PARKING PROBLEMS AT THE UC CAMPUS: SETTING THE RESEARCH AGENDA

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ABSTRACT

This study underscores the importance of adopting integrated parking management policies that ensure not only more rational use of the available parking spaces, evenly balancing supply and demand and bringing in revenues to cover the parking facilities costs, but also the improved attractiveness of alternative transportation modes.
Parking supply and demand flows within the UC campus are estimated. The results indicate that the parking facility is underpriced and that there is overcrowding. To reflect critically on these issues and identify research areas to address their socio-economic implications, some policy proposals theoretically-engaged but pragmatically-oriented, are discussed.

Keywords: Parking; Parking Policy; Campus; Travel Mode; Public Transport.

1. INTRODUCTION

Parking is a central topic in urban transportation planning and traffic management (Davis et al., 2010; Waters et al., 2006; Shoup, 2006; 1997a; 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 cost (Arnott and Rowse, 2009). Parking in a convenient parking spot tends to be expensive, while finding available curbside parking normally entails spending time and walking some distance. Often, the parking occupancy rate is saturated. Cars cruising for parking further exacerbate traffic congestion, originate accidents, waste fuel and other resources, pollute the air, degrade the pedestrian environment, and restrain levels of accessibility. According to Bonsal and Palmer (2004:322) surveys of drivers undertaken in British cities have indicated that during peak congestion periods, up to 40% of the average total travel time of journeys to central urban areas is taken up in searching for a parking space.
The problems generated by the lack of parking spaces are becoming more acute, particularly in more densely populated areas or at locations with significant restrictions on their ability to implement a sound planned parking supply (Arnott and Inci, 2006).
As a location that provides all staff and students with a place for their working, studying and even living, the provision of parking constitutes one of the most troublesome transportation

problems at many university campuses, all over the world (Alshuwaikhat and Abubakar, 2008; Shang et al., 2007; Balsas, 2003). This is true also for the University of Coimbra (UC) campus (Polo I) with a large number of commuters travelling to the University campus using their own cars.

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 a candidacy to UNESCO (United Nations Educational, Scientific and Cultural Organization) world cultural heritage[1] site in 2010.

The need to ensure a balance that does not jeopardize the normal fruition and preservation of these cultural heritage goods constitutes a challenging research agenda. This paper intends to establish a 'descriptive model', from which can be derived some opening contributions addressing a significant dimension of this challenge, concerning traffic management and parking issues within the UC campus. The analysis is organized as follows. Section 2 provides a review of the literature on the economics of parking. In Section 3 the analysis of parking supply and demand within the UC campus, will be implemented. Section 4 concludes the paper analyzing the main results of this research and anticipating some directions for future research.

2. LITERATURE

Once a comparatively neglected area of research within transport demand management policy, the study of parking is now receiving considerable attention as policy-makers and researchers are increasingly aware of the pivotal role that parking spaces and their regulation play in urban structures, modal choices, congestion, the economy and the environment (Blanco et al., 2009; Shoup, 2006; Albert and Mahalel, 2006). In spite of recent contributions, the literature on the economics of parking is still not abundant (Arnott and Inci, 2006). Early work on the economics of parking argued that parking, like any other commodity, should be priced at its social opportunity cost (Vickrey, 1954 *apud* Arnott and Inci, 2006). For decades, parking was largely ignored by economists in modal choice studies, being treated simply as a component of the fixed cost of a trip (Arnott and Rowse, 2009). Shoup has been leading the growing interest in the economics of parking. In the 1990s, he evaluated a cashing out employer-provided parking system (Shoup, 1997a), and has

[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".

considered many aspects of the economics of parking since then (Shoup, 2006; 1999; 1997b; Brown et al., 2001; King et al., 2007).

An economic analysis of the intricacies associated with the possibilities and effects of regulatory parking policies, focusing on the differences between the use of parking fees and physical restrictions on parking space supply, as a potentially decisive instrument for influencing traffic flows, was originally proposed by Verhoef et al. (1995). These researchers suggested that, despite important fundamental objections, regulatory parking policies are likely to offer an interesting alternative for urban traffic regulation. Later, Arnott and Rowse (1999) suggested a formal economic analysis which provides a conceptual basis to study the potential efficiency gains from parking fees or the effects of parking on congestion. The authors conclude that the parking fees should be set at the value of the parking congestion externalities (Arnott and Rowse, 1999:122). Further developments include an important contribution by Shoup (1999), where urban planners' imposition of minimum parking requirements to satisfy the peak demand for free parking is censured, considering that, he argues, it increases the supply and reduces the price, but not the cost, of parking, which means the existence of subsidized parking (ultimately parking is never actually free). Underpriced curb parking leads to mismanagement of scarce urban land, with widespread ramifications for transportation, land resources, the economy, and the environment (Dorsey, 2005). As a means to remove this distortion, Shoup (1999:570) suggests that cities should price on-street parking rather than require off-street parking.

Murray (2001) argues that the critical challenge for urban planners and decision-makers is to identify effective strategies for dealing with resistance to travel by public transport. In many large cities, particularly in Europe, parking fees are being implemented mainly to rebalance the modal split between private car and alternative public transit systems, stressing the potential of parking pricing strategies as Transportation Demand Management (TDM) policies in congested urban areas (D'Acierno et al., 2006). Moreover, the parking revenues are frequently used to cover parking facility costs, but could also fund improvements on other traffic and transportation components favouring their corresponding acceptability.

Kelly and Clinch (2006) review a number of studies which have considered the effectiveness and issues surrounding parking policy as a TDM tool, both in isolation (Verhoef et al., 1995; Arnott and Rowse, 1999) and in tandem with other TDM policies (Calthrop et al., 2000; Marshall and Banister, 2000).

The indication that there is a systematic opportunity cost associated with parking, has been invoked to support an enhanced approach which involves offering an incentive to drivers to opt for modes of residence-workplace travel that do not require parking facilities. The introduction of parking 'cash out' strategies (employees can be offered a cash-value *in lieu* of a parking space) is one such incentive (Watters et al., 2006; Shoup, 1997a). In general, however, the car is the most attractive mode of transport with convenience, speed, comfort and individual freedom featuring as the recurrent benefits. Hence, a decline in car use should not be expected simply by requesting individuals to do this voluntarily. Consequently, in addition to providing an economic incentive to reduce car dependence, it is crucial to articulate several approaches to adjust the potential alternatives to the attributes required by consumers to accept a modal shift[2]. Mardsen (2006) provides a review of the literature relating to the observed or stated behavioural responses of travellers to a series of real and hypothetical parking policies, concluding that parking policies should not be developed in isolation but as part of local and regional spatial and transport planning processes (Mardsen, 2006:448). Parking policies act as the intersection between the implementation of land-use and transport policies. Therefore, the objectives that parking policies should accomplish derive from the overall objectives of urban policy that typically include a strong economy supported by an efficient transport system, better accessibilities, a superior urban environment quality, a safe and secure atmosphere, and a more equitable society.

Overall, few systematic reports of studies on University or College campus parking problems can be found in the literature (Shang et al., 2007:135). These campuses seem particularly well suited for a TDM strategy that props up cost-effective solutions to parking problems (Shannon et al., 2006). They are communities with very distinct characteristics, where people of different backgrounds, incomes, lifestyles and attitudes come together to live, study, work, and recreate. Therefore, they can constitute a laboratory for testing and implementing various alternative TDM strategies, reducing infrastructure costs and minimizing their impacts on surrounding areas. According to Balsas (2003), one aspect often overlooked by campus administrators and planners is the college's potential to affect the transportation habits and the environmental awareness that students can develop in the long term, since students are more open-minded and have the potential to become 'movers and shakers'.

In order to secure a better understanding of the potential for modal change, the barriers and motivators affecting staff and student travel decisions, and what Universities could do to encourage a modal change from the single occupant vehicle to alternative modes, Shannon et al. (2006) implemented a survey at the University of Western Australia, confirming that Universities are major trip generators and suggesting that reducing actual and perceived travel time by alternative modes would have the greatest impact on commuting patterns. Additionally, some TDM strategies appeared to hold particular promise, including the implementation of a subsidized public transport pass and increased cost of parking.

Dorsey (2005) presents an insightful revision of multiple TDM interventions, including the above-mentioned subsidized public transport pass (sometimes also called UPass, ClassPass, Eco Pass, or Ed Pass programme, but collectively referred to as Unlimited Access). Unlimited Access programmes are frequently based on partnerships between universities and public transit agencies in which universities acquire large amounts of discounted transit passes, then allocated among staff and students. These 'free transit passes' might be funded with student fees, parking receipts[3], or through innovative partnerships with local municipalities. Besides being a truly integrated TDM strategy, the Unlimited Access programme potentially reduces the demand for parking, increases student access to housing and employment, helps universities recruit and retain students, reduces

[2] Public transport systems will only be a viable travel alternative if they are capable of getting people from where they are to where they need to be in a reasonable amount of time and comfort (Murray, 2001:176). Research has shown that reliability (being on time) is a decisive factor. The problem is not so much having to wait, but the uncertainty of when the transport will arrive. Other attributes reported as having a major negative impact on consumer satisfaction are travel time and fare level (Litman, 2009). Recent studies have revealed that experience of public transport can reduce drivers' negative perceptions (Balsas, 2003). To induce public transport experience among car users, several initiatives can be used, such as free trips or reduced fares (Beirão e Cabral, 2007:487).

[3] In addition to a comprehensive approach to promote alternative transportation modes, car use (namely parking) is expected to be charged at full cost and the funds redistributed to improve those alternative options.

the cost of attending university, increases environmental and societal benefits, as well as transportation equity (Brown et al., 2001). A survey of eight American University campuses (Balsas, 2003) showed that automobile trips have been reduced by 10-30% in some cases. Unlimited Access programmes have led to increases in student ridership up to 400% during the first year of the programme operation. In subsequent years, ridership increases ranged from 2% to 10% per year. Dorsey's (2005) findings support earlier analyses and underline analogous successes.

Due to the requirements concerning the UC campus UNESCO candidacy process, increasing congestion, lack of land for parking, the high cost of constructing new parking structures, pressures to reduce traffic's impact on surrounding neighbourhoods, and constraints on financial resources, UC administrators should not discount the possibility of exploring a range of environmentally-appealing solutions to alleviate current significant parking deficits and improve the overall quality of life for all campus users. This research agenda must include solutions based on the concept of transportation demand management, which indeed include market prices for parking, as well as expanded transit access, park and ride lots complemented by bus shuttles, rideshare programmes, bicycle and pedestrian facilities, etc..

3. PARKING FLOWS ANALYSIS

Firstly, an analysis was made concerning the existing places available for parking, their location and characteristics. Next, the inflow and outflow of vehicles was computed in order to assess the quantitative dimension of the potential parking problem at the UC campus.

3.1 The Supply of parking places

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	574	42,5
(TC)	Non-regular parking	136	10,1
(TD)	On-street paid parking	132	9,8
	Total	1351	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. A more detailed scrutiny of the number of parking places available in each of the sites with conditional access to UC staff members (TB parking places type)[4] is presented in Table II, below.

Table II: Parking places with conditional access to UC staff (TB)

Parking site	Number of places	Estimated dimension
(P1) Rector, Fac. of Law and Humanities	125	4 745 m^2
(P2) Colégio São Jerónimo	187	4 085 m^2
(P3) Colégio das Artes	95	4 462 m^2
(P4) Faculty of Medicine	90	2 959 m^2
(P5) Department of Mathematics	45	1 501 m^2
(P6) Department of Chemistry	32	391 m^2

Parking places with conditional access to UC staff are managed by the university administration. Access cards, which are generally subject to the payment of an annual fee (160€ in 2009), in spite of being issued on an over-the-booking basis, are largely insufficient to meet the current demand.

3.2 The Demand for parking places

The previous figures allow a succinct quantification of the supply of parking places at the UC campus. The parking supply is mainly a function of the physical conditions and the existing infrastructures. On the other hand the demand for parking computation is not so straightforward. 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 parking demand at the UC campus is the counting of traffic flows - a methodology commonly used in traffic and parking demand studies (see, e.g. Shang et al., 2007). 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, i.e., this approach allows the identification of incremental changes and their evolution through the period being considered.

3.2.1 Parking flows modelling hypotheses

Following, and bearing in mind the specificities already identified, an outline of the main hypothesis and procedures considered to assemble and perform the parking flows model will be presented.

1. In accordance with the traffic regulations and practices within the area, it was considered that counting, at the busiest time of the day (i.e. between 7:30 and 10:00 am), on the two main entrances – (L1) Padre António Vieira Street (entry direction only) and (L2) Calçada Martim de Freitas – and two main exit gates – (L3) Calçada Martim de Freitas and (L4) Couraça de Lisboa Street (exit direction only) – would represent a major segment of the overall campus traffic flows (i.e., flows at other less used gates were assumed as residual and therefore, not significant).

[4] According to figures made available by the UC administration.

2. The counting process includes only passenger cars and goods vehicles (buses were not considered in this analysis, as they are supposed to pass through the campus without parking).
3. Drivers follow the traffic rules concerning the driving, but it is admitted that they do not always obseve the rules applying to parking.
4. Parking places available on campus were classified according to five types (TA, TB, TC, TD e TZ):
   - TA includes the free parking places (TA1 = 484), as well as the parking places reserved for occasional non-UC staff and for people with disabilities (TA2=25);
   - TB comprises the 574 places reserved for the full complement of UC staff;
   - TC corresponds to the 136 non-regular places;
   - TD comprises the 132 on-street paid parking places;
   - TZ includes places already occupied (by residents) before the beginning of the counting process (i.e., before 7:30 am) and that meanwhile may became vacant.
5. Drivers without access to reserved parking places (TB) will preferably park on places free of charge (TA). When all free legal parking places become occupied, drivers are supposed to opt for non-regular spaces (TC), assuming the risk of being fined. Only as a last option will drivers consider the possibility of parking at on-street paid places (TD)[5].
6. The occupancy in conditional parking slots (TB) is estimated taking into account the campus rate of entry/exit flows of vehicles, as well as the rate of occupancy verified at all these parks before 7:30 (H0) and by 10:00 am (H16), for each working day.
7. The exit of cars estimated for the Couraça de Lisboa Street, throughout the week, is the result of a projection from the records collected in one single day[6].
8. When a parking place becomes occupied, it is assumed that such space will not be free until the end of the counting procedures.

The flows matrix and corresponding parking places occupancy that result from the application of this modelling approach should allow for a fairly accurate representation of the parking demand intensity (as well as of the interrelated level of supply saturation), since it proposes an estimation, for each time interval considered, of the parking places potentially yet vacant (or the associated excess of demand over supply). Nevertheless, the inability to establish the period of time that each vehicle remains inside the campus is a clear limitation of this model since it prevents an understanding the characteristics of the time spent looking for a parking place. Furthermore, it should be noticed that, in accordance with hypothesis 8, those drivers who access the campus after the saturation of parking places will be considered as leaving the campus without finding a place, despite the fact that it is not unequivocal that drivers leaving the campus at a specific moment do so because that is their

[5] It should be noted that these parking places, besides requiring an immediate payment, are those more distant from the majority of the University buildings, i.e. they involve additional walking time from the parked car to the final destination and back.

[6] The counting procedure at the exit gate of Couraça de Lisboa Street took place only once. The volume of outgoing vehicles counted was then used to estimate proportionally the traffic flows on the remaining days of the week. However, taking into account that the maximum value observed for the flows is significantly lower than the ones observed in all the other gates, this procedure will not distort the analysis.

own will or because they did not find a place to park. Despite these limitations, the associated potential bias on results is expected to be residual.

3.2.2 Matrix of the campus inflows and outflows of vehicles

The incoming and exiting vehicles at the gates mentioned in hypothesis 1 were counted, for every ten minutes, between 7:30 and 10:00 am[7], for the five working days of a 'typical' week (i.e., a middle week of the first semester 2009/10). Additionally, according to the different characteristics and access conditions of the existing parking places, the analysis of the flows at the different gates was articulated with a cautious observation of the parking lots reserved for UC staff (TB) occupation; i.e., the (entry and exit) counting of vehicles was systematically preceded and followed by counting the vehicles parked in sites of conditional access (P1 to P6). The quantity of cars located in the campus before 7:30 am (TZ) was also weighed, as they limit the number of available parking places[8].
These hypotheses allowed the construction of a set of matrices, one per each working day of the week (see Annex), with the structure presented in Table III, bellow.

Table III: General Structure of the Parking Flows Matrices and Occupancy of Parking Places

Week day

	L1	L2	L3	L4	Δ Total	Accumulated	TA	Δ TB	TB	TC	TD	TZ
Time interval	A0=G0+H0+J0					(F0=A0)	G0	0	H0	0	J0	
7:30 - 7:40	A1	B1	C1	D1	E1= A1+B1-C1-D1	F1=F0+E1	F1-H1	I1	H1=H0+I1	0	J0	
7:40 - 7:50	A2	B2	C2	D2	E2= A2+B2-C2-D2	F2=F1+E2	F2-H2	I2	H2=H1+I2	0	J0	
7:50 - 8:00	A3	B3	C3	D3	E3= A3+B3-C3-D3	F3=F2+E3	F3-H3	I3	H3=H2+I3	0	J0	
8:00 - 8:10	A4	B4	C4	D4	E4= A4+B4-C4-D4	F4=F3+E4	...	I4	H4=H3+I4	0	J0	
8:10 - 8:20	A5	B5	C5	D5	E5= A5+B5-C5-D5	F5=F4+E5	...	I5	H5=H4+I5	0	J0	
8:20 - 8:30	A6	B6	C6	D6	E6= A6+B6-C6-D6	F6=F5+E6	509	I6	H6=H5+I6	F6-H6-509	J0	
8:30 - 8:40	A7	B7	C7	D7	E7= A7+B7-C7-D7	F7=F6+E7		I7	H7=H6+I7	F7- H7-509	J0	
8:40 - 8:50	A8	B8	C8	D8	E8= A8+B8-C8-D8	F8=F7+E8		I8	H8=H7+I8	...	J0	
8:50 - 9:00	A9	B9	C9	D9	E9= A9+B9-C9-D9	F9=F8+E9		I9	H9=H8+I9	136	J0	
9:00 - 9:10	A10	B10	C10	D10	E10= A10+B10-C10-D10	F10=F9+E10		I10	H10=H9+I10		F10-H10-645	
9:10 - 9:20	A11	B11	C11	D11	E11= A11+B11-C11-D11	F11=F10+E11		I11	H11=H10+I11		132	
9:20 - 9:30	A12	B12	C12	D12	E12= A12+B12-C12-D12	F12=F11+E12		I12	H12=H11+I12			F12-H12-777
9:30 - 9:40	A13	B13	C13	D13	E13= A13+B13-C13-D13	F13=F12+E13		I13	H13=H12+I13			F13-H13-777
9:40 - 9:50	A14	B14	C14	D14	E14= A14+B14-C14-D14	F14=F13+E14		I14	H14=H13+I14			F14-H14-777
9:50 - 10:00	A15	B15	C15	D15	E15= A15+B15-C15-D15	F15=F14+E15		I15	H15=H14+I15			F15-H15-777
TOTAL = ∑	A16	B16	C16	D16	E16			I16	H16			

It should be noticed that the completion of column TB derives from modelling hypothesis 6. Thus, for example, I1=(A1+B1)/[A16+B16)*(H16-H0)].

[7] Counting the incoming and exiting vehicles between 7:30 and 10:00 am is expected to allow an appropriate picture of the demand for parking places at the UC campus. Indeed, anticipating the survey´s results that will be discussed in the following section, from those who indicate the car as the most used commuting mode, approximately 75% indicated arriving at the UC campus usually before 10:00 am, and almost 59% of these people stay on campus for more than six hours.

[8] This procedure was considered in order to obtain better adequacy between the theoretical discussion and the empirical reality, as the availability concerning free parking places cannot be considered analogous to the conditional or reserved parking places.

3.3 Results

On average (considering the five working days), the parking demand for the six parking sites with conditional access to UC staff (P1 to P6), as well as the corresponding average rates of occupancy registered at 10:00 am, is as presented in Table IV, below.

Table IV: Occupancy in Parking Places with Conditional Access to UC Staff (TB)

Parking site	Maximum Availability	Average occupancy (by 10 a.m.)	Average occupancy rates (%)
(P1) Rector, Fac. of Law and Humanities	125	105,1	84,0
(P2) Colégio São Jerónimo	187	110,6	59,1
(P3) Colégio das Artes	95	78,8	82,9
(P4) Faculty of Medicine	90	68,2	75,8
(P5) Department of Mathematics	45	35,2	78,2
(P6) Department of Chemistry	32	27,8	86,9
Total	574	425,6	74,2

According to Table IV, at 10:00 am, despite being relatively high, TB parking places[9] are not totally saturated, varying from 59,1% (P2) to 86,9% (P6).

On the other hand, besides the demand flows for these six parking sites (TB), total demand for parking on the UC campus includes demand for free places (TA), on-street paid parking (TD), and parking at non-regular spaces (TC). Output data from this modelling approach (see tables in Annex), 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), these 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 am on Tuesdays, although it is estimated that they become saturated earlier on the other weekdays, namely by 9:00-9:10 on Mondays and Fridays, 9:30-9:40 on Wednesdays, and 9:40-9:50 on Thursdays.

Another aspect of this analysis concerns the drivers' behaviour when they do not find a suitable parking place. The two main options to be considered include cruising while they wait for a parking spot or exiting the campus. Naturally, as the number of total available places decreases, the percentage of cars leaving the campus in relation to the incoming vehicles, is expected to increase. Indeed, data in Table V below confirm this proposition.

Table V: Proportion of outgoing/incoming vehicles [(1)]

Type of parking place yet available	Average incoming	Average outgoing	Outgoing/Incoming (%)
TA, TC and TD	608	188	30,9%
TC and TD	460	207	45,1%
TD	302	148	49,1%

[(1)] Per type of parking places yet available, according to parking flows modelling hypotheses.

[9] This study´s authors are firmly convinced that these average occupancy rates are underestimated; indeed, the number of places available in each of the parks with conditional access to UC staff was provided by the UC administration, but through the process of counting the number of vehicles parked by 10 am, it became clear to the surveyors that the number of vacant places was generally lower than the 'theoretical' difference between the 'maximum availability' and the 'average occupation'.

According to the figures in Table V, while TA parking places are not exhausted, 30.9% of the cars entering the UC campus are expected to leave during the same time span. In turn, when the available places only include TC and TD, the rate of cars leaving the campus is expected to increase to 45.1%. Finally, when there are only TD available places, the percentage of cars that leave the campus should correspond to 49.1% of the incoming vehicles.

Finally, as stated above, parking places that are reserved for UC staff (TB) are not fully occupied by 10:00 am. Thus, if one admits that the proportion of vehicles leaving the campus versus incoming ones is stable at the average rate (30,9%) until 8:30 (i.e., while there are free parking places available), and assuming, for academic purposes, that non-regular places are not occupied (i.e., TC=0), it can be estimated that the average demand for parking places will exceed supply in the proportion 2,12 vehicles per each free parking space (TA), and on 1,68 vehicles per each free plus on-street paid parking place (TA and TD).

In summary, parking flows modelling analysis has shown that the parking capacity is not enough to meet the current demand, i.e., the UC campus parking system is ineffective causing overcrowding.

4. DISCUSSION AND CONCLUSIONS

This study is guided by one major research ambition, i.e., to establish a 'descriptive model', from which can be derived some opening contributions addressing parking problems within the UC campus.

A literature review on the economics of parking stressed that parking pricing is an essential transportation demand management strategy. The full range of economic parking costs is no doubt complex, with many externalities being hidden. One of the leading barriers to the adoption of less parking-demanding commuting modes, e.g. public transportation, both by the public at large, and by university students and staff, is the low-cost of parking. Underpriced parking supply constitutes a potential perverse subsidy because it encourages drivers to do something that harms other people and may not even benefit the drivers themselves. Additionally, the shortage of parking spaces and poor control over non-regular parking at the UC campus, have boosted these difficulties. Currently, UC campus parking is underpriced and overcrowded. However, we believe that it might be overcrowded because it is underpriced. Indeed, the results of an ad hoc assessment process concerning the available UC campus parking places have shown that more than 45% of the current parking supply does not involve any kind of economic regulation. On the other hand, the modelling results in respect of the parking flows, presented in Section 3, fully demonstrate that the existing parking places are largely insufficient to meet current demand. This conclusion is strengthened by the circumstance that non-regular parking has actually become a 'valid alternative' to face the parking supply shortages at the UC campus (inducing even more externalities).

If one further considers the increasing shortages in educational funding, it is hard to understand why universities persist in subsidizing parking by providing it at no charge, or at prices that do not fully take into account parking costs. Therefore, one of the most obvious measures would be to increase control over non-regular parking and eliminate free on-street parking, encouraging both a modal shift away from private car use and the development of a parking meter revenue sharing plan towards public transportation projects.

Additionally, "colleges and universities must learn to act responsibly not only because it is right to be responsible, but also because it is in their self-interest" (Orr, 1992 *apud* Balsas, 2003). Three arguments can be extracted from this statement. Firstly, if fewer cars are travelling to the Campus, then fewer parking spaces are required, lower maintenance costs are incurred, and the land currently dedicated for parking can be converted to other, possibly more rewarding, uses. Secondly, the University campus may constitute an important laboratory to test and implement new transportation strategies leading to reductions in infrastructure costs and less negative impacts on the surrounding areas. One aspect often disregarded is the potential of academia to influence not only the student's mobility choices, 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. Thirdly, increasing transportation equity reduces the demand for parking, as well as can helping universities to recruit and retain students, reducing the overall costs of schooling and increasing participation in on-campus activities.

In spite of all these arguments, the authors are convinced that the implementation of the proposals in this research agenda is a complex task likely to encounter considerable opposition, namely because campus planners and administrators are expected to be reluctant to embrace such significant changes. However, the city of Coimbra and its University have the potential to take a leadership role and promote environmentally sound programmes well-matched with the preservation of the historical and cultural buildings comprising the Campus, an aim that should be realised especially in the light of aspirations to be classified as a world cultural heritage site by UNESCO.

Finally, despite the results achieved, more profound analyses are required, some of which call for the progress to a 'prescriptive' model. An important path to be pursued includes creating a comprehensive framework for estimating and quantifying the benefits and costs of the current *status quo versus* alternative transportation demand strategies, taking into account economic, environmental, health and societal effects (e.g. travel time, operation costs, noise and environmental emissions, safety and equity).

ACKNOWLEDGEMENTS

The authors of this study gratefully acknowledge the suggestions and advice of Professor Filipe Coelho, as well as Dr João Paulo Barbosa de Melo and Professor Raimundo Mendes da Silva for the very useful interviews granted. The authors also wish to thank the anonymous referees for their insightful comments and suggestions.

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ANNEX

Table A.I: Parking Flows and Occupancy of Parking Places

	Monday											
	L1	**L2**	**L3**	**L4**	**Δ Total**	**Accumulated**	**TA**	**Δ TB**	**TB**	**TC**	**TD**	**TZ**
Time interval	320					320	238		18	0	64	
7:30 - 7:40	19	19	4	4	30	350	259	9	27	0	64	
7:40 - 7:50	23	22	5	6	34	384	283	10	42	0	64	
7:50 - 8:00	47	41	20	11	57	441	320	20	68	0	64	
8:00 - 8:10	67	66	22	14	97	538	386	30	101	0	64	
8:10 - 8:20	65	79	30	10	104	642	457	33	130	0	64	
8:20 - 8:30	83	59	33	16	93	735	**509**	33	159	10	64	
8:30 - 8:40	91	44	26	18	91	826		31	192	70	64	
8:40 - 8:50	83	54	47	16	74	900		31	229	113	64	
8:50 - 9:00	116	76	51	23	118	1018		44	270	**136**	114	
9:00 - 9:10	98	65	64	12	87	1105		37	305		**132**	11
9:10 - 9:20	87	53	59	13	68	1173		32	325			47
9:20 - 9:30	81	58	67	16	56	1229		32	357			71
9:30 - 9:40	73	44	52	15	50	1279		27	384			94
9:40 - 9:50	70	56	57	17	52	1331		29	412			117
9:50 - 10:00	79	37	57	14	45	1376		27	439			136
TOTAL	1082	754	590	205	1041			421	**439**			

Table A.II: Parking Flows and Occupancy of Parking Places

	Tuesday											
	L1	**L2**	**L3**	**L4**	**Δ Total**	**Accumulated**	**TA**	**Δ TB**	**TB**	**TC**	**TD**	**TZ**
Time interval	238					238	163	0	21	0	54	
7:30 - 7:40	21	22	6	4	33	271	186	10	31	0	54	
7:40 - 7:50	30	32	14	6	42	313	215	14	44	0	54	
7:50 - 8:00	66	62	27	11	90	403	276	28	73	0	54	
8:00 - 8:10	61	79	35	14	91	494	336	31	104	0	54	
8:10 - 8:20	68	78	36	10	100	594	404	32	136	0	54	
8:20 - 8:30	74	69	35	16	92	686	464	32	168	0	54	
8:30 - 8:40	79	58	59	18	60	746	494	30	198	0	54	
8:40 - 8:50	81	76	66	16	75	821	**509**	35	233	26	54	
8:50 - 9:00	82	71	66	23	64	885		34	267	56	54	
9:00 - 9:10	80	77	72	12	73	958		35	302	94	54	
9:10 - 9:20	75	62	73	13	51	1009		30	332	115	54	
9:20 - 9:30	71	49	71	16	33	1042		27	359	121	54	
9:30 - 9:40	68	34	62	15	25	1067		23	381	124	54	
9:40 - 9:50	61	42	47	17	39	1106		23	404	**136**	57	
9:50 - 10:00	47	30	49	14	14	1120		17	421			
TOTAL	964	841	718	205	882			400	**421**			

Table A.III: Parking Flows and Occupancy of Parking Places

	Wednesday											
	L1	**L2**	**L3**	**L4**	**Δ Total**	**Accumulated**	**TA**	**Δ TB**	**TB**	**TC**	**TD**	**TZ**
Time interval	260					260	185	0	18	0	57	
7:30 - 7:40	14	26	4	4	32	292	208	9	27		57	
7:40 - 7:50	23	35	6	6	46	338	241	13	40		57	
7:50 - 8:00	60	34	17	11	66	404	285	21	62		57	
8:00 - 8:10	66	53	14	14	91	495	349	27	89		57	
8:10 - 8:20	75	57	20	10	102	597	421	30	119		57	
8:20 - 8:30	73	52	22	16	87	684	480	28	147		57	
8:30 - 8:40	97	62	33	18	108	792	**509**	36	183	44	57	
8:40 - 8:50	88	50	53	16	69	861		31	215	82	57	
8:50 - 9:00	102	63	53	23	89	950		38	252	133	57	
9:00 - 9:10	94	64	63	12	83	1033		36	288	**136**	60	
9:10 - 9:20	71	59	55	13	62	1095		30	318		92	
9:20 - 9:30	66	42	43	16	49	1144		25	342		117	
9:30 - 9:40	69	32	44	15	42	1186		23	365		**132**	4
9:40 - 9:50	74	41	54	17	44	1230		26	391			22
9:50 - 10:00	76	33	57	14	38	1268		25	416			35
TOTAL	1048	703	538	205	1008			398	**416**			

Table A.IV: Parking Flows and Occupancy of Parking Places

Thursday												
	L1	**L2**	**L3**	**L4**	**Δ Total**	**Accumulated**	**TA**	**Δ TB**	**TB**	**TC**	**TD**	**TZ**
Time interval	253					253	174	0	19	0	60	
7:30 - 7:40	16	21	9	4	24	277	190	8	27	0	60	
7:40 - 7:50	21	31	16	6	30	307	208	12	39	0	60	
7:50 - 8:00	64	50	24	11	79	386	261	26	65	0	60	
8:00 - 8:10	68	79	40	14	93	479	321	33	98	0	60	
8:10 - 8:20	74	49	31	10	82	561	375	28	126	0	60	
8:20 - 8:30	71	49	33	16	71	632	418	27	154	0	60	
8:30 - 8:40	80	56	30	18	88	720	476	31	184	0	60	
8:40 - 8:50	83	62	51	16	78	798	**509**	33	217	17	60	
8:50 - 9:00	108	67	59	23	93	891		40	257	70	60	
9:00 - 9:10	97	80	64	12	101	992		40	297	131	60	
9:10 - 9:20	78	64	58	13	71	1063		32	329	**136**	99	
9:20 - 9:30	64	47	61	16	34	1097		25	355		108	
9:30 - 9:40	66	35	49	15	37	1134		23	378		122	
9:40 - 9:50	69	34	45	17	41	1175		23	401		**132**	7
9:50 - 10:00	71	26	46	14	37	1212		22	423			22
TOTAL	1030	750	616	205	959			404	**423**			

Table A.V: Parking Flows and Occupancy of Parking Places

Friday												
	L1	**L2**	**L3**	**L4**	**Δ Total**	**Accumulated**	**TA**	**Δ TB**	**TB**	**TC**	**TD**	**TZ**
Time interval	332					332	227	0	23	0	82	
7:30 - 7:40	21	27	10	4	34	366	250	11	34	0	82	
7:40 - 7:50	24	32	12	6	38	404	276	12	46	0	82	
7:50 - 8:00	45	47	19	11	62	466	318	20	66	0	82	
8:00 - 8:10	75	66	35	14	92	558	378	31	98	0	82	
8:10 - 8:20	73	70	27	10	106	664	453	32	129	0	82	
8:20 - 8:30	82	63	28	16	101	**763**	**509**	32	162	12	82	
8:30 - 8:40	84	70	50	18	86	851		34	196	64	82	
8:40 - 8:50	86	52	45	16	77	928		31	226	110	82	
8:50 - 9:00	111	67	62	23	93	1021		39	266	**136**	109	
9:00 - 9:10	108	63	57	12	102	1123		38	304		**132**	41
9:10 - 9:20	86	47	50	13	70	1193		29	333			82
9:20 - 9:30	75	54	49	16	64	1257		29	362			117
9:30 - 9:40	72	40	43	15	54	1311		25	387			146
9:40 - 9:50	68	35	46	17	40	1351		23	410			163
9:50 - 10:00	65	36	52	14	35	1386		22	432			176
TOTAL	1075	769	585	205	1054			409	**432**			