women have more possibilities than men to adapt to a sustainable transportation system and show a more positive attitude toward change (Polk 2004), just as they are more willing to pay to reduce their environmental impact (Waygood and Avineri 2016). However, other authors suggest that the fact that women are making more short-distance trips and using the car more often (multipurpose trips, caretaking, etc.) appear to indicate the opposite (Root and Schintler 1999; Dickinson et al., 2003).

3. Materials and methods

3.1. Case study

The University of León is one of the four public universities in the autonomous region of Castilla y León. Its main campus is located in the city of León, and it has a second campus in Ponferrada, a town 110 km to the west of the provincial capital (Fig. 1). The influence area of the two campuses comprises 22 municipalities and 291,831 inhabitants. The León campus includes 14 schools, a Central Library, the Foreign Language Center, the Information Technology Center and the Regional Veterinary Hospital. The campus is located to the northeast of the city, while the administration and protocol office is found downtown, in the building that used to be the old Veterinary Medicine School. The Ponferrada campus includes three school and lies to the east of the city. Both campuses have a complete network of sport facilities. The university has

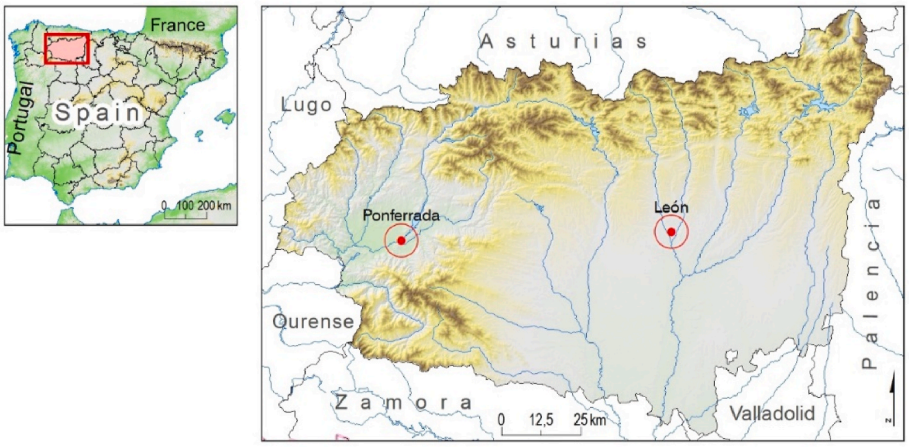

Fig. 1. Location of the University of León: Campuses of León and Ponferrada (León, Spain).

a so-called Oficina Verde (Green Office, http://servicios.unileon.es/oficina-verde/), the purpose of which is to promote sustainability and healthy habits among all university community members. In terms of sustainable mobility, it has published a Catálogo de buenas prácticas universitarias (University good practices catalogue), as part of its U MOB Project, and has a bicycle-sharing system called ULEBICI.

In terms of mobility infrastructures, the university has open-air car, motorcycle and bicycle parking areas, several bus stops and, in the case of the main campus, a train station that connects it to towns in the north of the province. In addition to the university bicycle lending service (ULEBICI), there is a similar municipal service, however, of little relevance. The main characteristics of the infrastructures and services associated with mobility are summarized in Table 1. For each of them, an inventory has been made of the available resources and, in the comments, an assessment of their condition and usefulness is included. Most of these infrastructures are located on the León campus, which is the actual nerve center of the university. The location and spatial distribution of these infrastructures/services of the León campus are shown in Fig. 2. Likewise, all campuses have pedestrian accesses, and the main campus in León is connected to the L-30 ring road.

3.2. Data collection and statistical analysis

As part of the cross-sectional study, self-informed data were collected from university community members through an online survey (managed with LIME SURVEY software), conducted on November 2016 via a mass email sent from the office of the University Vice-president for Social Responsibility, Culture and Sport. An anonymous structured questionnaire with multiple-choice and descriptive closed-end questions was used for this purpose. It was divided into three sections: the first one was meant to identify the respondents' gender and their connection to the university; the second one asked for general information on commuting habits: points of origin and destination, and transportation mode; finally, the third one demanded qualitative information on the possibilities and barriers to modal change. The university census for the 2016–2017 academic year was 10,079 students, 948 members of the Teaching and Research Staff (TRS), and 474 members of the Administration and Services Staff (ASS). Up to 482 survey responses were considered valid, and a 4.37% error margin was obtained for a confidence level of 95%. By dividing the sample according to the different groups analyzed, the error margin slightly increased. The results by groups were relevant because they complete, for this case study, a global and significant picture of general mobility at the ULE. The percentage of women' responses was 59.5% for the whole university community, 61.8% for students, and 55.2% for the Administration and Services Staff and the Teaching and Research Staff together (ASS + TRS). The results were analyzed using SPSS software, version 22. All variables failed the Lilliefors test for normality ($p < 0.05$). Consequently, the Mann-Whitney non-parametric *U* test was carried out to compare mobility indicators and NR CED at a level of significance $p < 0.05$ (Wayne, 1990).

3.3. Estimation of university mobility behavior

The second part of the survey provided primary information on the respondents' weekly commuting, from which distances, modal structure and passengers-kilometers (pkm) were estimated. The geographical coordinates of the points of origin and destination, and the walking distances were determined on the geolocation website CartoCiudad (www.cartociudad.es). Travel times and distances in motorized modes were estimated using Google Maps, which allows selecting various modes for every route and estimating travel times for every mode according to traffic conditions. For this purpose, enquire routines were established at the usual entry and exit hours in the work centers. Waiting times at bus stops and the time spent on parking (which can be considered "negligible" due to the proximity of parking areas to the work centers) were dismissed. From all the information collected and estimated, the weekly mobility of ULE users was assessed considering round trips from a "door-to-door" approach (Fig. 3) (Salonen and Toivonen 2013).

3.4. Non-renewable cumulative energy demand of weekly mobility

Through the indicator pkm, the non-renewable cumulative energy demand (NR CED) associated with the weekly commuting was estimated by transportation mode (Eq. (1)). The non-renewable energy required to move the vehicle is determined by the type of fuel and its consumption rate, the transportation conditions (traffic flow and topography), and the characteristics of the vehicle. Vehicle capacity and occupancy are also determining factors of energy use (Léonardi and Baumgartner 2004). Therefore, one of the most delicate steps in energy analysis is calculating the technological coefficients (Tc) best suited to the reality analyzed. In this case, the coefficients were obtained from the information available in studies that thoroughly analyze the life cycle of the transportation system in Spain (Sanz et al., 2014; Delgado-Cabeza et al., 2015), and adapted to the regional particularities of Castilla y León. This way, the values 2.08, 0.80 and 0.91 MJ pkm^{-1} were calculated, respectively, for inter-urban commuting by car, bus and train, while for urban commuting by car, motorcycle and bus, the values obtained were 3.61, 0.97 and 1.67 MJ pkm^{-1} (adapted from Sanz et al., 2014; Delgado-Cabeza et al., 2015; IDAE 2019; DGT 2019).

$$NR\ CED_{(t)} = \Sigma\ D_{(t)}\ x\ d_{(t)}\ x\ Tc \qquad \text{(Eq. 1)}$$

Table 1
Mobility infrastructures/services at the University of León (2016/2017).

Infrastructures	Number or Service (yes/no)	Per 100 users	Comments
Car			
a. Car parking area	1210 places	10.52	The car parking lots are located in large areas close to the entrances to the university centers. The university has reserved parking spaces for people with reduced mobility. There is a petrol station near the campus.
b. Car-sharing	No	–	–
Bicycle			
a. Bicycle parking area	525 places	4.56	Bicycle parking facilities are scattered around the campus. They are uncovered and unattended.
b. Bike-sharing	166 bikes	1.44	There are two loan systems: one from the university (ULEBICI) and one from the municipality. ULEBICI has 156 bikes available for loan and four bicycle rental points: three in the city of León—one in the campus—and one in the Ponferrada campus. The loan period is 15 days and a deposit of 80 euros must be paid. The bikes use a GPS tracking system. The campus has only one municipal bicycle rental point with only a few very dilapidated resources (10 bikes). This service is free for holders of the Citizen Card.
c. Bike lane	1 lane	–	The intermittent ring road around campus is unsafe, with no protective barriers and deteriorated accesses.
Bus			
Bus stops	3 bus stops	–	There are three lines in León running every half hour from 7.00 a.m. to 10.30 p.m. There is one line in Ponferrada running every hour from 7.30 a.m. to 21.30 p.m.
Motorcycle			
Motorcycle parking area	12 parking areas	0.00	There are 10 specific parking areas for motorbikes, but motorcycles also use car parking spaces.
Train			
Railway station	1 station	–	There is one line (to/from Cistierna) running every hour from 7.10 a.m. to 21.15 p.m. There are railroad tracks and infrastructures in the direction of the city center, but they are not in use.

Where, NR $CED_{(t)}$ = Non-renewable Cumulative Energy Demand by transportation mode (t); (t) = transportation mode (walking, car, bus, train/railway, motorcycle and bicycle); $D_{(t)}$ = commuting flow by transportation mode (t) (number); $d_{(t)}$ = distance travelled by commuter by transportation mode (t) (km); and Tc = technological coefficients for each transportation mode (t) measuring the relationship between direct energy consumption and pkm (MJ pkm^{-1}).

3.5. Analysis of disincentives and barriers to modal shift

The third section of the survey focused on the respondents' perception of the possibility of changing (or not) their transportation habits, as well as about the main barriers to change and the disincentives to use a specific transportation mode more often. For this purpose, a first question was asked about the transportation modes that the respondents considered as viable alternatives for their commutes to the ULE. The following questions explored the barriers and disincentives. From the information gathered, three scenarios were built to evaluate the reduction/increase of the environmental impact in relation to a greater use of (1) the bus, (2) the bicycle, and (3) the car. NR CED variations were calculated according to the assumptions synthesized on Table 2. Thus, the data obtained reflect the maximum variation in the energy consumption of users of a specific transportation mode (t) who see the possibility of using an alternative mode (t_a) more often as well as the barriers to do it, and would actually start using that alternative mode (t_a) if those barriers and disincentives were eliminated.

4. Results

4.1. Commutes, modal structure and energy consumption of weekly mobility at the ULE

Table 3 shows the trips (number and pkm), travel times and NR CED of weekly commuting to the ULE, as well as their disaggregation by group and gender, while Fig. 4 presents the modal structure. In average terms, students and ASS + TRS go to university and back eleven to twelve times per week and travel 43.1 and 64.5 pkm, respectively, which is an average of 50.5 pkm for all university users. The time spent on commuting is 83 min per week for the entire sample population and higher for the group of workers than for the students (105.1 vs. 71.5 min). In terms of energy, the workers' demand is double that of the students (189.8 MJ vs. 92.1 MJ), with an average of 125.5 MJ for the whole university community. This is due to the fact that most students walk to university (50.7% of the commutes), or drive a car (their own or shared) (28.8%), the other modes being much less used. In contrast, the ASS + TRS group use their own cars most often (48.0%), and only walk 21.9% of the times. As regards gender, there are no significant differences between the behavior of women and men students. However, the data appear to show that women students walk, share their cars and use the bus more often than men students do (3.4%, 2.1% and 4.6% more, respectively). In the same way, and this is also common among workers, men use the bicycle and motorcycle more than women, in number of trips as much as in travel time and pkm. Among workers, women use the car significantly more often —both their own and shared— and travel more km than men. Up to 92.3% of the pkm travelled by women workers correspond to car use, which is 9.6% more than among men. The differences between men and women students regarding the number of pkm travelled in their commutes to university are not significant.

In relation to time, women students' walking commutes determine the global results: this group spends 68% of their commuting time in this mode, in contrast with women workers, who only spend 32.8% of the time this way. The time used by women workers commuting by car is 56.8% of the total, which is 19.3% more than among men workers. On the other hand, the time spent on bus commuting is similar in all groups, and amounts to around 8.4% of the total for the entire university community. The car is the transportation mode with the highest NR CED (93.7%–98.6%) regardless of group and gender, followed by the bus (1.5%–9.0%), while the other modes have a much lower quantitative relevance (0.2%–2.2%). By group, women workers accumulate the highest energy demand (98.6% of the total), higher than that of men workers by 3.8%. Although the differences are not significant, women students demand less energy through car use than men students (2.8% less), but they compensate this with a higher NR CED in bus use (4.0% more than among men).

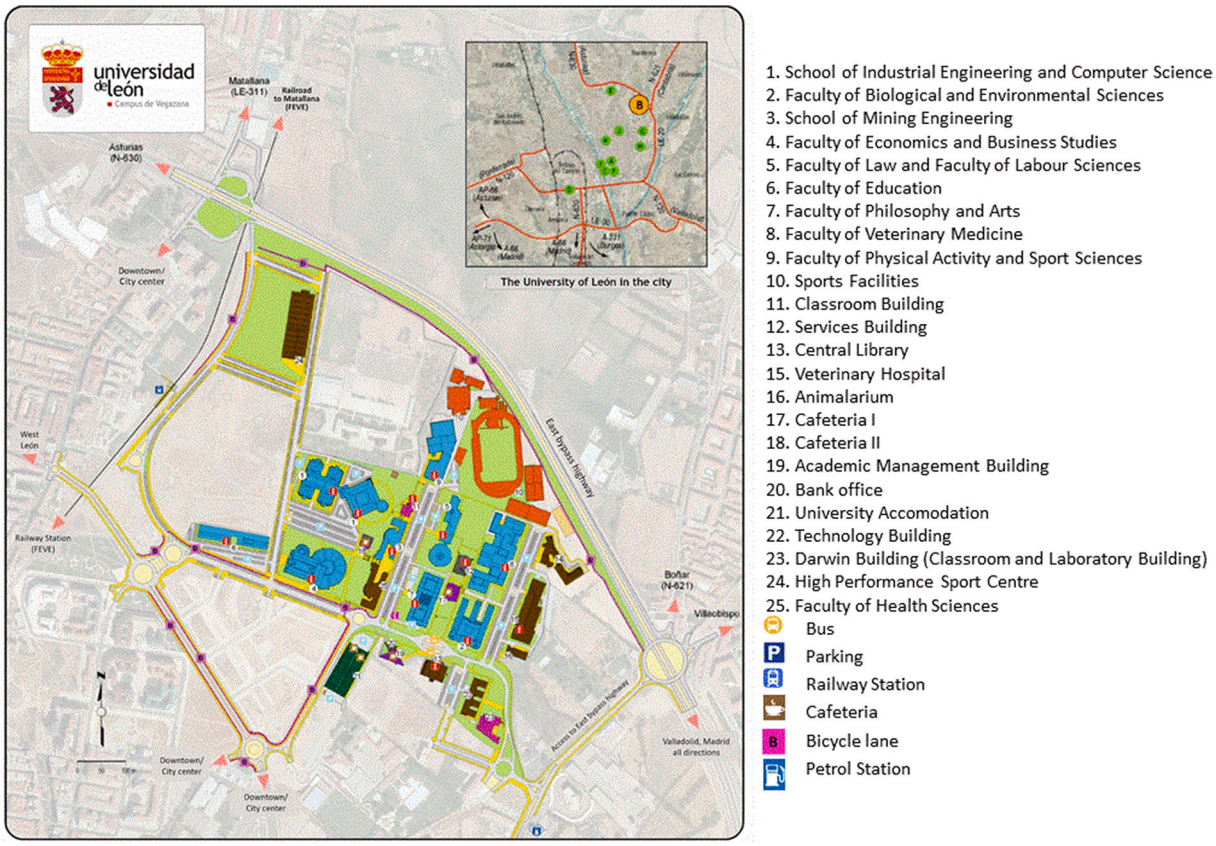

Fig. 2. Map of infrastructures/services of the León campus (2016/2017).

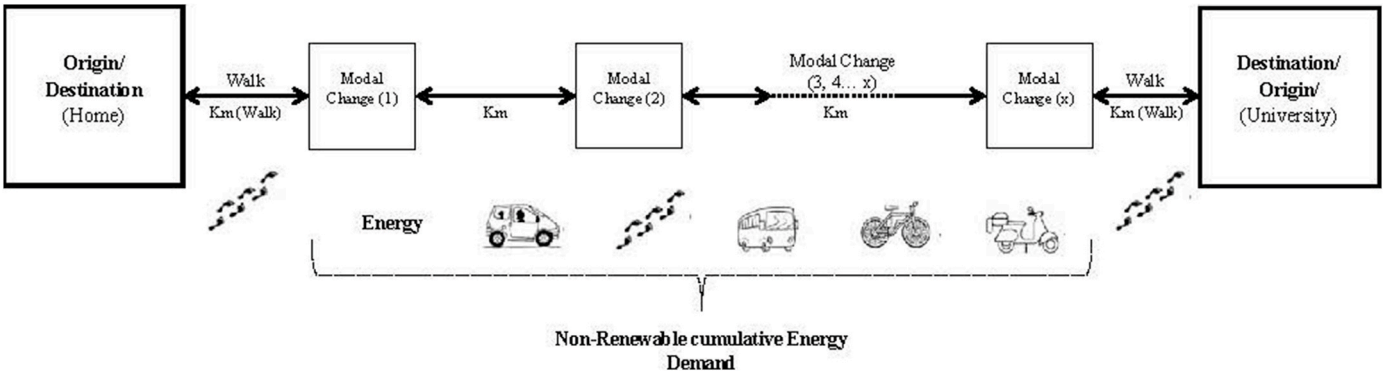

Fig. 3. University mobility scheme (door-to-door approach) and its impact in terms of energy.

Table 2
NR CED variation scenarios according to the barriers declared.

Scenarios	Users of mode (t)	See the possibility of and the barriers to using an alternative mode (t_a)
(S1) More bus	Car	Bus
(S2) More bicycle	Car and bus	Bicycle
(S3) More car	Walking, bicycle and bus	Individual car

Table 3
Average number of trips, passenger-kilometers, time and cumulative energy demand of weekly commutes (round trip) to the ULE by group and gender.

Particulars	Commutes		Time	NR CED
	No.	pkm	min	MJ
University (i + ii)	**11.9**	**50.5**	**83.0**	**125.5**
i. Students	**12.4**[a]	**43.1**[a]	**71.5**[a]	**92.1**[a]
Men	12.6	44.5	73.1	93.2
Women	12.2	42.3	70.4	91.4
ii. ASS + TRS	**11.0**[a]	**64.5**[a]	**105.1**[a]	**189.8**[a]
Men	11.6	37.4	110.6	120.5[b]
Women	10.6	86.6	100.6	246.2[b]

Where, a = statistically significant differences between groups (students vs. ASS + TRS) at a level of significance $p < 0.05$; b = statistically significant differences between men and women within each group at a level of significance $p < 0.10$.

4.2. Main barriers to modal shift and energy consumption reduction scenarios

Table 4 reflects the main barriers identified by ULE users to the possibility of changing their modal behavior. It is important to highlight that 81.0%–86.0% of the ULE students who do not use active modes (bus, bicycle and walking) perceive them as possible alternatives, while the car is considered a viable option for 29.8% of the students and 4.1% of the ASS + TRS group who do not use that mode. The main barriers to change are related to (Table 4): a) for the bus, frequency of service (a1: 41.3% of the users) and fare (a2: 31.3%); b) for the bicycle, state of the cycle paths (b1: 52%) and thefts on campus (b2: 46.6%); and c) for the car, ownership of the vehicle (c1: 30.3%) and price of fuel (c2: 27.2%). In addition, the data show that a greater number of bus lines (a4) and the possibility of avoiding transfers (a5) are less relevant as variables encouraging bus use. Similarly, in relation to bicycles, access to ownership (a3), covered parking areas (a4) or access to bicycles (their own or through sharing systems) (a5) are also less relevant for ULE users, as are availability (a3) and the possibility of sharing (a4) in the case of cars, especially among ASS + TRS members.

These barriers are not the same for all groups and genders. Thus, for instance, the main barriers preventing a modal shift towards bus riding among students are frequency of service (a1) and fare (a2), while, for workers, bus time schedules (a3) are more relevant than the fare. In what concerns cycling, workers give more importance to safe paths (b1) than students, while the latter, because they use bicycles more often, value on-campus security more (b2). Likewise, car ownership (c1) and the price of fuel (c2) are more important for students, whereas for workers, who commute by car more often, lack of parking space (c5) appears as the second barrier. By gender, women students care more than their male counterparts for the variables connected to bus use (a2, a3, a4, a5), and, where bicycle use is concerned, they also highlight security (b1, b2) and availability (b3, b5). Ownership and accessibility (c1, c2) are also the most important barriers to car use among women students. As regards the ASS + TRS group, bus frequency of service (b2) and fare (b1) appear to have a more negative impact on men, while the state of the cycle paths and security on campus (b1, b2) still weigh more on women. Similarly, women in this group point more than men to the price of fuel (c2) and the availability of parking space (c5) as the main barriers to using the car more often.

From an environmental perspective, Table 5 shows how measures intended to reduce the barriers declared by bus and car users in relation to the bicycle could lead to a maximum reduction of 21.9%–35.6% in the NR CED of the whole ULE population, while measures focused on encouraging bus use among car users could help reduce the NR CED by between 6.5% and 18.1%. In addition, if commuters who travel by bus, walk or cycle to university had greater access to car ownership and availability, the NR CED of the university would increase by up to 27.8% due, mainly, to the students' behavior. In the case of women (both students and ASS + TRS) and men workers, an improvement in the state and safety of cycle paths could reduce their weekly energy consumption by 34.5%, 54.8% and 34%, respectively. In contrast, men students could reduce the NR CED by 26.4% if security on campus were improved to avoid thefts.

5. Discussion

5.1. Differences in university mobility by work status and gender

In the case of the ULE, results show some important differences in behavior patterns, especially by work status, although some differences by gender are also observed, which are especially relevant for the group of workers. Previous studies agree on the fact that men students use the bicycle more often than women students do (Rodríguez and Joo 2004; Zhou 2012; Akar et al., 2013; Simons et al., 2017). However, for other transportation modes, the results are more divergent. For instance, in the United States, Zhou (2012) and Lundberg and Weber (2014) observe that men are more prone to walking than women, while Delmelle and Delmelle (2012) find no significant differences by gender in walking or bus commuting to university. At the ULE, the data show that men use the bicycle and the motorcycle more than women, while women take the bus more often, and also walk to and from university slightly more often. However, these differences are not significant. In relation to car use, Lundberg and Weber (2014) affirm that women students use the car more than men students do, while Zhou (2012), similarly to the present case, finds no significant differences in this sense. Work status has a decisive influence on university commuting. Workers, as opposed to students, commute by motorized modes more frequently, particularly by car, a mode that is widely used by women workers. Again, studies about car use are not conclusive (Gil-Solá and Vilhelmson 2012; Vance et al., 2005). The results obtained for the ULE point in the same direction as those provided by Paleti et al. (2013) or Simons et al. (2017), where women in the United States or Belgium use private cars to go to school, university or work more often than men.

Despite data discrepancies, there is agreement on the fact men's and women's mode choices are strongly associated with the sexual division of labor, according to which women take on more domestic and care responsibilities than men. As a result, women's spatial-temporal organization and mobility are different and unequal in relation to men's (Hjorthol 2008; Schwanen 2011; Gil-Solá 2016). As a result, women suffer from greater time poverty (Anand and Tiwari 2006; Monzón and De la Hoz 2009), need to make more multipurpose trips (Mahadevia and Advani 2016; Scheiner and Kasper 2003), and prioritize transportation modes that allow greater flexibility (Mahadevia 2017; Craig and Van Tienoven 2019). Among students, as shown on time use surveys conducted in Spain (INE 2020), differences in care responsibilities may not be so obvious and, consequently, as determining a factor to explain the groups' mode choices. But for women workers, using the car, even if the distance is short, reduces the travel time to university. Shannon et al. (2006) indicate that the most important barrier for university users is the travel time, regardless of the distance and the mode choice. Car use can be adapted to the complicated family schedules to a greater extent

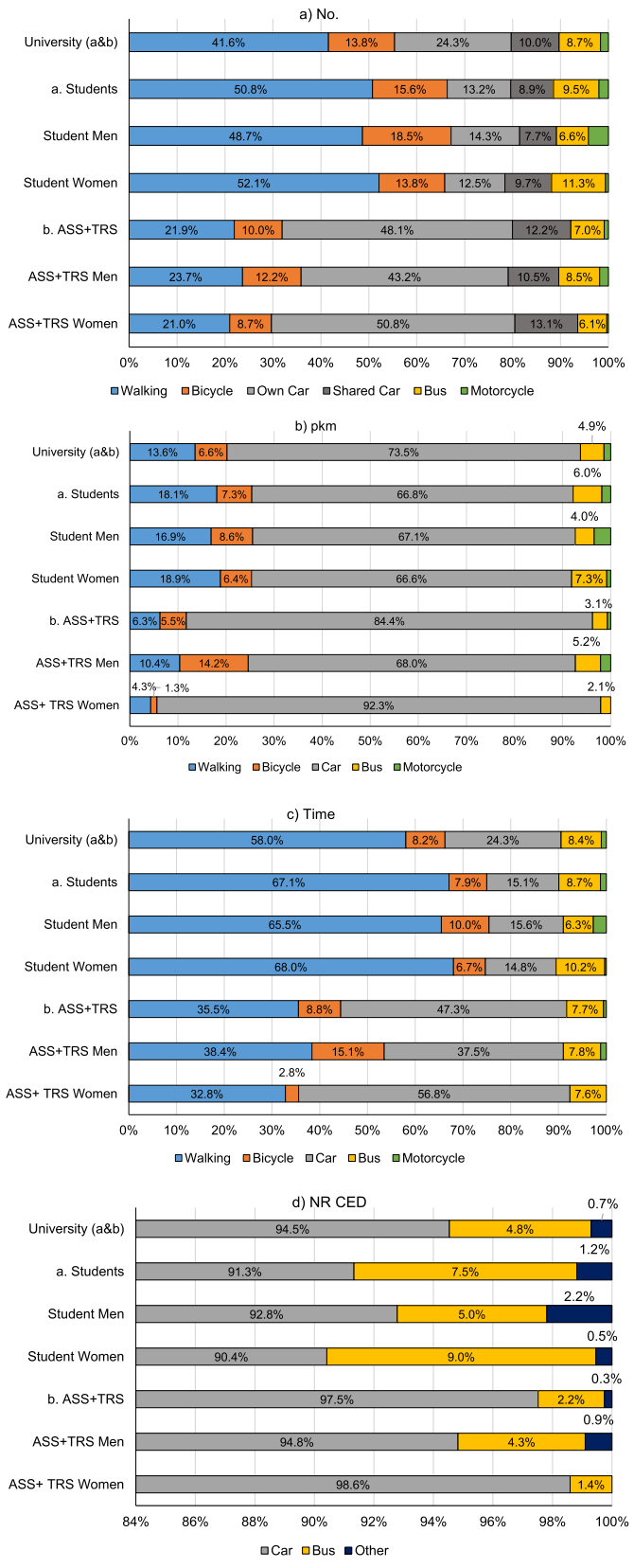

Fig. 4. Modal behavior structure of weekly commutes to the ULE by group and gender (%): a) Number of commutes; b) pkm; c) time, and d) NR CED. The train is not included because its use is residual (less than 0.07%).

than the use of other modes; it also allows more freedom and mitigates some of the risks perceived, such as transit safety (Craig and Van Tienoven 2019).

5.2. *Design of strategies and policies aimed at achieving sustainable university mobility*

Even if the city of León is relatively accessible by active transportation modes due to its size, the use of the car, even for short distances (less than 4–6 km) is the main source of energy consumption (see also Dell'Olio et al., (2018); Larsen et al., (2013); Moniruzzaman and Farber (2018); Pérez-López et al., (2021) . Therefore, in terms of energy sustainability, reducing car commuting in favor of cycling, bus riding or walking should be a priority of university policy (Balsas 2003; Llurda et al., 2016; Muromachi 2017). Data show how changing the car for the bus could lead to important energy savings (maximum 18.1%). Survey respondents would be willing to use the bus more often should the fare go down and the frequency of service and the time schedules improve (see also Gurrutxaga et al., 2017; Sisiopiku 2018; Zhou 2016). Introducing a parking-fee on campus would also discourage car use, especially among students (Sousa-Vale et al., 2021), and serve as an incentive for alternative modes (Sobrino and Arce-Ruiz 2021). A modal shift towards cycling is the option with greater possibilities of reducing energy consumption (a maximum of 35.6%), and is perceived as possible by more than 86% of the ULE users. Lack of security on campus and inadequate and unsafe infrastructures are two of the main barriers to the promotion of cycling (Rybarczyk, 2014; Mrkajic et al., 2015; Agarwal et al., 2019; Mehdizadeh et al., 2019); barriers that are congruent, to a large extent, with the state of the infrastructures and the quality of the services (Table 1). Similarly to previous research works (Delmelle and Delmelle 2012), this study shows how women users are more concerned about these barriers than men are, which underlines the need to integrate a gender perspective into sustainable mobility policies. Thus, Dickinson et al. (2003) argue that, for instance, the provision of cycling facilities may have a lower impact on women cyclers, while Prati (2018) and Prati et al. (2019) connect the quality and security of the infrastructures with women's relatively high participation in cycling in countries with a well-developed cycling culture.

Therefore, in addition to improving on-campus infrastructures, university authorities, in coordination with local governments, should put a greater effort on the consolidation of high quality and safe cycle paths to the campuses (Akar and Clifton 2009). In another direction, Thigpen (2019) suggests the need to develop programs that encourage trying other transportation modes. In other words, as a complement to campaigns promoting the use of active modes, it is necessary to foster practical learning to improve motility and consolidate cycling habits (for instance, on the first year of studies, focused on women students). Nurul-Habib (2018) also notes how owning a public transportation pass may be a tool to deter students from obtaining their driving license. Data also show how the students' economic status is a limiting factor in relation to car use (Monirruzaman and Farber 2018; Dell'Olio et al., 2018; Sousa-Vale et al., 2021). If ownership and availability to private vehicles were made more accessible (Lundberg and Weber 2014; Saria-Lara et al., 2017), the NR CED associated with commuting to the ULE would increase by up to 27.8%. This tendency is more pronounced among women students than among their male counterparts, who, because of their greater access to vehicles, highlight the price of fuel as a barrier more than women do. Buch-Geertsema and Lanzendorf (2017) affirm that university students adjust and may change their commuting habits once they start their work life. In fact, the data show that students are willing to drive a car to university more than they currently do, which shows a clearly positive perception of this transportation mode, despite its larger environmental impact (see Beria et al., 2021). This result reveals the need to keep reinforcing environmental marketing and awareness campaigns among ULE users in order to foster healthier and more sustainable mobility habits (WHO 2017; Mejía-Dorantes 2018;

Table 4
Main barriers to modal shift as declared by ULE users (%).

Particulars	Main barriers				
a. Bus	**1. Frequency of service**	**2. Fare**	**3. Time schedules**	**4. More bus lines**	**5. No transfers**
University (i + ii)	**41.3**	**31.3**	**22.0**	**20.1**	**10.8**
i. Students	38.2	40.4	23.0	21.8	10.4
Men	33.9	41.3	17.4	15.7	7.4
Women	40.8	39.8	26.5	25.5	12.2
ii. ASS + TRS	44.6	12.2	18.9	17.6	13.5
Men	49.5	15.4	20.9	16.5	9.9
Women	47.3	13.9	20.0	17.0	11.5
b. Bike	**1. State of the cycle paths**	**2. Thefts on campus**	**3. Ownership**	**4. Covered parking areas**	**5. Access to bicycles**
University (i + ii)	**52.1**	**45.6**	**27**	**13.9**	**8.9**
i. Students	50.8	54.3	31.5	18.6	11
Men	43.0	52.9	28.1	21.5	9.1
Women	55.6	55.1	33.7	16.8	12.2
ii. ASS + TRS	58.1	14.9	14.9	9.5	6.8
Men	51.6	17.6	20.9	1.1	3.3
Women	54.5	29.1	18.2	4.8	4.8
c. Car	**1. Ownership**	**2. Price of fuel**	**3. Availability**	**4. Possibility of sharing**	**5. More parking space**
University (i + ii)	**30.3**	**27.2**	**16.8**	**9.1**	**6.8**
i. Students	41.6	31.9	21.8	11.7	5.0
Men	36.4	34.7	17.4	10.7	5.8
Women	44.9	30.1	24.5	12.2	4.6
ii. ASS + TRS	6.8	23.0	5.4	4.1	12.2
Men	9.9	14.3	8.8	4.4	8.8
Women	8.5	18.2	7.3	4.2	10.3

Where, for the bus: a1 = low frequency of service (long waiting time); a2 = expensive bus fare; a3 = time schedules not adjusted to class and work schedules; a4 = more lines connecting other city areas with the university; a5 = possibility of avoiding transfers. For bicycles: b1 = inadequate and unsafe cycle paths; b2 = lack of security on campus; b3 = no access to ownership; b4 = covered parking areas to protect the bicycles from inclement weather; b5 = Access to bicycles (their own or through sharing systems). For the car: c1 = no access to ownership; c2 = high price of fuel; c3 = no availability of the family car; c4 = possibility of sharing with other students or colleagues; c5 = more parking space available on campus.

Table 5
Maximum increase or decrease of the NR CED if, after the barriers declared are eliminated, the commuters used the indicated transportation mode (% of the NR CED of each group and subgroup).

	S.1 More bus		S2. More bicycle		S3. More car	
Particulars	Greater frequency of service	Lower fare	Better and safer cycle paths	More security on campus	Greater access to ownership + availability	Lower price of fuel
University (i + ii)	**−18.1**	**−6.5**	**−35.6**	**−21.9**	**27.8**	**13.1**
i. Students	−19.6	−7.7	−30.3	−25.7	52.5	23.6
Men	−16.0	−8.2	−23.6	−26.4	47.0	23.5
Women	−21.9	−7.4	−34.5	−25.3	56.0	23.6
ii. ASS + TRS	−16.7	−5.4	−40.5	−18.3	4.7	3.3
Men	−16.7	−3.5	−54.8	−39.8	7.3	10.4
Women	−16.7	−6.1	−34.8	−9.8	3.7	0.5

Sobrino. and Arce-Ruiz, 2021).

6. Conclusions

Analyzing the commuting behavior of university users is essential to design effective planning and management policies that favor sustainable mobility. The non-inclusion of the working status or gender variables in the design of such policies may lead to unexpected results or to results that increase unequal mobility patterns among groups and between men and women. In this sense, it is necessary to develop tools to assess and compare mobility habits, as well as strong indicators, such as energy consumption, to facilitate and focus public and institutional policies. The results drawn from this study show clear disparities between the behavior and environmental impact of workers and students, especially in relation to car use, due to differences in economic status. As regards gender, the results are not as clear; however, they show how men tend to commute to the ULE by bicycle and motorcycle more than women do, while the latter use the bus more often and walk to and from university slightly more often also. Nevertheless, these differences do not translate into a higher average energy consumption among men and women students because of the short distances travelled, among other factors. Even if both León and Ponferrada are small and accessible cities, reducing the number of commutes by car in favor of other transportation modes (bus, cycling or walking) is the main challenge on university campuses. The results show how the state of the cycle paths, on-campus security, bus fares and frequency of service are the main barriers declared by ULE students and workers to a greater use of bicycle and bus. Overcoming these barriers may lead to important energy savings in daily mobility at the university. For this purpose, the competent authorities —the university board in coordination with the local

governments— should define their political priorities bearing in mind the differentiated demand by groups and gender in order to promote sustainable mobility on campus and in people's daily life.

CRediT author contribution statement

Cristina Hidalgo-González: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Software; Writing - original draft. **M Pilar Rodríguez-Fernández:** Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Software; Writing - original draft. **David Pérez-Neira:** Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Software; Writing - original draft.

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