ISEE Conference 16-19 june 2012 Rio de Janeiro - Brazil
Ecological Economics and Rio+20: Challenges and Contributions for a Green Economy

Greening commuters’ transportation and parking at the University of Coimbra Campus

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Keywords: *Transport Demand Management; Parking; Commuting; Life-Cycle Assessment;* Travel Mode; Public Transport.

Abstract

Transport Demand Management is a critical urban strategy which is mostly applied with the aim of rebalancing the modal split between private car and alternative public transport systems.

This study explores the importance of integrated parking management policies: (*i)* to ensure more rational use of the available parking spaces, evenly balancing supply and demand, and (*ii)* to reduce greenhouse gas (GHG) emissions, fossil fuel consumption and primary energy requirements by commuters to the University of Coimbra (UC) Campus, in Portugal.

For this, firstly, parking supply and demand flows within the UC campus are estimated. The results indicate that the parking facilities are underpriced and that there is overcrowding. Actually, at the early morning hours the parking places are fully occupied, or nearly, while many drivers continue to enter the Campus searching for something that they can hardly find. While searching for a parking place, drivers continue to consume fuel, pollute and mischaracterize an area with outstanding artistic and architectural value (as confirmed by an ongoing candidacy to UNESCO world cultural heritage site).

Secondly, a survey regarding commuters’ characterization and their responses to potential measures towards car use abandon and/or increases in public transportation use is presented. The analysis demonstrates that decreasing parking subsidization should not only reduce car driving (relative) attractiveness, but can also constitute an important source of revenues to encourage car drivers to use public transport. Indeed, an important number of car drivers exhibit a positive willingness to accept a compensation in order to use public transport.

The corresponding quantitative and qualitative analysis of the UC Campus’ situation allows for the understanding of different impacts on parking and traffic inside the UC Campus that may occur with the introduction of specific measures. Accordingly, thirdly, some scenarios are considered, mainly focused on potential changes in commuters’ behavior regarding changes in the modal split towards the use of public transport and corresponding environmental impacts. Finally, in order to assess changes in fuel and electricity consumption by passenger cars and buses, life-cycle energy requirements and GHG emissions, a Life-Cycle (LC) study is implemented. The LC study aims at identifying environmentally preferable solutions for commuting to the UC Campus. The various commuting strategies and scenarios are comparatively assessed. The LC study implemented is based on traffic information collected for the current situation together with prospective data accounting for the modifications in traffic patterns inside the UC Campus.

To sum up, some improvement opportunities have been identified such as, e.g., that an effective control of illegal parking may contribute to reduce nearly 10% of GHG emissions, and that different forms of modal shift from private cars towards public transportation can contribute to emissions reductions above 50% when compared with the current ones. Moreover, the results of the survey allow concluding that there is room for the authorities to adopt the measures required, as commuters’ revealed availability to participate in the collective effort for greening transportation and parking at the UC Campus.

1. Introduction

Transport Demand Management is a critical urban strategy which is mostly applied with the aim of rebalancing the modal split between private car and alternative public transport systems. Often, the management of parking places can constitute one of the critical elements to change behaviors, supporting the move from individual/private car use towards collective/public transports. Thus, parking is a central topic in urban transportation planning and traffic management (Davis et al., 2010; Waters et al., 2006; Shoup, 2006; Marsden, 2006; Verhoef et al., 1995). Anyone who has parked in the downtown area of a major city during the business day will attest to its high socio-economic and environmental costs (Arnott and Rowse, 2009). Cars cruising for parking further exacerbate traffic congestion, origin accidents, waste fuel and other resources, pollute the air, degrade pedestrian environment and restrain levels of accessibility.

As a location that provides all staff and students a place for their working, studying and even living, the provision of parking constitutes one of the most troublesome transportation problems at many universities campuses, all over the world (Alshuwaikhat and Abubakar, 2008; Shang et al., 2007; Balsas, 2003). This is true too for the University of Coimbra (UC) campus (Polo I), in Portugal, with a large number of commuters travelling to University campus using their own car.

The University of Coimbra is the oldest academic institution in the Portuguese-speaking world and one of the oldest in Europe. Situated on a hill overlooking the city and the Mondego river, the University of Coimbra comprises a cluster of historical buildings, which has grown and evolved over more than seven centuries, and which unquestionably constitutes its own noble and well-defined urban area within the city. The Paço das Escolas, which includes an old library dating from the XVI century, known as Biblioteca Joanina, the ancient Colleges; the Botanical Garden; the Machado de Castro National Museum and the Church of St. John of Almedina; the New Cathedral or Sé Nova and the College of Jesus; the Church of the Holy Cross; the Chemistry Laboratory; the ancient Cathedral School or Sé Velha, the student rooming-houses on campus, or repúblicas; and the twentieth-century university buildings, are meaningful examples of a significant cultural heritage cluster which expressively illustrates an outstanding artistic and architectural value, confirmed by an ongoing candidacy to UNESCO world cultural heritage[1] site.

The need to ensure a balance that does not jeopardizes the normal fruition and preservation of these cultural heritage goods constitutes a challenging research agenda. Barata et al.

[1] According to Bedate et al. (2004: 101) cultural heritage can be defined as "the entire set of goods, tangible and intangible assets […] which have great historic, artistic, scientific and cultural value and which, therefore, are worthy of preservation by nations and peoples, serving as permanent features of people's identity down through the generations".

(2011) offer a first and important contribute in this endeavour, establishing solid basis for further analysis regarding the assessment of integrated parking management policies. Indeed, the authors established an ‘integrated modelling approach’ from which were derived some significant contributions concerning parking issues within the UC campus. The current paper intends to go beyond establishing additional contributes addressing another important dimension of this challenge, namely assessing environmental impacts associated with changes in traffic and parking management within the UC campus.

Accordingly, this study explores the importance of integrated parking management policies: (*i*) to ensure more rational use of the available parking spaces, evenly balancing supply and demand, and (*ii*) to reduce greenhouse gas (GHG) emissions, fossil fuel consumption and primary energy requirement by commuters to the University of Coimbra (UC) Campus.

For this, the analysis is structured as follows. Section 2 provides a quantitative and qualitative analysis of the situation regarding parking demand and supply, as well as on the use of public transport services, within the UC Campus. Section 3 presents the main methodological issues regarding the calculation of life-cycle energy requirements and greenhouse gas (GHG) emissions associated with the alternative scenarios to address potential changes in parking and traffic policies. Section 4 concludes.

2. Supply and Demand for Parking and the use of public transportation

This section briefly characterizes supply and demand for parking at the UC Campus, with the aim of allowing for the understanding of different impacts on parking and traffic inside the UC Campus that may occur with the potential introduction of specific measures. For this, regarding supply, an analysis was made concerning the existing places available for parking, their location and characteristics. Accordingly, the number of available parking places by type, as well as the number of (electric and diesel) buses that serve the Campus, is presented in sub-section 2.1. Demand characterization requires a more detailed analysis, with the aims of identifying peak congestion periods, as well as the type of parking places preferred by those who try to park in this area. The most relevant results regarding demand characterization, as well as their appraisal against supply, are offered in the sub-section 2.2. In sub-section 2.3 are presented some of the most relevant components of the survey applied, in order to allow for the socio-economic characterization of UC campus commuters and to evaluate their (actual and potential) travel options.

It is worth to note that the elements to be offered in this section are confined to what is considered to be more relevant regarding the understanding of different impacts on parking and traffic inside the UC Campus that may occur with the introduction of specific measures that will be identified and assessed in section 3. Those interested in further details on the methods followed and results achieved regarding supply and demand for parking, as well as in a more comprehensive and detailed analysis of the survey implemented can see Barata et al. (2011).

2.1 Supply of Parking Places and Public Transportation Services

Regarding parking at the UC Campus, the results of an ad-hoc computation process concerning the available parking places within the study area can be found in Table I. The figures are displayed according to the various types of parking places identified.

Table I – Parking places available at the UC campus

Type of parking places		Number of places	% of total supply
(TA1)	Free parking (legal)	484	35.8
(TA2)	Reserved parking for occasional non-UC staff, and for people with disabilities	25	1.9
(TB)	Conditional parking access for UC staff (distributed through six sites)	574	42.5
(TC)	Non-regular parking[2]	136	10.1
(TD)	On-street paid parking	132	9.8
	Total	1359	100.0

These data show that more than 45% of the parking places (TA1 and TC) do not involve any kind of parking charges. On-street paid parking places (TD), all located at Padre António Vieira Street, are managed by the Coimbra City Council. Parking places with conditional access to UC staff are managed by the university administration[3].

Besides the supply for parking places, the supply of road public transport services in the Campus was also estimated. According with information available through the local transport authority, there are 117 (approximately 80% diesel and 20% electric or trolley) buses per day that flow through the Campus, running an average path of 1.7 km. So, the buses travel nearly 149 Km per day. Then, the values obtained were projected to one year according with the provision of bus services (distinguishing the periods of the academic year with and without classes).

2.2 Demand for Parking Places

The estimation of demand for parking is not as straightforward as for supply. Vehicles that circulate and park at the Campus should be considered to explain the corresponding demand for parking. Accordingly, the empirical approach selected to describe, and quantify, the

[2] It is worth note that there is a generalized practice of occupying non-regular spaces (TC), assuming the risk of being fined. Nevertheless the current parking control level at the UC campus is sporadic and drivers are expected to have the perception that the risk of being fined is very low. Indeed, during the period this study took place, not a single situation of parking intervention by authorities was noticed.

[3] Access cards, which are generally subject to the payment of an annual fee (160€), in spite of being issued on an over-the-booking basis, are largely insufficient to meet the current demand.

parking demand at the UC campus was the counting of traffic flows. For this, the inflow and outflow of vehicles was computed in order to assess the quantitative dimension of the potential parking problem at the UC Campus. The idea is that the volume of vehicles coming in and out, in articulation with the parking average occupancy rates, can be used to evaluate, at a specific moment in time, how many vehicles might be (potentially) benefiting from a specific type of parking place on campus. It is important to mention that different parking options are also associated with different travelling distances inside the Campus.

Regarding the demand for the parking sites with conditional access for UC staff (TB), average occupancy rates reveal that those parking facilities are not totally saturated, varying from 59,1% to 86,9%among the six sites.

Moreover, besides the demand flows for the TB parking sites, total demand for parking on UC campus includes demand for free places (TA), on-street paid parking (TD), and parking at non-regular spaces (TC). Output data from the modelling approach used indicate that the parking supply saturation concerning free parking spaces (TA) should be achieved between 8:20 and 8:50 (i.e., 8:20-8:30 on Mondays and Fridays, 8:30-8:40 on Wednesdays, and 8:40-8:50 on Tuesdays and Thursdays). Concerning non-regular parking places (TC), they are expected to become fully occupied at 8:50-9:00 on Mondays and Fridays, 9:00-9:10 on Wednesdays, 9:10-9:20 on Thursdays, and 9:40-9:50 on Tuesdays. Regarding on-street paid parking places (TD), they should not be fully occupied until 10:00 a.m. on Tuesdays, although it is estimated that these parking places become saturated on the other week days, namely by 9:00-9:10 on Mondays and Fridays, 9:30-9:40 on Wednesdays, and 9:40-9:50 on Thursdays. On average, the supply saturation for each type of parking places is expected to be achieved as follows: TA by 8:30-8:40, TC by 9:00-9:10, and TD by 9:20-9:30. Average numbers also indicate that nearby 8:00 a.m. parking demand grows faster, ascending to a maximum near 9:00 a.m., and then declining until 10:00 a.m..

To sum up, comparing supply and demand estimations, the results indicate that the parking facilities are underpriced and that there is overcrowding. Actually, at the early morning hours the parking places are fully occupied, or nearly, while many drivers continue to enter the Campus searching for something that they can hardly find. Moreover, while searching for a parking place, drivers continue to consume fuel, pollute and mischaracterize an area with outstanding artistic and architectural value. This conclusion is strengthened by the circumstance that non-regular parking has actually become a ‘valid parking alternative’ (inducing even more externalities).

The counting process was also used in order to estimate total in-flows of cars in the UC Campus and associate each car to a specific occupied parking place and to the path travelled inside the Campus (and corresponding distance). Accordingly, it was estimated that approximately 5 500 cars enter the Campus every day, travelling approximately 7 600 kilometres per day (and nearly 1 640 000 kilometres per year).

2.3. The Survey

Further, a survey regarding commuters' characterization and their answers to potential measures towards car use abandon and/or increases in public transportation use was built and implemented by the authors. The survey form was organized in two groups that include questions about mobility characteristics and the respondent him/herself.

One group of questions, about the characteristics of the respondent him/herself, are mainly of a descriptive nature such as the gender, the academic qualifications, the household net income, the monthly expenses concerning the Campus commuting trips, car possession, the area of the city where the respondent lives or the type of formal connection with the University.

The other group of questions, about UC campus users' mobility, considers issues relating to the number of weekly commuting trips, arrival time on each day, the frequency of public transport use (last month) and the predominant transport mode. Depending on the transport mode most used by the respondent there were made a different set of questions. Those who indicate the predominant use of private car were asked, among other issues, how much they would be willing to pay for having guaranteed parking on campus, and (by hypothesis or not) in the case of having access to conditional parking, how much they would accept to receive as a compensation for giving up of this privilege. Further, those usually going by car were also asked about the value of the city's urban transport pass free percentage that they would be willing to consider as 'enough' to make then change the transport mode towards the public service. The idea is that this process further allows the study of commuters' reaction to potential suggestions that have emerged regarding the attribution of a price to parking (Tolley, 1996; Brown et al. 2001; Balsas, 2003;; Shang et al., 2007; Anastasiadou et al., 2009; Khodaii et al., 2010).

Concerning the regularity of commuting travels to the UC campus, from the sample of 217 individuals, 75.6% have reported travelling five or more days per week, 14.7% four days per week, and the remaining 9.7% three or less days per week. 41.5% of respondents revealed that they regularly walk to the UC Campus, 32.3% drive (of which, 82.9% drive their own car, and 42.9% travel alone), and 25.3% stated that they regularly take public transport. However, when questioned if they had ever used a public transport alternative during the previous month (even if this option is not the most frequent one), the majority (51.2%) answered positively.

Those who mainly use cars were also asked to indicate their satisfaction with parking availability and the flow of traffic within the campus. Most of them (52.2%) reported being very dissatisfied with the availability of parking, and 40% declared the same attitude towards the traffic flow. A similar question was asked exclusively to respondents who indicated that they commute mainly using public transport. Half of these individuals gave a positive evaluation of the public transport service, and only 25.9% declared their dissatisfaction in this respect. The disparity between the levels of satisfaction for these two groups of respondents also suggests the existence of significant welfare losses associated with travelling to the campus by car.

Concerning the 10 statements about potential measures that could lead to an individual public transport increase, 87.7% of the car drivers declared that they would be receptive to use public transportation on the basis of a waiting time reduction; 79.7% stressed the role of increasing public transportation feasibility and 77.1% considered a reduction on travel time as critical. Comfort improvements were mentioned by 63% of the respondents. Finally, only 4.4% of the drivers said that they would not abandon the use of car in favour of public transportation in any circumstances. Car drivers were also invited to reply to several questions about their willingness to accept compensation in return for a modal change to public transport. One of these questions concerns the minimum percentage of the pass for unlimited access to public transport that they would be prepared to accept in order to change their method of commuting to the Campus by car. Surprisingly, 49.1% were prepared to accept a compensation equivalent to 50% of the cost of it, and only 26.4% said that this remedy would be totally unavailable to them irrespective of the subsidy.

Accordingly, the analysis demonstrates that decreasing parking subsidization should not only reduce car driving (relative) attractiveness, but can also constitute an important source of revenues to encourage car drivers to use public transport. Indeed, an important number (73.6%) of car drivers exhibit a positive willingness to accept compensation in order to use public transport.

3. Measuring environmental impacts of changes in commuters’ modal split

This section presents the main methodological issues regarding the calculation of life-cycle energy requirements and greenhouse gas (GHG) emissions associated with the alternative scenarios to address potential changes in parking and traffic policies. This section also presents the foundations for settling six specific scenarios, as well as the corresponding estimated changes in final fuel and electricity consumption by passenger cars and buses, life-cycle energy requirements and greenhouse gas (GHG) emissions.

3.1. Methodology: Life-Cycle Energy requirements and Greenhouse gas emissions

To calculate the overall impacts associated with alternative parking and traffic scenarios a Life-Cycle (LC) approach must be employed. The LC approach offers a comprehensive picture of the flows of energy and materials through a system and gives a holistic and objective basis for comparison among the various alternative scenarios. The most well-known Life cycle approach or tool is the Life Cycle Assessment (LCA) methodology (ISO 14040, 2006). LCA is based on systems analysis, treating the product process chain as a sequence of sub-systems that exchange inputs and outputs. The results of an LCA quantify the potential environmental impacts of a product system over the life-cycle, help to identify opportunities for improvement and indicate more sustainable options where a comparison is made. The LCA methodology consists of four major steps (ISO 14044, 2006): definition of the goal and scope; Life-Cycle Inventory (LCI); Life-Cycle Impact Assessment (LCIA) and Interpretation.

The calculations performed in this research and presented in this section followed the LCA methodology but focus in 2 types of LC impacts: primary energy and Greenhouse Gas (GHG) emissions. Primary energy is the sum of the final energy with all the transformation losses, with fuel primary energy values being greater than their final energy values. In fact, consumers buy final energy, but what is really consumed is primary energy, which represents the cumulative energy content of all resources (renewable and non-renewable) extracted from the environment. Life-cycle GHG emissions can be calculated by summing up the GHG emissions of the several LC stages, namely: vehicle and all infrastructure production; fuel production and/or electricity generation and, last but not least, the transportation process itself with fuel combustion (in the case of vehicles with internal combustion engines). A number of GHG have been considered in the calculations, but the most important one is carbon dioxide (CO_2) followed by methane (CH_4) and nitrous oxide (N_2O), with average global warming potentials (GWP) of 25 for CH_4 and 298 for N_2O, in 100 year-time horizon. The Global Warming Potentials used by the IPCC provide “CO_2 equivalence” factors for greenhouse gases other than CO_2, which allows aggregation of emissions of different gases into a single metric (IPCC, 2007). In terms of global warming, a GWP of 25 (for CH_4) means that 1 g of methane released to the atmosphere is equivalent to the release of 25 g of carbon dioxide. In practical terms, GHG emissions in each step are multiplied by the respective equivalence factors and summed up yielding a single figure in CO_2 equivalents. Finally, the GHG emissions of the overall transportation scenario can be calculated for the 6 scenarios presented in Table II, relatively to the BAU situation. The calculations have been performed based on the total number of kilometres driven per type of transportation mode associated with each of the scenarios. Table II summarizes the final energy (fuel/electricity) consumption required by the various types of transportation vehicles. Diesel and electric bus consumption was calculated from fleet actual annual consumption data, collected from the City bus company (SMTUC, 2010). Data for passenger electric car was estimated based on Marques and Freire 2012. Consumption data for diesel and petrol car is based on European fleet average data (Spielmann, 2007).

Table II – Final vehicle energy consumption

Vehicle	Fuel/electricity	Units
Diesel car	6,6	L/100 km
Petrol car	8,1	L/100 km
Electric car	16	kWh/100 km
Diesel bus	51,2	L/100 km
Electric Bus	300	kWh/100 km

3.2. Scenarios definition

This sub-section presents the main reasons and assumptions taken to define several scenarios on potential changes in parking and traffic policies, which are focused on eventual modifications in commuters' behaviour, namely changes in the modal split towards the use of public transport. Indeed, changes in the number of cars crossing the Campus, as well as in students and workers modal choices influence transports' environmental impacts at the UC Campus.

Through the counting processes explained in section 2, it was estimated the total amount of kilometres per year travelled by cars and (electrical and diesel) buses within the UC Campus. This allowed the depiction of the Business as Usual (BAU) scenario. Then, considering the hypothetical application of different parking and traffic policies, mostly founded on the results shown in the previous section, six different scenarios were derived.

Before defining each scenario, it is worth note that it is all of them consider an increase in public transportation efficiency. Indeed, it is considered that the observed average occupation rate (32%) in the buses that serve the Campus can increase up to 70% without the need to bring additional buses to the Campus. In other words, the reductions in the use of cars (and taking into account the observed average occupancy rate of 1.2) to travel to the Campus considered in the scenarios, are 'compensated' by a corresponding increase in the number of bus passengers, which will result in a greater number of buses travelling through the Campus only when the occupation rate would surpass 70% if the number of buses remained equal.

The first scenario considers that an effective control of illegal parking banishes this practise, contributing to reduce the number of cars in the Campus by approximately 10%. Accordingly, the corresponding growth in the number of bus passengers would be completely absorbed by existing buses (since it is compatible with an occupancy rate below 70%).

The second scenario considers banishing all the parking places except the conditional parking access for UC staff (TB). This would result both in a decrease of approximately 55% in the number of cars and in an increase of one bus per day travelling in the Campus.

The third scenario is similar to the previous one, with the exception of the hypothesis that all the diesel buses travelling in the Campus would be ‘substituted’ by electric buses.

The fourth scenario considers a new traffic/parking policy that would only allow electrical vehicles (either private/individual or public/collective) in the UC campus. Further, it is assumed that the percentage of electrical cars can represent, in the near future, nearly 5% of the present number of cars. Concerning the public transportation service, these hypotheses would mean the need to increase the number of (electric) buses travelling in the Campus in 44 buses per day.

The following two scenarios consider a traffic/parking policy less restrictive than the one in the previous scenario, namely that regarding public transportation services only electrical buses would be allowed to circulate in the UC campus (but diesel or petrol cars can circulate). The distinctive additional assumptions taken in each of these scenarios result specifically from the survey analysis, namely regarding the application of the “Willingness to Pay” and “Willingness to Accept” concepts.

Thus, the fifth scenario considers drivers’ reaction to the introduction of a parking price of two Euros per day for all places in the Campus. Indeed, according with the survey results, only 11% of the drivers are available to pay an amount over two Euros per day to park at the Campus. Thus it is considered that 89% of the drivers would stop driving to the Campus, implying the need to reinforce (more 38 buses per day) the provision of (electric) public transportation.

The sixth scenario reflects driver’s answers concerning the Willingness to Accept concept. In the survey, drivers were asked about the value of the city's urban transport pass free percentage that they would be prepared to accept in order to consider a modal change in favour of public transportation services. Thus, as 73.6% of the drivers stated that they would be available to take the decisive step of changing to public transportation if there is a reduction in the cost of this service, we consider that all of these will cease using their cars if the University or the City Council take any kind of policy that could result in a reduction of the public transport cost supported by UC campus commuters. Further, in order to accommodate this modal change, the supply of public transportation services in the Campus would have to increase 20 buses per day.

3.3. Results: estimated environmental impacts

Table III presents the results of all the scenarios in terms of *total km driven* by each transportation type: fuel and electric cars; diesel and electric buses. The variation relatively to the BAU situation is also presented (Dif. BAU).

Table III – *Total km driven* by transportation mode in the scenarios considered

		Total km driven			
		Fuel Cars	Diesel Buses	Electric Buses	Electric Cars
BAU		1 640 000	25 500	6 400	--
Scenario 1	Value	1 474 852	25 500	6 400	--
	Dif. BAU	*-165 148*	--	--	--
Scenario 2	Value	727 012	25 718	6 455	--
	Dif. BAU	*-912 988*	*218*	*55*	--
Scenario 3	Value	727 012	--	32 391	--
	Dif. BAU	*-912 988*	*-25 500*	*25 991*	--
Scenario 4	Value	--	--	44 176	82 000
	Dif. BAU	*-1 640 000*	*-25 500*	*37 776*	*82 000*
Scenario 5	Value	175 480	--	42 399	--
	Dif. BAU	*-1 464 520*	*-25 500*	*35 999*	--
Scenario 6	Value	436 240	--	37 441	--
	Dif. BAU	*-1 203 760*	*-25 500*	*31 041*	--

These estimations allow asserting that Scenario 4 is the one that considers the most relevant decrease in terms of fuel cars use in the Campus. However, it is also worth to note that this is the single scenario where the existence of electric cars is considered, and further that it is the one where the most significant use of electric buses is considered. Scenario 5 follows as the best in terms of reduction in car use, suggesting that the attribution of a price to parking can effectively contribute for reducing the number of cars in the Campus.

Following the methodology presented in section 3.1 and considering the *total km driven* by transportation mode in each of the scenarios considered, it was possible to calculate the final electricity and fuel required, as well as the Primary Energy consumption and LC GHG emissions, as presented in Table IV.

Table IV –Energy Consumption and LC GHG Emissions

	Electricity consumption (kWh)	Fuel (Liters)	Primary Energy (MJ)	LC GHG Emissions (kg CO_2eq)
BAU	19 456	133 809	5 695 718	501 718
Scenario 1	0.0%	-9.1%	-8.8%	-9.1%
Scenario 2	0.9%	-50.2%	-48.3%	-50.3%
Scenario 3	406.1%	-60.0%	-45.8%	-49.5%
Scenario 4	656.1%	-100.0%	-76.7%	-83.7%
Scenario 5	562.5%	-90.3%	-70.3%	-76.8%
Scenario 6	485.0%	-76.0%	-58.9%	-64.0%

The results show that scenarios 4, 5 and 6 present significant reductions in LC GHG Emissions, due to important decreases in Fuel Energy consumption, but also to the technological change towards electric buses (as well as to electric cars in scenario 4).

The results for Scenario 1 show that if local authorities really control illegal parking it would have relevant effects, not only in terms of fairness, but also in terms of the quality of life associated with both the reduction in GHG emissions and more and better areas for walking (as non-regular parking occurs predominantly in pedestrian walking zones).

Through scenario 2 is possible to conclude that restricting private car use at the campus for those who have access to UC staff conditional parking can result in a reduction of Primary Energy consumption and GHG emissions to nearly half of the current ones. Scenario 3, where diesel buses are ‘substituted’ by electric ones, presents savings in Primary Energy consumption and GHG emissions almost as important as the ones in the conditions of scenario 2.

Scenario 4, the most extreme one, where only electrical vehicles can circulate, is the one in which parking and traffic management is more efficient regarding (final and primary) energy consumption and GHG emissions. Indeed, the results underscore the positive environmental impacts of substituting the intensive use of cars by well-organized public transportation services.

Additionally, the estimations for scenarios 5 and 6 show, as in the previous scenario, that well applied parking policies may also contribute to important reductions in energy consumption and GHG Emissions. The attribution of a price to parking and the change in the transportation mode used inside the Campus could significantly contribute to a much more environmental sustainable solution and, in addition, to generate new revenues that can be consigned to contribute for improvements in the service provided by local public transportation authorities. Actually, according with the results presented, the isolated introduction of a parking price of 2 Euros per day has the potential to reduce GHG emissions in more than 75%, while the subsidization of the public transportation pass can contribute to reduce GHG emissions in 64%.

4. Conclusions

This study was guided by two main ambitions: first, to characterize and confront supply and demand for parking at the UC Campus, supporting the derivation of specific contributes and recommendations regarding more adequate traffic and parking management policies; and, second, to assess potential environmental impacts associated with possible corresponding changes in traffic and parking management.

For this was used an ‘integrated modelling approach’, combining, among others: an ad-hoc computation process concerning the existing places available for parking, their location and characteristics; the analysis of reports from the local transport authorities and semi-structured interviews of their managers concerning the analysis of road public transport services supply and characteristics; the counting of traffic flows in order to estimate demand; the creation and implementation of a survey regarding commuters’ characterization and their answers to potential measures towards car use abandon and/or increases in public transportation; and an LCA approach focused in 2 types of LC impacts, namely primary energy and GHG emissions. Accordingly, an approach as comprehensive as the one used in this specific case for a University Campus has the potential to be illustrative of the importance that integrated traffic and parking management measures can have for greening commuters’ transportation and parking in urban areas.

In this case, the area studied is the UC Campus, considered to have an outstanding artistic and architectural value, where approximately 45% of the parking places are free and without any kind of access restrictions. Further, the analysis showed that there are an important number of illegal parking places being used every day. This fact is especially worrying considering that Universities have the potential to influence not only the student’s mobility choices in the present, but also the environmental awareness and habits they can develop in the long term, i.e., they can become powerful forces to reshape the future society’s transportation patterns (Barata et al., 2011).

It was demonstrated that a policy measure as simple as controlling illegal parking may contribute to reduce nearly 10% of GHG emissions due to the transportation use in the Campus. Further, as showed in scenarios 2 to 6, different forms of modal shift from private cars towards public transportation (in this specific case to buses) can also contribute to important emissions reduction. Noteworthy, among the results achieved, the introduction of a parking fee may result in an overall reduction in GHG emissions above 75%. Concurrently, these revenues can be used by the University Administration and/or Local Authorities to subsidize the price of the public transportation pass and/or to improve the quality of the service, promoting the reduction of some resistance to decrease the use of the private car.

Certainly, these results should be considered by local transportation authorities and the University Administration, in order to study the implementation of solutions capable of allowing people to park farther from the University and simultaneously the provision of bus services able to carrying them with feasibility and comfort to anyplace inside the Campus. And one of the most interesting aspects of this comprehensive analysis is that the ones that can take the decisions have the comfort of knowing that UC campus commuters are available to accept such kind of changes and, reinforcing this, are willing to contribute (even if involving some payment) for it. In other words, if commuters' current behaviour is part of the existing problem, it is clear that there is important commuters' disposition to become part of the solution for greening transportation and parking at the University of Coimbra Campus.

Finally, it is worth note that although the results of this research are limited to the UC case, this integrated modelling approach is applicable to many other cases. Indeed, "big universities resemble small cities" (Shoup, 2008:147), and the interventions in traffic and parking demand management at UC can provide important lessons concerning the (positive) environmental impacts that could result of the generalization of this type of policy in most of the University Campus and in historical downtown areas that face the same kind of problems regarding overcrowding, traffic congestion, non-regulated parking and exacerbated car use.

Acknowledgments

This work is framed under the Energy for Sustainability Initiative of the University of Coimbra and was supported by the FCT (Fundação para a Ciência e Tecnologia, Portugal), through the MIT-PORTUGAL program. This work was supported in part by FCT under the following projects: MIT/SET/0014/2009 and PTDC/SEN-TRA/117251/2010.

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