Evaluating the long-term impacts of bus-based park and ride

Mills, G. and White, P.

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ABSTRACT

While many park and ride (P&R) schemes worldwide are based on rail transport, there has also been substantial development of bus-based P&R, in which an enhanced bus service operates between a P&R site, and an urban centre. This has been particularly marked in Britain, often in historic cities (such as York, Oxford and Cambridge). Development of busways has also provided opportunities for complementary P&R development.

Nonetheless, a net increase in pcu (passenger car unit)-kilometres may be observed, despite a reduction on the principal radial corridor, due to increased car-kilometres in catchment areas of P&R sites, but this simple additive approach to changes in pcu-km may not reflect overall impacts, if pcu-km are removed from a congested urban corridor. By using monetised external cost per pcu-km for different road types and traffic conditions (such as those in 'WebTAG' guidance in Britain) the net effect can be expressed in economic terms, presented here as a case study of the Chelmsford system, showing that a net economic benefit may be attained, even though a net increase in pcu-km has occurred. Energy savings through diversion of car occupant trips to the Cambridgeshire busway are also assessed.

Key words

Buses Park & Ride Environmental impacts energy savings economic evaluation congestion

Classification codes

L92, R41, R48

1. Background

Park and Ride (P&R) systems have gained increasing importance in many countries in recent years. Typically, they provide a means by which existing car users are diverted to public transport by locating a car park at a convenient point along major corridor into an urban centre. Car users may be attracted by financial factors (such as savings in parking charges in comparison with central areas, and direct running costs), and/or time factors (a faster journey overall, in which wait time and interchange penalties at the P&R site are offset by a faster journey over the section between the site and the users' final destination). Physical limits on parking supply in the central area may also encourage temporary P&R use (for example, shopping trips in the period leading up to Christmas). Door-to-door journey time will also be affected by search time in central areas where parking supply - especially on-street - is limited.

In most countries, such P&R provision is normally rail-based, since that mode is more likely to offer substantial journey time savings vis a vis car use. This can be seen in cases such as Toronto or Hamburg for heavy rail, or Dublin (LUAS) for light rail. In Britain, London displays extensive P&R use via heavy rail, but light rail P&R operation in Britain has developed to only a very limited degree (apart from Nottingham). The emphasis on bus-based P&R is untypical of the pattern in Europe, although a number of earlier examples may be found in the USA and Australia, where rail networks are less extensive, as described in the Seattle regional case study by Rutherford et al (1986), and the literature and practice review by

Caltrans (2010). Another feature of the British case is the fairly limited use of P&R in major conurbations outside London – much of the bus-based P&R is in older, more compact centres, often historic cities whose character would be greatly changed by extensive car access in the central area (such as Oxford, Cambridge or York).

The earliest examples for bus-based P&R in Britain can be traced back to the scheme in Oxford, commencing in 1973, as part of a wider policy of car restraint and public transport - encouragement, following a decision to abandon major road building in the historic city centre. Some six P&R sites are now served with dedicated bus services over the main radial corridors provided by the Oxford Bus Company (whom also operates a substantial part of the general public network in the city). These are all operated commercially, including provision on Monday-Saturday evenings, and Sundays. A total of over 4930 spaces are provided, at five sites within or on the fringe of Oxford itself, plus 580 at Bicester, located at a greater distance from Oxford, to the north east. Some dedicated services are also provided by Stagecoach, the other principal operator in the city (via an existing commercial service at the Bicester site), as well as tendered links to hospitals from other sites. Many other schemes have followed, although there have also been examples of cutbacks where P&R sites were little-used, or costs of running the dedicated bus service were unacceptably high (for example, in Hull, Worcester, Coventry).

In the case of the larger schemes, there is potential for commercially-viable bus operation of a dedicated service (including vehicle capital costs). This is a function both of absolute demand level, and its distribution. If a site is full at the end of the morning peak period it may be highly effective in diverting cars, but may produce a sharply peaked demand which is difficult to serve efficiently. Conversely, if there is adequate capacity for off-peak traffic (such as for shopping trips) this may help to produce a more balanced load on the bus services. Historic centres also attract tourist demand during weekends and holiday periods, aiding this outcome. Hence, in Oxford, Cambridge, Norwich and some other cities almost all P&R bus provision is commercially viable. Indeed, in one case, York, a premium was being paid by the operator for the right to operate the service in 2016, and a premium was also included in the revised contract which took effect from January 2018. In another case, a bus operator has taken the initiative to develop the P&R site as well as running the service commercially - Stagecoach Manchester at Hazel Grove in the south-east of that city, served by existing service 192, albeit offering rather slow links to the central area.

An unusual feature of bus-based P&R is that a wholly separate service is usually provided. Conversely, rail-based P&R is normally based on existing rail corridors, although in some cases stations built purely or largely for P&R use may be served (such as Callerton on the Tyne & Wear Metro). In the case of bus rapid transit service, the P&R provision is from intermediate sites served by through routes (such as the Cambridgeshire busway, or Leigh - Manchester), akin to rail provision. In some cases, P&R sites with modest use are now served by diversion of conventional bus services in the same area (for example, in Coventry since 2014).

Site provision costs may also be recovered from a charge on users (as for a period in Cambridge city, and Oxford, for example). In these cases, making its collection convenient may be important, but the cost is more often met directly by the local authority concerned. In some cases, much greater expenditure is incurred on supporting the P&R bus service as such, and for these an assessment of the net economic benefits is of particular importance.

2. Costs and benefits

A number of customer categories may be identified, using the illustrative diagram shown (figure 1).

1. Car users diverting to the P&R service, having previously driven to point A (the central area). Financial savings from avoiding central area car park charges and marginal running costs of the car between A and B (the P&R site), less charges made for the P&R site use, and the bus fare paid (car occupancy might thus be critical, higher savings per person-trip being made for single-occupant cars). Net journey time change would be variable – additional time would be incurred in waiting for the P&R bus service at each end of the trip, but 'search' time in securing a central area parking space avoided. In the original Oxford Balanced Transport Plan of 1973 availability of parking was considered to be as important as pricing. For simplicity, it is assumed that in-vehicle journey time between A and B is the same by bus or car, but in some cases where extensive bus priorities are provided, such as between Thornhill P&R and central Oxford, bus journey times may be substantially lower than by car. Note that some car users diverting to the P&R site may not currently pass it, but divert from other radial corridors. These may incur additional pcu-km, especially over orbital roads, which may themselves be congested, for example from point C as shown. However where general improvements have occurred in the same region as the P&R policy implementation, increased ridership may be shown on inter-urban bus services. This may be seen most clearly in the Cambridgeshire busway case (discussed later in this paper), but can also be seen around Oxford, where concentration of new housing in market towns has helped to strengthen demand for inter-urban services.

2. Other road users. Time savings through reduced road traffic on congested sections of road, offset in part by increased traffic elsewhere.

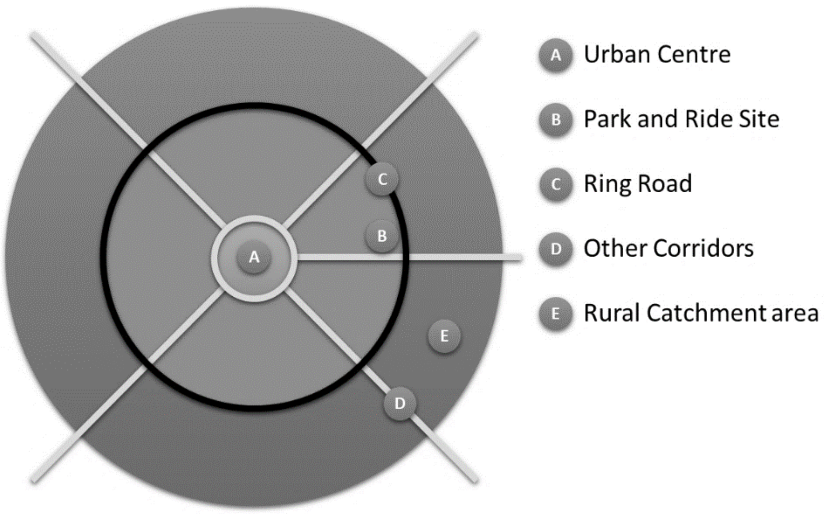
3. Bus operators. Where the service would not be commercially viable, the operator is assumed to set a contract price which is a realistic reflection of costs, including a 'normal' profit margin. Where commercial operation is provided, then revenue risk is incurred. In a few cases, the operator may also take responsibility for running the P&R site itself, either through a local authority contract payment, or (rarely) covering costs from charges to users. Revenue loss may arise on rural services losing passenger numbers due to diversion P&R usage.

4. The local authority. Additional costs are incurred, typically including P&R site provision (capital and operation), in some cases offset wholly or in part by user charges additional to the bus fare. Where the bus service is not commercially viable, then additional contract costs are incurred. Parking revenue may also be lost in the central area (the net loss depends upon operating costs), but such sites may also have high land values for alternative uses, hence, an 'opportunity cost' may arise.

5. The state may lose tax revenue as a result of diversion from car to bus, through loss of fuel duty.

6. Wider impacts. In addition to road user time savings on the B to A section, lower congestion is likely to result in less ‘stop-start’ running, improving fuel consumption and reducing environmental emissions. Overall energy consumption by those who divert from car to bus over the B to A section is likely to fall (unless bus load factors are very poor), but may be offset in whole or part by additional car-km en route to point B. Pedestrians may benefit, and also non-car-owners living within walking distance of the P&R site who are able to use the P&R bus, which may be faster, cheaper and/or more frequent than alternative conventional services.

Figure 1: An illustrative sketch map of the case considered



An equity issue arises where the P&R bus requires substantial public financial support, since car users are generally more affluent than bus users, especially if support to other bus services is being cut back due to overall public expenditure constraints.

For purposes of this paper, it is assumed that the main trade-off is between the reduction in external costs imposed by cars diverted from the B to A section, offset in part by additional costs incurred by additional pcu-km elsewhere. Lost car park net revenue in the central area is assumed to be a reflection of the opportunity costs of land occupied, and a net financial benefit to users is produced from the difference between payment for P&R use (the bus fare, and if applicable, car park user charge) and the central area parking charge.

The above line of argument assumes that road pricing is not applicable. Where this is the case, then a much stronger purely commercial case might be made for P&R operations, since a more realistic price would be set for road use to reflect marginal external costs - see, for example, Inturri and Ignaccolo (2011). This might also encourage trip retiming and/or car sharing. In a theoretical case, one can envisage all costs being expressed in financial terms, notably the use of road pricing to reflect external marginal social costs over congested sections, and pricing of all parking to reflect the opportunity costs of land used for that purpose (including private non-residential parking (PNR) at places of work). An individual user would thus make a choice that was personally and socially optimal, by comparing monetary costs (fares, set to cover all operating and capital costs of the P&R scheme, against car running costs, parking and road user charges), and the value of net changes in travel time. In reality, such a situation very rarely applies, but estimates can be made of changes in road congestion and environmental impacts.

3. Other factors in P&R evaluation

Additional factors may influence P&R provision. For example, in some cases there is evidence that central area parking provision has not necessarily been reduced (and hence car flows within the urban area), but that P&R provides in effect a means of increasing parking capacity for customers whilst allowing them to avoid additional congestion in inner and central areas. This may, for example, increase employment and shopping activities in an urban centre, and P&R may be used in part as a means of urban areas competing with one another.

Regarding the shift from bus to car for those journeys currently using buses from the rural catchment area, the time period considered may be critical. If studies are conducted over a long period, then some shift from bus to car might be expected in any case as car ownership rises (thus the counterfactual case for a proportion of users would be one in which the car might be driven all the way into the urban centre, not use of a bus). From the viewpoint of individual users who transfer from bus to car for the ‘rural’ section of the journey, substantial personal benefits may arise (for example, accessibility to a 10-minute headway P&R service compared with an hourly rural bus). An analogy may be drawn with light rail schemes’ evaluation – these may attract many of their users from existing buses, but nonetheless benefits would be included in terms of user time savings.

4. An illustrative example

Where bus-based park and ride services are established, they are typically located on the fringe of the built-up urban area, with a dedicated bus service to the centre. In the case of Oxford, sites were initially placed at (approximately) the point where peak-period queuing commenced. At this point they intercept flows of cars travelling toward the centre of the urban area. In the simplest case, cars would be diverted from the section of road between the P&R site and the urban centre (hereinafter ‘the urban section’). Each car parked at the P&R site would thus represent the removal of a return trip over this section. Traffic flow is estimated in terms of passenger car units (pcus), each equal to one car. Total pcu-km diverted would be offset to some extent by additional pcu-km incurred by buses, for which a pcu value of 2.5 is assumed (DfT 2015a, table A7). For example, if the distance between the P&R site and the centre was 4 km, and 1,000 cars were parked there over the course of a day, each would represent the removal of a return trip, and total car pcu-km removed would be 1,000 x 8 = 8,000. If the bus service ran every 12 minutes (5 buses per hour) for a 12-hour day, then 60 return bus trips would be generated, comprising 60 x 8 = 480 bus-km per day. At a value of 2.5 pcu per bus, this would correspond to 1200 pcu-km per day. The net reduction in pcu-km over the section between the P&R site and the centre would thus total 6,800, or 566 per hour. The reduction in pcu flow would average one eighth of this, or 71 pcu per hour.

The reduction in traffic would provide corresponding improvements in speed for the remaining traffic over the urban section, which could be derived from a speed/flow curve relationship (often simplified to a linear relationship over the range being considered). For example, if the total traffic flow over the urban section was 1,000 pcu per hour in each direction, averaged over a 12-hour day (the same as that during which the P&R bus service operates), it would fall to 929. If speed of the remaining traffic rose from 15 to 16 km/h in consequence, journey times would fall from 16.00 minutes (to 2 d.p.) to 15.00 minutes. Total time savings per day to remaining car occupants would thus total [929 (flow) x 12 (hours) x 2 (directions) x 1 (minutes saving)]/60 (minutes per hour) = 371.60 hours. At an illustrative value of travel time savings of £6 per hour, this would correspond to £2,229.60 per day.

It may be noted at this stage that a very small time saving (1 minute per trip) is being used in evaluation, an issue which has been extensively debated in the literature. However, given the continued use of this convention in much economic evaluation, its application to the P&R case would be no more controversial than to other traffic engineering measures. It may also be noted that if traffic were at a critical level, in which the speed/flow relationship becomes unstable, then substantial gains in reliability of journey time might also be produced. In practice, the outcome would vary by time period, with larger reductions in traffic flow at peak periods and smaller effects off-peak.

Figure 1 shows this illustrative case. ‘A’ represents the urban centre, and ‘B’ the P&R site, some 4 km apart. Some car trips approach from corridors other than that directly passing the P&R site, joining the ring road at point C. These incur additional distances of 2 km compared with their previous direct route to A, made on the ring road. The ‘rural’ length of the car trips, joining at points B or C, averages 8 km. It is thus possible for an increase in pcu-km to occur, if the additional pcu-km along the ring road, and in the rural catchment area were greater than the pcu-km diverted from within the urban area. This has been found in a number of previous studies, for example by Parkhurst (2000), and Meek et al (2008, 2011). In particular, this may arise from users who previously travelled through by public transport, shifting to use of the car to access the P&R site, as considered in section 3 above. A study of rail-based P&R in the Netherlands, taking locations in the Rotterdam and Den Haag regions, produced a similar outcome (Mingardo 2013). However, the costs to other road users imposed by these extra pcu-km may be relatively low, insofar as these sections of road are far less congested than the urban section. Some costs may be imposed on the ring road section, but those added in the low density rural catchment area may be very small.

5. Evaluation using Transport Analysis Guidance (‘TAG’)

Within England, a comprehensive range of guidance for forecasting and evaluation is provided by the government-supported ‘WebTAG’ site, drawing on a wide range of research evidence to provide data for this purpose. It is widely used in evaluation work, especially by local authorities and consultancies: broadly similar approaches also apply in Wales and Scotland. A general description of the underlying rationale may be found in DfT (2014). The guidance is regularly updated, with recommended values provided for a wide range of variables, such as the value of travel time savings, and vehicle operating costs.

Estimates are now shown for external costs imposed by traffic under different conditions, in table A5.4.2 ‘Marginal External Costs by road type and congestion band’ (DfT 2015b). This shows such costs for 2010, 2015 and at five-year intervals to 2035, adjusted for anticipated real changes in GDP and other factors. They are expressed in pence per car-km (taken here as per pcu-km). In this paper the 2010 values have been used, since empirical data from a survey in 2011 is being used to demonstrate a real case. Table 1 of this paper shows some selected values for that year. The ‘congestion level’ is analogous to the speed/flow curve mentioned earlier, being derived from the ratio of observed volume (v) to theoretical capacity (c) [‘v/c’] in pcu per lane. For example, congestion band 1 corresponds to a ratio of less than

0.25; band 4 to a ratio between 0.75 and 1; and 5 to over 1, in practice producing unstable flows (DfT 2015a, table A4).

Table 1: Marginal External Costs - selected values from WebTAG Table A5.4.2

Cost type	Congestion band	Urban A road	Urban other roads	Rural A roads	Rural Other roads
Congestion	1	0.6	2.3	0.4	0.2
	2	1.8	8.7	1.3	1.4
	3	10.7	18.8	3.3	7.5
	4	45.5	130.1	49.2	39.1
	5	71.0	215.2	116.8	129.6
Infrastructure	All	0.1	0.1	0.1	0.1
Accident	All	3.0	3.0	3.0	3.0
Local air quality	All	0.1	0.1	0	0
Noise	All	0.2	0.2	0	0
Greenhouse gases	All	0.8	0.9	0.8	0.8
Indirect taxation	All	-4.8	-5.4	-4.8	-4.7
Net (a)		12.6	9.7	-1.0	-0.3
Net (b)		-0.6	-1.1	-3.2	-3.1

Notes: Values are shown in pence per car-km, at 2010 values, to 1 decimal place, from autumn 2015, release v1.4. The selected values do not include those for London, motorways or conurbations. Net (a) corresponds to the net outcome where an average value of congestion effects is included, and net (b) to that in which this is not included. Negative values indicate a net loss arising from the indirect taxation effects.

It will be seen that monetised congestion costs rise very rapidly with congestion level, especially around level 4. They are generally higher for urban roads, although rise notably for rural roads at level 5. The other monetised values are generally much smaller, and perhaps surprisingly, do not vary with congestion level (for example, local air quality). These are exceeded by the loss of indirect taxation (i.e. loss of revenue to the state). The overall outcome is thus very strongly dependent upon the relative mix of traffic between different road types and congestion levels.

Table 2 shows some of the outcomes of applying these values to the hypothetical case described earlier, i.e. 1,000 cars per day are parked at the P&R site, of which 800 are parked in a two-hour morning period, returning over a two-hour evening period. It is assumed that one lane of traffic is provided in each direction over all sections of road considered. Over the urban section, 400 pcu per peak hour are removed from the peak direction flow. These would represent about 500 persons at an average car occupancy of 1.25. If the P&R bus ran every 6 minutes (10 bph) to provide sufficient capacity (i.e. an average of 50 passengers per bus) some 25 pcu/hour would be produced, giving a net reduction of 375 pcu. It is assumed that the contra-peak flow during this period diverted to the P&R bus is negligible, and likewise any effect of the additional bus pcu-km on congestion. During the other 8 hours per day, traffic flows are equal in both directions, some 25 pcu per hour (200 cars divided by 8), likewise offset by 12.5 extra bus pcu/hour (a service of 5 bph).

Of the 400 cars diverted per peak hour, it is assumed that 300 would pass point B in any case, but that 100 diverted from other (similarly congested) corridors make use of part of the ring road averaging 2 km. B to A is categorised as ‘Other urban A’, and C to B as ‘Rural A’. In addition it is assumed that in the rural areas cars travel an average of 5 km to reach point C or B. Of the 400 in the peak, it is assumed that 200 already made this trip, but that the other 200 represents former conventional bus trips, and this generates new car-km in the rural areas (this would be a very high proportion). Congestion bands are assumed as shown in the table. It is assumed that the marginal value is applicable over the whole range of change considered (on an incremental basis a different outcome could be produced – for example, if a new P&R service were introduced and its usage rose gradually, the initial diversion might reduce congestion from band 4 to band 3, but later diversion would then take place from that lower band).

On this basis, a net overall outcome (including other components and indirect taxation effects) can be calculated: a net reduction in total economic congestion costs associated with changes in traffic flow of about £694,000 p.a. is obtained (or £688,000 after other components are included, due to the loss of tax revenue). In grossing up from daily to annual, a working year of 250 days is assumed, with no allowance for weekend traffic. This is driven overwhelmingly by the reductions due to peak period diversion, and is largely insensitive to other factors. It will, however, be sensitive to congestion levels assumed. These calculations also omit effects of induced traffic, which would offset some of the benefits shown.

Table 2: Illustrative example of applying WebTAG values to a P&R scheme

Road section	Road type	Congestion band (peak)	Monetised net change/day
B to A	Urban A	4	-2815.0
C to B	Rural A	3	29.6
Rural beyond B or C	Rural other	1	8.0
Sub-total			-2777.4
Other net changes (including indirect taxation)			24.6
Overall change per day			-2752.8
Annual change			-688200

Notes: All units are shown in £ (GBP), 2010 values. A negative sign indicates a reduction in external costs

Applying this theoretical case to a real example would then depend on making assumptions about the congestion band applicable to each road section by time period, as well as observed data on P&R usage, and degree of diversion from other modes by P&R users. A survey intercepting respondents at the P&R site would produce much of this data, apart from congestion band. It would also be necessary to make assumptions about assignment of car flows diverted on the road network (a user survey would typically ask about ultimate origin and destination, but it would not be reasonable to demand exact route followed).

6. A case study of Chelmsford, UK

6.1 Local background

The city of Chelmsford in Essex has a population of approximately 100,000 people. It is home to a number of major employers including Essex County Council, Royal Sun Alliance and Chelmsford City Council. The town's train station is also the busiest in the East of England and is only a 35 minutes journey to the London terminus of Liverpool Street station. Chelmsford is expected to accommodate a large amount of additional housing and employment with over 16,000 new homes and over 24,000 new jobs. The County Council and City Council identified Park and Ride as a key component not only in terms of congestion relief on the town's key radial routes but also as a way to release prime land in the town centre for development. A Park and Ride strategy was produced to deliver Park and Ride schemes around the town.

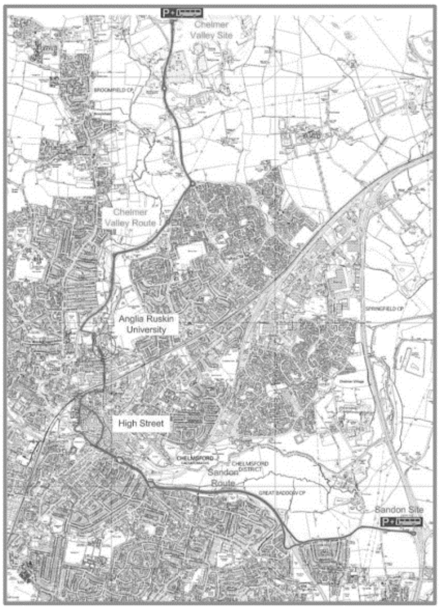


Figure 2 - Park and Ride in Chelmsford showing the two separate Park and Ride routes as of August 2011 (scale 1:50,000)

Sandon

The first Park and Ride site opened in Sandon, to the east of the city, in March 2006 with the site originally providing space for 500 cars. Increased demand meant two additional expansions for the site being undertaken since opening (one in December 2006 and the second in April 2008) raising the site's capacity to 1,200. The catchment area covers east and south east Essex and includes the towns of Maldon, Southend-on-Sea and Basildon together with the A12 Corridor north towards Colchester. The site is located on junction 18 of the A12 (the main London to Ipswich trunk route) on its junction with the A414.

Chelmer Valley

Against the backdrop of a general reduction in Park and Ride provision nationally at that time, the town's second Park and Ride (Chelmer Valley) opened to the north of the town on the A130 in April 2011 with space for 700 cars. The sites catchment primarily serves those north of the town including Bishop Stortford/Stansted Airport and Braintree.

At the time when the surveys were undertaken (June 2011), the return fare per adult was £2.20, whilst it remained free at all times for children under 16 and those who held concessionary passes after 0900 Monday to Friday and all day on Saturday (at that time, concessionary travel was offered on P&R services. Local authorities now have discretion whether to offer concessions on specialised services such as P&R). The weekday fare has since risen to £3.50 daily for an adult and £1.00 for children between the ages of 5 and 15. Concessionary pass holders continue to travel free after 0900. Special rates apply at weekends.

The cost of constructing the two sites, including associated bus priority measures and the two expansions at Sandon, totalled around £13.7million. The County Council estimated that in 2011/12, it would financially support the scheme by around £640,000 for both sites based on a fare of £2.20. This financial support was likely to decrease over the year as the effects of the increasing of fares gradually to £2.50, £3.00 and now £3.50 were realised. Furthermore, it was anticipated that as with the Sandon site, Chelmer Valley would continue to grow in terms of passenger numbers further reducing the financial liability on the council.

Both sites are serviced by dedicated bus services to city centre locations including Chelmsford station. Having originally operated as individual routes between the sites and the city centre, the two P&R services were combined into a single Chelmer Valley – City Centre - Sandon route in August 2016, operating about every 10-12 minutes' daytime, augmented to 5-6 minutes in peaks on the Sandon section. The one route operation was identified to lower the amount of 'dead running' reducing the cost of running buses to support the service overall. Additionally, since August 2016, a 23-minute headway shuttle service operates between Chelmer Valley Park and Ride and Broomfield Hospital.

Through counters placed at the entrance to the Park and Ride sites, it was possible to determine the vehicular usage of the park and ride sites. Taking a three month average (April to June 2011) across the two sites it was found that approximately 270 cars used Chelmer Valley on a weekday, with over 1,000 cars at the Sandon site. If all of these were diverted car journeys previously destined for the central area this would also correspond to a reduction in traffic over the urban section (in practice this outcome may be more complex, as discussed above). To this end, a journey time reduction averaging up to 2 minutes per vehicle on the section of road between the Sandon P&R site and the city centre were observed (Mills, 2011). Note that this case study builds on a survey and analysis completed by Gareth Mills in 2011 as Master's dissertation under the supervision of Peter White, with appropriate updating (notably use of the WebTAG monetised values now available) as described in the text.

6.2 Survey data

In April 2011, Essex County Council (ECC) commissioned a second survey at the Sandon site, together with the first at Chelmer Valley thus updating the data available for Sandon, and to assess the usage at the newly-opened Chelmer Valley site. The questionnaire asked respondents to indicate aspects of their journey including previous modes used, rating of aspects of the service and how they had travelled to the site on that day. Surveys were undertaken on by passengers on bus on both a weekday (Thursday) and Saturday in June 2011. In total 1,608 individual and valid questionnaires were returned (distribution shown in Table 3).

Table 3 - Distribution of Park and Ride survey responses returned

Period	Sandon		Chelmer Valley	
	Completed responses	Response rate	Completed responses	Response rate
Weekday AM Peak Period	679	86%	221	96%
Weekday Interpeak Period	440		138	
Saturday	489	71%	158	66%
Total	**1,608**	**81%**	**517**	**84%**

This survey data has been used to inform analysis of the costs and benefits of Park and Ride and was used as the primary data source to establish both monetary and attitudinal information relating to the service.

The user survey invited respondents to indicate the principal reason for using P&R: the most frequently cited factor was the cost savings (about 70% of peak users, but lower in the interpeak, as might be expected). The second factor was 'convenience': this may have encompassed searching for parking spaces in the central area, and also possible diversion from rail stations with parking constraints (discussed further below) with only about 5% citing time savings (although the diversion of traffic to P&R sites will have produced time savings for other road users in consequence). Ratings for P&R provision as such were generally very favourable, especially for parking capacity and parking facilities (Mills 2011, figures 4.10 and 4.11). Only about 5% of all respondents had diverted from rural bus services, a lower proportion than in the previous survey in 2008 (Mills 2011, page 66).

6.3 Estimation of net change in pcu-kilometres

To understand the effects of potential additional vehicle kilometres arising from the Park and Ride, an evaluation of both the users of the service and the buses used to operate the Park and Ride service was compared to the distance users previously travelled before the implementation of Park and Ride (Table 2). Following on from work by Meek et al (2008), key consideration was given to those who previously used public transport, walked or cycled all of which now contributed to additional car kilometres in diverting to the P&R site by car (Table 4).

Table 4 – Daily weekday network implications of Park and Ride

	Previously Parked in city centre			Previously used Public Transport to travel to city centre			P&R bus pcu-kms (@1 bus = 2.5 pcu)	Net change in pcu-kms travelled per day
	Before P&R	After P&R	Net	Before	After	Net		
Sandon	30,420	23,953	-6,466	0	10,084	10,084	2,172	5,790
Chelmer Valley	14,745	11,735	-3,009	0	1,574	1,574	2,715	1,280
Total	**45,165**	**35,689**	**-9,476**	**0**	**11,658**	**11,658**	**4,887**	**7,070**

Notes: Data are shown in pcu-kms. Note that these data were derived from the original user survey, in which a simple doubling of AM peak data was used to estimate the PM peak, and a sample period was taken for the inter-peak period, which may not correspond exactly to data on which monetised calculations below are based

The impact of P&R on pcu kilometres at Sandon and Chelmer Valley is consistent with previous evidence as quoted above. When taking both sites combined, a net increase in pcu kilometres is evident, of about 15%.

However, whilst an increase in vehicle kilometres is shown, most of the growth is located outside the built-up area of the town, where it is considered that there may be adequate capacity to accommodate it (any additional congestion costs are monetised in line with assumptions described earlier in this paper). On the urban sections between the P&R sites and the centre, a reduction of 9,476 pcu-km is calculated for the two sites combined from P&R customers who previously travelled into the centre to park. This overall reduction is offset somewhat by an additional 4,887 pcu-km on the network resulting from new bus journeys required to operate the service (at 2.5 pcu-km per bus-km between the P&R site and the centre, for both directions of flow over the whole period the bus service operated). However, a net reduction of about 4,590 pcu is still realised between the P&R site and the urban centre. Note that in the peaks the proportion of car pcu-km to bus pcu-km will be much higher than the average shown above, increasing the benefits obtained. Conversely, bus pcu-km may form a higher proportion at off-peak times, but these may have less impact when congestion is much lower.

6.4 Monetised evaluation of changes

By using the values for marginal external costs per pcu-km by road type and congestion level (table 1), the aggregate monetised impacts can be estimated.

The following methodology was used in calculations:

1. Each road section within the urban area for which traffic flow data were available was identified separately. For example, the Sandon P&R site the city centre corridor was divided into 12 sections. For each of these, Annual Average Daily Traffic Flow (AADF) 12-hour traffic counts (covering the period 0700-1900) were available, classified by direction and time-period (three periods were used – AM peak 0700-0900, inter-peak 0900-1400, and PM peak 1600-1800). The flows were classified by vehicle type, enabling conversion into pcu totals, using standard weightings. These were converted into a flow per lane by reference to the number of lanes in each direction. A marked imbalance by direction in the peak was seen (typically around 65:35), as might be expected. Using standard webtag guidance, capacity per lane was then applied (this is substantially lower for urban than rural roads, reflecting the effects of signalised junctions, etc. - for example 1,100 pcu/lane/hour for a 'principal urban' road versus 2,100 for a 'principal rural' road). In practice, conditions will be unique to each route, dependent, on traffic signal phasing for example, but it was not practicable to go into such depth. A volume to capacity ratio (v/c) was then calculated for each section of road in order to derive the congestion level applicable in WebTAG table A5.4.2.
2. Analysis was confined to the Monday-Friday time period, as in the Chelmsford case, Saturday usage of the P&R sites was much lower than on weekdays, and effects likely to be small.
3. Using data on the occupancy of the P&R sites, an estimate could then be made of cars removed from the urban section. The net change in pcu was calculated, with an allowance made for extra pcu generated by P&R bus services. The marginal values could then be applied to estimate economic benefits arising from this. It should be

noted that some users parked at the P&R site would previously travelled by bus past the site. This is particularly relevant at the Sandon site where around 5-10% are estimated to have done this. These have been excluded from the calculation related to the urban section. For Chelmer Valley the situation is less clear with over 60% hailing from catchments north of the site, particularly in and around the town of Braintree. Many of the users are assumed to have travelled to Chelmsford by train from Braintree. It is likely that these journeys could already add to congested routes and result in empty seats on trains 'upstream' of Chelmsford. As an assumption however it is considered that inclusion of these trips is warranted in calculations as the numbers who would travel by bus is small.

4. In addition, financial, impacts on P&R users previously travelling by car could be estimated (the average savings in central area car park charges per time period, less P&R fares). For simplicity, direct car operating costs were omitted.
5. Similar calculations were then made for changes on other road sections, including those where some additional congestion may have arisen (such as the A12 in the vicinity of Sandon), and rural sections beyond the P&R site. Given limits to the feasible complexity of the calculations, these were grouped in corridors approaching Chelmsford from different directions, based on the user survey data. An average for the cost of travel from people's residence (identified through postcode data) and the starting points of corridors was used to account for this travel.

It should be noted that some complexity arises from the effects of diversion from rail use, a somewhat unusual outcome of the Chelmsford case. Diversion from rural bus to car travel to the P&R site was notable in the zone due east of the Sandon site (principally Maldon and Danbury). However, in other directions, especially north and north east of the P&R sites, substantial diversion was found in the user survey from rail. Instead of driving to their nearest rail station, users from some locations (notably Colchester, Witham and Braintree), were found to be using the Chelmsford bus P&R sites, presumably for onward commuting to London. This may reflect the benefits of access to more frequent rail services at Chelmsford (especially in comparison with the Braintree branch), the high price of rail travel compared to driving and travelling via P&R services, and possibly capacity constraints at rail station car parks elsewhere, despite the additional interchange involved. In consequence, some additional car traffic was generated, especially along the A12, adding to congestion there, and reducing the net benefits that might otherwise be found.

Provision of P&R services has also allowed for land use changes to take place within the city centre. High value land previously used for car parking can now be released for other land uses. Not only does this provide capital gain through land sales; social and regeneration opportunities have also been realised. For example, the former Bond Street car park site within the city centre was sold for development and is now home to a major retail and cinema development which opened in 2016.

Table 5 shows the net outcome of the calculations applied to the two Chelmsford sites. The 'gross reduction in pcu-km due to the P&R scheme' is a monetised estimation of the effects of diverted pcu-km in reducing congestion. In practice, these are offset in part by the monetised effects of additional pcu-km associated with diversion from existing bus and rail services, and the pcu-km incurred by the dedicated bus service. Nonetheless, a clear net benefit is shown, especially for the Sandon site.

Table 5 Monetised impacts of the Chelmsford P&R schemes

Site	Sandon	Chelmer
Car parking costs savings	446	117

Gross reduction in pcu-km due to P&R scheme	868	204
Effects of additional pcu-km due to P&R scheme	592	176
Net benefit (including parking cost savings)	722	146
Net benefit (excluding parking costs savings)	276	28

Units are shown in £ ‘000 at 2010 values, rounded to the nearest whole number, based on the 2011 survey data.

7. Cambridgeshire busway case

The Chelmsford case may be considered broadly typical of urban bus-based P&R schemes in Britain. However, it is also possible to divert car users at much greater distances from urban centres, where a sufficiently high quality and speed of service is provided. This still makes use of large P&R sites to support high service frequency, but enables potentially large changes in pcu-km.

The Cambridgeshire busway is the longest in Britain, and indeed the longest guided busway in the world. Opened in 2011, over a total of about 25 km, it provides a link from St Ives to Cambridge through the rural region north-west of the city, and also a short link south of the city to Addenbrookes Hospital and Trumpington Park & Ride. Major park and ride sites are provided at Longstanton and St Ives. A large-scale user survey was undertaken about one year after opening by the Atkins consultancy (2013) and a further account, including developments subsequent to the survey, is provided by Brett and Menzies (2014).

A high proportion of those with cars available were identified which indicates substantial diversion from that mode. It would not be reasonable to assume that all those with a car available are newly-diverted however, since a substantial element of such users can be found on other bus services. The analysis of the Atkins passenger surveys also indicates a user profile closer to that for rail users in terms of income, mode choice available, and age: a similar outcome has been observed for users of bus P&R services in Oxford. A striking feature of the user survey is the substantial diversion of car users with free parking available in central Cambridge.

Services over busways such as Cambridge are likely to attain a higher-than-average output in terms of passenger-km per litre of fuel used than bus services in general. This is due to the high load factors being attained, and further benefits provided through diversion of car trips to bus via the P&R sites, producing a net reduction in litres of fuel used. It is also likely that bus fuel consumption per vehicle-km may lower than for urban buses, in light of higher average speed and wider stop spacing on the busway section. An estimate of average bus fuel consumption was derived from WebTAG guidance.

The Atkins study (2013) indicates that 24% of busway users were diverted from car, with a further 13% formerly using lifts or car-sharing (as a cautious assumption, the effect of reduced energy consumption from the latter group is regarded as negligible). It is not assumed that the whole length of car vehicle trips is diverted onto busway services, as those using P&R sites will have an access leg made by car. It is implicitly assumed that the car trip would have travelled past, or close to, the P&R site (for example to access the A14) prior to diversion. In reality, the pattern may be more complex, as discussed earlier in this paper, but the Atkins survey only identifies origin and destination (O&D) at the level of bus stop used, not ultimate O&D. The combination of good use of the busway service plus the diversion from car gives an average bus load of about 30, and passenger-km per litre of about 75, vastly better than current average figures for local bus services in Britain. Further savings in energy use would be produced by the diversion of car trips between the P&R sites and the city centre. A fuller account is provided elsewhere (White 2015).

8. Other developments and consideration of park and ride provision

In some cases, scope may arise for smaller sites served by existing routes, potentially reducing the pcu-km generated by car feeder trips through intercepting car trips closer to the users' trip origin than at larger sites. This was proposed by Meek et al (2011), for example. The Bicester and Cambridge busway P&R sites can be seen as large-scale examples of this concept. However, this carries a risk that alternative sites, if smaller, would each generate a lower level of bus demand, making commercial operation more difficult to justify.

However, where this can be placed adjacent to an existing service this risk would not apply. For example, in autumn 2014, a site for 50 cars (plus cycles) was opened on the A2 road south east of London, served by existing commuter coach services. In some cases it has been argued that existing large sites should be moved further away from existing urban centres, to intercept trips closer to user origins, and reducing congestion on major roads in the area, for example in the case of Oxford (Local Transport Today 2015, 2016).

A further complication in analysis of P&R impacts is that informal parking may also develop around stops on existing bus or rail routes, where no formal (off-street) parking site has been provided. This may give some of the same user benefits as described above, but local problems from kerbside or grass verge parking may arise. This has been observed, for example, on the Croydon Tramlink in south London, where no P&R sites were provided on opening (Davidson, 2003).

The use of land purely for park and ride may incur high costs and be difficult to justify both in terms of planning environmental considerations. In some cases, an existing parking site may be available for complementary use. For example, sports facilities are used most heavily at weekends, making their capacity available for P&R use during the working week – for example, in Guildford (utilising a sports and leisure centre), and in Leeds (utilising the Elland Road football ground). Opportunities may also arise at out-of-town shopping centres, whose peak demand tends to be on Thursday and Friday evenings, and at weekends.

9. Conclusion and next steps

Within the British context, a major element of the debate about bus-based park & ride has focused upon physical measures of the effects. Most notably, the net changes in pcu-km arising from additional pcu-km in feeder trips, offset by the reduction in pcu-km on the section of the network between the P&R site and the urban centre. However, by applying well-established economic evaluation techniques such as those in 'WebTAG' a more sensitive evaluation can be produced, applying appropriate values for the external costs imposed for each pcu-km, by category of road and level of congestion. In the case study shown, it is evident that a net benefit is produced, since the external cost per pcu-km over the sections of the network from which pcu-km are removed is much higher than on the roads on which additional pcu-km are generated.

This must be qualified, in that the case study considered has some unique features, notably in the role of rail commuting to London, and user shifts between alterative railheads. In other free-standing urban areas, this factor is less likely to apply. It would therefore be desirable for further case studies to be undertaken in a wider sample of areas.

The study by Rutherford et al (1986) in the Puget Sound (Seattle) region also indicates a net economic benefit, despite a substantial proportion of P&R users having previously walked to a local transit stop, and a small increase in person-miles travelled: vehicle-miles travelled fell (in this case, P&R sites appear to have been at a much greater distance from the main city centre than in the example considered here).

Whilst the majority of this paper is devoted to a specific case of monetised effects of changes in pcu-km, some broader considerations are also introduced in sections 7 and 8, highlighting the strong benefits that may arise from considering P&R with longer-distance busway provision, and to present developments in Britain relevant to the future role of bus-based P&R.

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