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## What Happens to Travel Behaviour When Parking is Removed?

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### Abstract

What happens to travel behaviour when the right to park is removed? This controversial question, fundamental to travel demand management and land-use planning, has only been partially addressed by the literature so far. The impacts on travel to the destination concerned have been studied, but not the impacts on wider travel behaviour. This study reports on a natural experiment related to destination parking, where a university removed the right of most new undergraduates living in an 'Exclusion Zone' (a large majority) to park on its main suburban campus. 927 undergraduates, who started before and after the change in policy were surveyed in two waves to assess the impact of the policy on travel to campus, travel elsewhere, car ownership and licence-holding. Observations were also made of overspill parking on surrounding streets and a nearby superstore car park. The policy change was associated with a fall in the modal share of driving to campus of 9 percentage points. Car availability also reduced, although countervailing factors (which may have included road space freed up by the policy change) encouraged modal shift towards driving between the two waves. The policy change also introduced a gender difference in driving to campus for the first time; males without parking permits were more likely to drive than females without permits. The study supports the policy recommendation that modal shift 'carrots' are more effective when accompanied by 'sticks'. It shows that restricting parking at frequently-visited destinations may reduce parking pressures and traffic generation elsewhere in a city or region.

### 1. Introduction and Context

What happens to travel behaviour when the right to park is removed? This controversial question, fundamental to travel demand management and land-use planning, has only been partially addressed. Previous studies of destination and/or residential parking have found varying relationships between parking availability and travel behaviour but there are significant gaps. In general, easier or cheaper parking (at the home or destination) is associated with more driving, whilst parking restraint is associated with less driving, although in many studies the causal relationships and availability of alternative parking or travel options are unclear. Several studies of behaviour change measures have found that restricting parking, or increasing its cost, can influence modal choice in the travel to *that destination*. Many studies have used stated preference methods and some have analysed cross-sectional data. Some studies have analysed aggregate area-based trends over time; some have analysed changes in parking prices. However, a literature search failed to identify any before-and-after studies of the impacts of removing the right to park at a destination on car ownership, licence-holding or travel for other purposes.

The study presented in this paper aimed to address this evidence gap. It evaluates a natural experiment related to destination parking, where a university removed the right of newly-starting undergraduates living in an 'Exclusion Zone' (a large majority) to park on its main suburban campus. Two waves of third-year undergraduates, who started before and after the introduction of the new parking policy were surveyed. Observations were also made during term-time of overspill parking on surrounding streets and a nearby superstore car park during and out of term-time. This paper reports on the differences in the travel

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behaviour, car availability and licence-holding of those students and reflects on the implications for parking policy and travel demand management.

## 2. Literature Review

Constraining the availability of parking is a controversial method for managing travel demand. On one side of the debate Shoup (2005) argues that minimum parking standards impose unnecessary costs on society, through more expensive housing, higher local taxes, environmental externalities and longer travel distances, with the greatest burden falling on the poorest communities. On the other side, the RAC Foundation (2010) argues that sufficient parking capacity is needed to ensure the “flexibility and freedom” desired by motorists and that parking constraints generally fail to influence car ownership or traffic conditions. Thus a normative political debate often focusses on empirical questions about the effectiveness of parking measures as demand management tools.

The empirical literature has established several links between parking conditions and different aspects of travel behaviour. As this study concerns changes to *destination* parking, the literature review will mainly reflect this, although it also examines the wider body of literature on parking (including residential parking) and travel behaviour.

Several studies of travel behaviour change measures have found that changes in parking availability or cost can exert a significant impact on the modal choice of travel to that destination (e.g. Cairns *et al.*, 2010). An ongoing panel study of employment sites in north Bristol, which includes the university campus described below, found greater parking availability encouraged modal switches towards single occupancy car use (Chatterjee *et al.*, 2016). Petrunoff *et al.* (2015) evaluated a natural experiment of two hospital sites in Perth, Australia, both of which introduced positive incentives to reduce driving whilst only one reduced the availability of parking; considerably greater modal shift occurred at the latter. None of these studies sought to assess the impact of these changes on car ownership or travel to other destinations, however.

Many studies of destination parking have used stated preference methods to estimate the impacts of changes in parking prices or availability. Rye *et al.* (2006) surveyed employees who commuted by car to Edinburgh city centre; they estimated that removing free workplace parking and extending the controlled parking zone would reduce car driving by 8 percentage points. Kelly and Clinch (2006) found that non-business travellers were more likely than business travellers to cease parking in central Dublin in response to on-street price increases; the gap between the two groups widened with each hypothetical price increase.

Hensher and King (2001) conducted a stated preference experiment combining different options of pricing and availability (starting at 6.30am or 9.30am) for travellers to central Sydney. They found that changes in pricing had a much greater impact on the decision to drive than did the start time, which simply changed the location of parking or time of travel. They estimated that increasing the daily cost of parking in the centre could nearly double the modal share of public transport whilst causing relatively little overspill parking.

Milosavljević and Simićević (2016) note that studies using revealed preferences generally find higher price elasticities for parking than those using stated preferences. Using both methods they found a larger than projected fall in garage parking in central Belgrade when prices were increased. By analysing cross-sectional survey data for Cambridge, England, Carse *et al.* (2013) found that free workplace parking increases the likelihood of driving to work by a factor of 1.8, suggesting a stronger effect than Rye *et al.* (2006) found in Dublin.

A few studies have analysed the impact of parking and other travel demand measures on university campuses. Riggs (2014) analysed a stated preference questionnaire issued to staff and students at the University of California. This confirmed cost and availability of parking as two factors amongst several that influenced decisions of staff and students not to drive (only 6% of students drove to those urban campuses). Overspill parking on surrounding streets was mentioned as a problem but not quantified. Using cross-sectional data Whalen *et al.* (2013) found that purchase of a student parking permit was a strong predictor of driving to McMaster University in Canada. The permits effectively gave the holder a zero marginal cost of parking once purchased. Pretty (1994) analysed travel surveys conducted before and after the introduction of parking charges at the University of

Queensland in Brisbane. He found they made relatively little difference to modal choice or parking numbers; other parkers took the place of those who chose to park off campus or use another mode.

A larger body of literature has examined the relationship between parking capacity (residential or total), land-use and travel behaviour. This has typically found that cities or neighbourhoods with more parking tend to have higher car ownership and use, whilst parking constraints are associated with low car ownership and use. Some of these studies have used stated preference methods (e.g. Guo, 2013); some have used cross-sectional data (e.g. Weinberger, 2012, Melia, 2014) or hypothetical modelling (Li *et al.*, 2007) and others have analysed aggregate trends over time (e.g. McCahill and Garrick, 2014, McCahill *et al.*, 2015). The last two confirm the expected impacts of gradual increases or gradual reductions in parking capacity but a wider search of this literature failed to identify any before-and-after studies of a specific change in parking availability.

Thus it seems that a question fundamental to policy debates around travel demand management, and around urban policy in general, has only been partially addressed: what happens to travel behaviour when the right to park at a regular destination is removed?

### 3. Study Context

This study was conducted at a university campus where parking constraints were progressively introduced, starting with higher parking prices for staff and students, accompanied by a parking ban applied to newly-starting undergraduates living within an 'Exclusion Zone'.

Frenchay campus is located in a suburban area, on a major ring road, roughly four miles north of Bristol city centre. It is the largest campus of the University of the West of England (UWE), with 2,900 staff and 18,300 registered students. Two railway stations are within walking distance and a city-wide network of cycle routes links to the campus. The roads around the campus are heavily congested at peak times. The campus has been expanding in recent years with substantial growth of student accommodation and some departments transferred from another site. In order to obtain planning permission for several new buildings, UWE has been required to demonstrate how the site can be intensified without increasing traffic generation.

In 2006 UWE hired its first Travel Planner, charged with developing and implementing a strategy to reduce travel to the campus by single occupancy vehicles. A Travel Plan was published in 2008 and updated in 2012. The principal objective in the early years was to improve the quality and frequency of the bus services. From 2007 until 2014 UWE ran a network of tendered bus services with a low flat-rate fare (£3 a day for most of that time). This increased patronage and eventually stimulated competition from the main bus operator in Bristol, which now competes with the original operator on a commercial basis.

Measures to increase the cost and reduce the availability of parking were implemented later, following lengthy discussions with the trade unions and student union. An annual charge of £79 per annum was introduced in 2008 for staff and students, accompanied by a small daily payment. The biggest changes were implemented between 2013 and 2015. The cost of staff parking permits was gradually increased from 0.3% to 0.45% of salary. Student parking permits were increased from £106 to £119 per annum or alternatively a daily charge, which was increased from 75p to £3. An 'Exclusion Zone' was introduced covering the areas of northern and central Bristol, where most students live (see Figure 1). Undergraduates who started at UWE after September 2013 became ineligible for parking permits if they lived within the Exclusion Zone during term time. Exceptions could be made for students with disabilities or childcare commitments. Students who live on the campus are not allowed to park there.

Until early 2016 visitor parking was available at £5 per day. Although students living within the Exclusion Zone were not supposed to use the visitor car park, there was no effective system of enforcement. Unlike the campus study reported by Pretty (1994) the capacity of the Frenchay car parks was not a direct constraint; it was always possible to park somewhere. Early in 2016 the main visitor car park closed and students without permits were no longer allowed to park anywhere on the campus, although UWE's Facilities Department was unable to legally enforce the parking tickets which they sometimes

administered. (That situation changed after the surveys described below were completed, when UWE became registered with the British Parking Association.)



**Figure 1: Frenchay Campus (shaded darker) and the parking permit Exclusion Zone**

The campus is surrounded by residential streets and some retail sites with large car parks. Overspill parking by students (and a few staff) has caused some tension with surrounding residents. UWE has responded by supporting, and in one case helping to finance, the extension of parking controls on surrounding streets, a process which is still continuing; it is still possible to park on some surrounding streets and in the free car parks of some retail outlets, although the one closest to the campus, described below, has since closed down. UWE asks students and staff not to park on surrounding streets but neither UWE nor the residents have any legal right to prevent parking on uncontrolled streets.

The combined impact of these changes on the modal share of travel to Frenchay Campus is shown in Table 1, as measured through cordon count surveys. The cordon counts were conducted on single days in November on the years shown. In the first two years everyone entering on foot was recorded as 'Walk'. In the last two years pedestrians were asked whether they had travelled by car and parked elsewhere, shown as 'Park and Walk' above. The cordon counts did not differentiate between staff and students. Some campus-wide surveys were conducted before 2012 but their sampling methods made them susceptible to self-selection bias, a problem which led the Travel Planner to switch to cordon counts. A small-scale study using similar methods to the ones described below was conducted in 2010 amongst a subset of 305 undergraduates studying built environment subjects (Melia, 2011). 50% stated that they normally drove to the campus with 7% as passengers, suggesting that the modal shift had already begun before the cordon counts shown in Table 1. Car availability during term time (66%) and during the holidays (83%) was also considerably higher than reported in 2015 (Table 4 below).

	2012	2013	2014	2015	Change v 2012
Car on own	39.8%	37.2%	27.9%	26.9%	-12.9%
Park & Walk	N/A	N/A	2.1%	4.5%	4.5%
Car share	16.2%	13.0%	16.9%	14.2%	-1.9%
Bus	25.8%	31.4%	32.3%	33.2%	7.3%
Walk	10.3%	10.7%	12.6%	15.6%	5.3%
Cycle	6.4%	5.7%	6.5%	4.0%	-2.4%
Rail	0.8%	1.4%	0.9%	0.8%	0.0%
Motorcycle/moped	0.6%	0.7%	0.8%	0.8%	0.1%
Sample size	6471	6559	6313	6136	

**Table 1: Cordon Counts Conducted at the Entries to Frenchay Campus**

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Initial concerns about the possible impact of removing parking on applications for undergraduate courses were not confirmed; applications rose by 5% in the year following the change of policy and remained at a similar level for the following two years.

#### 4. Methodology

The aim of the primary research was to analyse the travel behaviour impacts of removing the right to park on campus from undergraduates who started after September 2013. Apart from travel to campus, we were also interested to investigate whether car ownership (or availability) and licence-holding might be influenced by a change in parking rules at a frequent destination.

This was done by comparing the last cohort of third year undergraduates who had the right to park on campus, in 2015 with an equivalent cohort in 2016, most of whom would not have that right. The sampling strategy aimed to survey students in each of the departments represented on Frenchay campus and to repeat the survey at roughly the same time in the Spring term of the following year with students studying the same modules. Modules were selected that were planned to run in the same way in the two years with no significant changes expected to alter the characteristics of the students studying them.

Several steps were taken to minimise the risk of various biases that may affect self-reported travel behaviour surveys (discussed in Melia, 2015a). The questionnaires were distributed at the beginning of lectures with students given a few minutes to complete them before returning them to a researcher, the lecturer or a box on the way out. Those who did not wish to participate were asked to return the form uncompleted. This technique was piloted by Melia (2011) and observed to achieve response rates close to 100%. Anonymity was emphasised and the questions were carefully worded to elicit key information about parking without asking anyone to directly reveal behaviour that the university might disapprove of.

This method did impose some limitations; as time was limited, the questionnaires were designed for ease of rapid completion. This limited the range of data collected, which was not sufficient to build a complete explanatory model of modal choice. The intention was to compare two matched samples for 2015 and 2016, assuming that the only significant change between the two waves would be the eligibility for a parking permit. When the data was analysed that assumption was not entirely satisfied, as explained below.

In order to assess the pattern of overspill parking separate observations were made during 2016 of vehicles parked on surrounding streets and in the car park of a retail outlet close to the campus, where students were believed to park. Two observations were made during term time and one during the holidays when very few students were attending the campus.

#### 5. Survey Findings

507 students completed the survey in 2015 and 420 in 2016. The questionnaires asked about the mode of travel to the campus on that day, the 'normal' mode of travel to the campus and the mode used on the last trip made anywhere for any purpose except travel to campus. Table 2 shows the mode of travel to campus on the day of the survey, excluding the 6% who lived on the campus.

The modal shift towards car driving, mainly at the expense of bus travel, was unexpected. The modal shares of 'normal travel to campus' were similar and the last trip for other purposes showed an even larger (+7%) increase in driving.

Survey Year:	2015	2016	Change <sup>1</sup>
Driver	27.9%	30.4%	+2.4%
Passenger	9.4%	10.4%	+1.0%
Bus	38.4%	34.8%	-3.6%
Walk	15.7%	14.5%	-1.2%
Cycle	5.5%	5.7%	+0.3%
Train	1.5%	2.3%	+0.8%
Motorbike	1.3%	1.6%	+0.2%
Other	0.2%	0.3%	+0.1%
Valid completions	458	385	

**Table 2: Mode of Travel to Campus on the Day of the Survey**

Table 3 shows the same measure of modal share but differentiated by the start date of the student, with data from both waves of the survey combined. Most students who started after September 2013 would be ineligible for a parking permit so would be expected to drive less. Dividing the data in that way shows the expected modal shift away from car driving. The mode share of driving for the 'last trip for another purpose' also fell, by a more modest 4%.

Start Date of Student:	Before Sept 13	After Sept 13	Change <sup>1</sup>
Driver	33.0%	23.8%	-9.2%
Passenger	10.5%	8.6%	-1.8%
Bus	31.6%	44.0%	12.5%
Walk	15.9%	14.0%	-1.9%
Cycle	6.0%	5.1%	-1.0%
Train	1.2%	3.0%	+1.8%
Motorbike	1.6%	1.2%	-0.4%
Other	.2%	.3%	+0.1%
Valid completions	497	336	

**Table 3: Mode of Travel to Campus on the Day of the Survey, by Start Date of Student**

Thus Table 2 and Table 3 appeared at first sight to be giving two contradictory messages; the former suggested that the policy change had failed to reduce driving to campus, whereas the latter suggested that it had succeeded. To explore the reasons for this apparent contradiction we first examined the characteristics of the samples, by wave and by start date, and then performed a series of binary logistic regressions with different measures of driving, car availability and licence-holding as the dependent variables.

Table 4 shows the characteristics of the two waves of the sample. The progression of cohorts by start-date did not occur as abruptly as we had anticipated. The 2015 wave included 24% of students who started after September 2013, and were therefore ineligible for parking permits; by 2016 this had increased to 67% but there remained a substantial minority who started before that date and therefore remained eligible under the previous rules. This would be expected to dilute but not negate the impacts of the policy change.

<sup>1</sup> All percentages are shown as a proportion of the valid answers to that question (excluding missing data). "Change" refers to absolute change in the percentages of all the valid responses i.e. "change in percentage points" not "percentage change".

<b>Survey Date:</b>	<b>2015 Wave</b>		<b>2016 Wave</b>		<b>Change</b>
Started after Sept 2013	120	24.0%	277	66.7%	+42.7%
Parking permit holder	116	24.1%	89	22.1%	-2.0%
Gender - female	229	45.8%	183	44.1%	-1.7%
Aged over 26	29	5.8%	34	8.2%	+2.4%
Living in Exclusion Zone	395	85.5%	315	82.5%	-3.0%
Living on campus	34	6.7%	25	6.0%	-0.8%
Full licence holder	365	72.1%	311	74.4%	+2.3%
Car available in term	223	45.0%	209	51.1%	+6.1%
Car available in holidays	305	63.7%	265	65.8%	+2.1%

**Table 4: Characteristics of the two Samples by Wave**

The proportion of permit holders fell only marginally between the two dates. Only 19% of those students living within the Exclusion Zone had a permit in the 2015 wave; this fell to 13% in the 2016 wave; these would mainly be students with disabilities or child care responsibilities, although they might also include some who had transferred from other campuses (permits are not transferrable between campuses but some students have wittingly or unwittingly parked with invalid permits at Frenchay). Car availability and licence-holding also rose between the two years, consistent with the increased driving shown in Table 2. Mature students aged over 26 were more likely to drive; their increased proportion in 2016 would explain part of the increased driving.

A series of cross-tabulations showed that the increase in driving between the two waves applied to all of the following sub-categories: by start date, by permit-holding and by location inside or outside the Exclusion Zone. One exception was gender. In 2015 there was no difference in the rate of driving by gender but by 2016 a substantial gap had opened up; 36% of men and just 23% of women drove to the campus. This will be further analysed below.

Table 5 shows the same information differentiated by start date (with both waves combined). The proportions of licence-holding and car availability were both lower amongst those who started after the change in policy. A higher proportion of females would partly explain the lower rate of driving amongst those who started after September 2013. More of that group were also living on campus although that would not influence the modal shares in Table 3, from which on-campus students were excluded.

<b>Start Date of Student:</b>	<b>Started before Sept 2013</b>		<b>Started after Sept 2013</b>		<b>Change</b>
Parking permit holder	149	30.0%	56	14.6%	-15.4%
Gender - female	209	40.6%	201	50.9%	10.3%
Aged over 26	41	7.9%	21	5.3%	-2.6%
Living in Exclusion Zone	383	82.7%	319	86.0%	3.3%
Living on campus	6	1.2%	52	13.1%	11.9%
Full licence holder	401	77.6%	268	67.7%	-9.9%
Car available in term	280	54.8%	150	38.7%	-16.1%
Car available in holidays	363	72.9%	203	53.7%	-19.2%

**Table 5: Characteristics of the Samples by Start Date of Student**

Table 6 shows where those who drove to campus parked. The proportion parking on campus did not fall as far as might have been expected. Of the 94 students who parked on campus in 2016 12 of them had no permit, so were admitting to breaking the rules. The proportion of missing data in that question was around 20% in both surveys, suggesting no greater concealment of behaviour between the two waves.

	2015 Wave		2016 Wave		Change
Parked on campus	103	75.2%	94	73.4%	-1.7%
Parked on street	20	14.6%	13	10.2%	-4.4%
Parked elsewhere	14	10.2%	21	16.4%	6.2%

**Table 6: Parking Locations**

## 6. Evidence of Overspill Parking

Three observations were made in 2016 of two housing estates adjoining the campus and a retail outlet, roughly ten minutes' walk to the campus, where students were known to park. Two observations were made at around the same time as the 2016 survey during the Spring term and a third observation was made early in the summer vacation, when the vast majority of students had departed.

The parking capacity of the streets was estimated ignoring illegal parking, of which a few examples were observed. The capacity of the relevant section of the retail car park was also estimated separately. In the retail car park vehicles were parked in two separate areas; the southern area was furthest from the store and closest to the pedestrian exit leading to the ring-road and the campus. Another cluster of vehicles was observed closer to the store with empty spaces in between; thus it was fairly easy to identify vehicles which seemed likely to belong to UWE students. Notices threatened fines of £90 for unauthorised parking but there was no evidence of verification or enforcement.

Table 7 shows the results of these observations. Note that the area of search was not comprehensive (some people were believed to park further afield). Although precise attribution cannot be made it shows a significant, though not overwhelming, pattern of overspill parking.

	Term Time		Vacation		Change	
	Average Count	Capacity Occupied	Count	Capacity Occupied	Count	Capacity Occupied
Housing Estates	263	78%	155	46%	-108	-32%
Retail Outlet (southern area)	70	71%	N/A Closed down		N/A	N/A

**Table 7 Observational Surveys of Overspill Parking Around the Campus**

Another concern expressed before the introduction of the new parking policy was whether the Exclusion Zone would encourage students to live further away in order to obtain the right to park. There was no evidence of that in the survey findings; with on-campus students removed, there was no statistically significant difference in the proportions inside or outside the Zone (identified by postcode, which was completed by over 90% of respondents in both waves). In a few instances students had attempted to give a false address outside the Zone in order to obtain a permit. Where a student moves from inside the Zone and wishes to apply for a permit evidence such as a utility bill is required to confirm a new address outside the Zone. The Travel Planner believed these methods had closed that loophole; the survey results would not necessarily confirm this, as the postcode on the questionnaire might differ from the one given to the university.

## 7. Regression Analysis

Seven binary logistic regressions were conducted to identify factors associated with the various measures of travel behaviour captured by the survey. Table 8 shows the result of each model, with the seven dependent variables listed in the first column. In each case the independent variables included the four binary variables listed in the first row plus gender and age (over 26), neither of which was statistically significant in any of the regressions. The models were able to correctly predict between 63% and 78% of the outcomes, which represents a reasonable fit for models with a limited range of variables. These outputs



confirm that the change in policy was associated with lower probabilities of driving, car availability and licence-holding and with higher probabilities of public transport use. The Odds Ratio for 'Driving Today' implies that a start date after September 2013 halved the probability of driving to campus. On the other hand, other factors, not measured in this survey, were causing higher rates of driving and lower rates of public transport use in 2016 compared to 2015. We examine possible reasons for this in the next section.

Independent Variables:	After Sept 13		2016 Wave		Exclusion Zone		Living On Campus	
	Odds Ratio	$\rho$	Odds Ratio	$\rho$	Odds Ratio	$\rho$	Odds Ratio	$\rho$
Drive to campus today	0.502	0.001	1.519	0.036	0.135	<0.001	0.000	0.997
Public Transport today	1.767	<0.001	0.653	0.017	2.976	<0.001	0.075	<0.001
Normally drive to campus	0.508	0.001	1.749	0.005	0.136	<0.001	0.000	0.997
Last trip: driven	0.640	0.017	1.610	0.009	0.237	<0.001	0.055	0.004
Car available in term	0.410	<0.001	1.733	0.002	0.238	<0.001	0.098	0.001
Car available in holidays	0.377	<0.001	1.679	0.004	0.312	<0.001	0.527	0.042
Licence-holding	0.655	0.025	1.292	0.162	0.455	.004	0.532	0.034

Table 8 Binary Logistic Regression Outputs

## 8. Discussion

The combination of measures implemented at Frenchay campus since 2006 had clearly achieved substantial modal shift even before the removal of the right to park from most undergraduates. Only 25% of those who lived within the Exclusion Zone and started before September 2013 held a permit in 2015, even though they were entitled to one.

The lower levels of driving to the campus amongst those who started after that date reaffirmed the findings of the literature that removing the right to park at a destination does reduce driving to it; the scale of overspill parking has been relatively modest by comparison (although it has caused resentment amongst some surrounding residents and created some problems for UWE as a result). Of greater significance is the finding that licence-holding, car availability and travel to other destinations for other purposes were all substantially lower amongst those who started after the change in policy.

The survey findings raise two questions which cannot be directly answered by the data collected:

1. Why was there modal shift towards car driving between 2015 and 2016, and;
2. Why did a gender gap appear in the modal shares of the second wave?

Broader national trends are relevant to the first question. After several years of decline, national traffic volumes began to rise after 2013, with a 1.5% increase between 2015 and 2016 (DfT, 2016b). Bus patronage fell by 2.6% over the same year (DfT, 2016a). One reason for these changes has been the falling price of fuel; in the three years to March 2016 the average price of unleaded petrol fell by 26% with an 8% fall between the two waves of the survey (BEIS, 2016). The lower incomes of students are likely to make their travel decisions more price-sensitive than the general population.

Given the congestion surrounding the campus the removal of parking rights from some students might have freed up road space for others to take their place. Most of those others would come from the minority entitled to parking permits, including those who started before September 2013. If so, this would illustrate an aspect of 'induced traffic', a phenomenon which is usually discussed in the context of road capacity increases (Goodwin, 1996, Clegg, 2007), although it may also apply where road capacity is held constant, whilst measures are taken that prevent or dissuade some people, but not everyone, from driving on those roads.

Discussions with the Travel Planner identified one other factor which may have encouraged more driving in 2016. When the main visitor car park closed, smaller new car parks were made available to students with permits (and a few who were breaking the rules). These were in more convenient locations than the old visitor car park, which was slightly removed from the campus.

In addressing the question about gender, it may be noted that the 2010 survey also found no gender difference in the modal share of driving to campus (Melia, 2011); the change occurred between 2015 and 2016. Combining both waves 18% of males without a parking permit drove to the campus compared to just 8% of females. Partly because of this, females who drove were more likely to park on-campus (86%) than males who drove (66%). Both of those differences were significant at the 99% confidence level ( $\chi^2$  tests). This suggests one reason why the change in policy (and the closure of the visitors' car park) influenced females more than males. The Travel Planner indicated that most of the cases of unauthorised parking they have encountered on campus have involved male students. It seems likely therefore that the policy to remove parking rights on campus provoked avoidance strategies amongst more males than females. This is consistent with a large body of literature demonstrating a greater propensity amongst males to commit driving violations (for example Maxwell *et al.*, 2005 provide evidence of this using a sample of students in the UK) and specifically to defy parking restrictions (e.g. Fletcher, 1995).

Splitting the data by wave revealed that in 2016 females also had lower car availability, fewer licences and made fewer trips to other destinations than males ( $\chi^2$  tests with  $p$  values of 0.001 or smaller), whereas in 2015 there were no statistically significant differences. Similarly females who started after September 2013 had lower car availability, fewer licences and made fewer trips to other destinations than males (with  $p$  values of 0.001 or smaller), whereas there were no significant gender differences between those who started before that date. This confirmed the more general observation that factors influencing travel to the campus (including the change in parking policy) also influenced those wider measures of travel behaviour.

## 9. Conclusions

This study supports the well-established finding that removing the right to park at a destination reduces driving to that destination. It also demonstrated for the first time that such measures may also reduce licence-holding, car availability and driving for other purposes. Concerns that a parking exclusion zone might provide an incentive for people to live further away were not borne out by this study, although there had been a few instances of students attempting to give false addresses. However, the increase in driving observed in 2016 may be evidence of an unintended consequence, where parking opportunities are reduced but road capacity is maintained, freed-up road space may be filled by additional drivers. The falling price of fuel was also believed to have encouraged more driving in 2016.

To what extent these findings may be generalised from students travelling to a campus, to other groups, such as employees, or other types of destination would merit further research. It may be reasonable to infer that a restriction or discouragement to drive to study leads to lower car ownership and less driving in general, although the nature of the causal links would also merit further research.

This study has also found, consistent with the literature on driving violations, that measures to restrict or remove the right to park influence females more than males, who are more likely to circumvent restrictions, where possible. Prior to the removal of parking rights, a twin-track policy of parking charges and bus improvements had already reduced driving to the campus. Whether for that or other reasons (such as increased tuition fees), car availability amongst UWE students had already fallen before the new policy was introduced. Those earlier measures appeared to influence males and females equally. Only when the right to park on campus was removed from most students did a gender differential appear.

Removing parking at major destinations can be expected to cause overspill parking on surrounding streets or other sites nearby, although the scale of overspill parking may be exaggerated; in this study, the increase in students travelling by other modes far outnumbered those who parked on streets or sites surrounding the campus. Nevertheless,

overspill parking may create tensions between the management of the destination site and surrounding residents or businesses. Parking controls and enforcement may be required to manage those problems.

This study reinforces the commonly advanced policy recommendation that 'sticks' are required as well as 'carrots' if transport planners, public authorities or private developers wish to achieve modal shift or restrain the traffic generation of sites where intensification of activities is planned (Cairns *et al.*, 2010, Petrunoff *et al.*, 2015, Melia, 2015b). At a city or regional level it shows that such efforts may be mutually reinforcing; restricting parking at regularly-visited destinations may reduce parking pressures and traffic generation across the city or region as a whole.

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