TAG UNIT M5.1

Modelling Parking and Park and Ride

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Department for Transport

Transport Analysis Guidance (TAG)

https://www.gov.uk/transport-analysis-guidance-tag

This TAG Unit is guidance for the **MODELLING PRACTITIONER**

This TAG Unit is part of the family **M5 – ADVANCED MODELLING TECHNIQUES**

Technical queries and comments on this TAG Unit should be referred to:

Contents

1 Modelling Parking and Park-and-Ride

1.1 Introduction

1.1.1 This Unit provides advice on modelling parking to assess the impacts of parking policies. The advice is relevant to forecasting changes in trips to and from an area where parking controls are applied or may be applied in the future. These parking controls may be either part of the core scenario forecasting assumptions or they may be parking interventions which it is desired to assess.

1.1.2 In this context, 'modelling' means setting up the base year model with the required functionality and using the model in forecasting. The Unit does not cover the appraisal of parking interventions.

1.1.3 The Unit is a companion to the following Units:

- TAG Unit M3.1 - Highway Assignment Modelling;

- TAG Unit M3.2 - Public Transport Assignment Modelling; and

- TAG Unit M2 – Variable Demand Modelling.

1.1.4 Parking interventions fall into two main groups, each of which needs to be treated differently:

- urban centre parking interventions; and

- park-and-ride schemes.

1.1.5 Guidance on the modelling of these two groups of parking interventions forms the main part of this Unit.

1.1.6 Urban centres are the areas where parking constraints have the highest impacts on travel demands. Outside of urban centres, parking at the attraction end of the trip is not generally a significant issue.

1.1.7 The Unit is not concerned with the explicit modelling of residential parking constraints. Limits on residential parking space can constrain car ownership, particularly in long-established urban areas where off-street parking is often insufficient to accommodate aspirations for car ownership. These effects are best dealt with at the trip generation stage, through either manual methods or explicit treatment within a land-use model.

1.1.8 Where the spaces available are used for a mixture of residential and non-residential purposes on the periphery of urban centres, some allowance must be made for residential parking demand, and advice on this issue is provided in this Unit. The key concern here is the degree of parking related to central area activities that may occur in residential areas surrounding an urban centre. The impact of restricting these areas to parking by residents only can be of considerable significance.

1.1.9 Park-and-ride can usefully be considered under the following headings:

- rail based park-and-ride using rail station car parks, where spaces may be limited;

- rail based park-and-ride using available parking spaces in the areas surrounding rail stations (which may or may not have a car park of limited capacity as specified above);

- rail based park-and-ride at large scale 'parkway' stations with substantial car parks able to cope with projected demands, and with little opportunity for off-site parking;

- formal bus based park-and-ride schemes with dedicated services (operating non-stop between the parking site and the urban central area) and substantial car parks able to cope with projected demands; and

- informal use of car as an access mode to a standard bus service, tram or metro, with parking on highway near to the bus or tram stop or metro station.

1.1.10   Guidance on the modelling of the first four of the above circumstances is provided in this Unit. The last case in the above list is not considered to be of sufficient significance to warrant special attention and so is not addressed.

1.2   Proportionality

1.2.1   Following the advice on modelling urban centre parking and park-and-ride, some briefer advice is provided on modelling of area-wide workplace parking levies (WPLs). However, the Unit does not cover the option of modelling demand and supply for all non-residential parking across an urban area as a whole because, generally, there are insufficient constraints on parking to make such complexity worthwhile. Any local pockets of existing (or likely future) constraints can be modelled in the same way as urban centre parking.

1.2.2   The full modelling of parking is very complex and may be disproportionate for many schemes. Analysts for Major Transport Schemes are encouraged to engage with the Department in the early stages of their project to agree the parking modelling capability that is appropriate and proportionate for the scheme. For further guidance on the principles of proportionality see Guidance for the Technical Project Manager.

1.2.3   At the stage of scoping a model, it is important to consider:

- whether parking needs to be modelled; and, if so,

- the way in which parking should be modelled, that is, the sophistication of the approach that is appropriate in the circumstances.

1.2.4   Parking may not need to be modelled in any detail where a satisfactorily validated model without parking functionality will be adequate to:

- forecast from the base year to the future without-scheme scenario; and

- model the impacts of the scheme itself.

1.2.5   In forecasting demands in the without-scheme case, it will be important to ensure that the forecast demands are commensurate with the parking supply available. If demands exceed the supply, some means within the model will be required to reallocate the surplus demand. A simple approach may often suffice for this purpose.

1.2.6   For modelling the impacts of a scheme, the capability for modelling parking is unlikely to be required when all of the following conditions hold:

- there is ample parking capacity available in the without-scheme and with-scheme scenarios;

- there is little change in the spatial distribution or accessibility of parking spaces as a result of the scheme; and

- monetary charges (parking charges by location and, for park-and-ride schemes only, public transport fares) change proportionately with values of time between the base and future year, and are the same in both future year scenarios.

1.2.7   Even when one or more of the above conditions does not hold, it may be disproportionate to model parking in full detail and simplified approaches may suffice.

1.2.8   This Unit considers comprehensive treatments first and works towards progressively simplified methods. This approach is intended to make analysts aware of all the complexities of a proper

treatment of parking and so enable them to appreciate the approximate nature of the treatment they may be forced, for reasons of practicality, to adopt.

2 Modelling Urban Centre Parking

2.1 Introduction

2.1.1 There are two **main** reasons for modelling urban centre parking, as follows:

- to ensure that the forecasts of the demand for travel to the urban centre by car are consistent with the forecasts of the available parking spaces; and, **within that constraint**,

- to ensure that the car vehicle trips end at zones containing car parks as opposed to zones where the activities of the occupants take place and where there might be insufficient parking.

The Balance Between Demand and Supply

2.1.2 The total number of trips by car to urban centres will be influenced by the availability of parking spaces, walk times to final destinations (where the car occupants will undertake their activities), restrictions on parking durations, monetary charges, and enforcement levels and penalties. If these parking constraints are ignored, forecast numbers of car trips to urban centres could be over-estimated.

2.1.3 Moreover, in cases where parking supply is less than demand, forecasts of demand to other parts of the urban area could be under-estimated unless parking constraints in the urban centres are properly accounted for in the forecasts.

2.1.4 It is important to ensure an appropriate balance between car parking demand and supply in all forecasts using all kinds of transport models. Various approaches may suffice, depending on the purpose of the forecasts, varying from the simple approximation to a fully specified treatment of parking. The different approaches to ensuring a balance between demand and supply are explained later in this Unit.

Allocating Car Trips to Car Park Zones

2.1.5 The zones where car occupants undertake their activities may not contain sufficient car parking spaces for all car users to park their cars in the same zone. In these instances, car users might use car parks in nearby zones and their choice of car park will depend on the availability of parking spaces, walk times to final destinations, restrictions on parking durations, monetary charges, and enforcement levels and penalties.

2.1.6 Detailed zoning systems and networks covering the urban centre and its environs will be required so that the routes taken to access appropriate car parks can be modelled and so that traffic flows on individual links can be modelled realistically.

2.2 Special Features Required for Modelling Parking in Urban Centres

2.2.1 In order to judge the risks inherent in approximate methods, it is necessary to appreciate what a fully specified treatment involves, as now explained.

2.2.2 Some features are more important for modelling parking capacity constraint (which may cause behaviour change through changes in the number and / or location of parking spaces, but also through changes in parking demand), whilst some features are more important for modelling changes in parking charges (which may have a different impact on different trip purposes and income segments).

2.2.3 It should be noted that even if the scheme does not involve changes to both parking capacity and parking charges, there may be a material disadvantage in not modelling both responses.

Features Beneficial for Modelling Parking Charges and Parking Capacity Constraint

2.2.4   Modelling parking is better done using tours as the behavioural unit rather than trips. Usually, transport users travel in order to carry out activities, many of which need to be undertaken for a given period of time. Use of tours allows constraints to be placed upon changes to the times of outbound trips and the times of return trips so that, where appropriate, any change in time period of the outbound trip will also apply to the return trip. Without the use of tours, shifts in the timing of the outbound and return trips may imply unreasonable changes to the given time required for the activity (e.g. an excessive lengthening or shortening), distorting the cost of parking and the calculation of car park occupancy levels for each time period. Further discussion of the modelling of tours is contained in paragraph 2.3.13.

Features Important for Modelling Parking Capacity Constraint

2.2.5   If parking capacity is constrained, the availability of parking spaces will be restricted at some point. The availability of a parking space depends on the car park capacity and car park occupancy levels at the time that the space is required. In order to model car park occupancy, it is necessary to model the 'history' of parking throughout the day, as arrivals in time period 'n' and their associated durations govern the available spaces in all subsequent time periods (n+1.....n+x). This means that the day should be divided into a number of time slices or periods and the numbers of parked vehicles accumulated for each period throughout the day.

2.2.6   The calculation of the parking accumulations requires information about parking durations, which will vary by trip purpose. Car park occupancy levels will also be affected by the search and queuing times required to access a space, the charges levied and the length of stay permitted. While the charges and length of stay restrictions are data inputs, the relationship between space availability and search and queuing time needs to be established and included in the model.

2.2.7   Other desirable features include:

- an increased segmentation of demand to represent the situation where access to certain spaces, such as private non-residential spaces, is restricted to particular users;

- representation of the trade-off between search and queuing times, charges, and walking distances and times in order to model the choice of parking location; and

- representation of the effects of varying levels of enforcement and penalties.

Features Important for Modelling Parking Charges

2.2.8   If the model is to be used for investigating alternative charging strategies, income segmentation will also be required, as for road pricing. For further information see TAG Unit M2 - Variable Demand Modelling.

2.2.9   These features come at the price of increased model complexity, increased data requirements, and longer model run times.

Techniques for Modelling Urban Centre Parking

2.2.10   This section considers techniques for modelling parking, starting with a comprehensive treatment and working towards progressively simplified methods.

2.2.11   Three broad levels of treatment of parking can be identified:

- the full treatment, which involves special functionality being introduced in both the demand model and the interface with the highway assignment model;

- more approximate treatments in demand models and highway assignment models, which range from the use of explicit but simplified parking models through to models that have no special functionality for the modelling of parking and which essentially represent the 'cost' of parking impacts through the imposition of exogenously developed generalised cost changes; and

- a more limited treatment which involves special functionality being introduced in the highway assignment model only.

2.2.12 Each of the above levels of complexity is considered in this Unit.

2.3   Full Treatment of Parking

2.3.1   This section provides guidance on a comprehensive approach to the modelling of central area parking. It is based primarily on the specification developed in the Department's **Study of Parking and Traffic Demand**, but makes references to other approaches where additional features and functionality have been provided.

2.3.2   The full treatment of parking entails the following:

- treatment of parking choice as an integral part of the demand modelling process, along with the more commonly modelled responses of destination, mode, time period and trip frequency;

- linkages between model time periods, undertaken though the use of tours modelling;

- segmentation of travel demand by trip purpose and income (value of time);

- estimation of average durations of stay by trip purpose and departure time;

- tracking of arrivals, departures, occupancies across (and within) time periods, so that the number of available spaces for further arrivals is always known;

- an explicit recognition that the zone for parking could be different to that where the car occupants' activity is undertaken, with allowance for access/egress by walking or public transport;

- definition of an appropriate set of parking types, in particular the distinction between publicly-available parking and private non-residential (PNR) parking;

- definition of parking sites, as a combination of zone and parking type;

- specification of parking charges, for combinations of parking site, arrival time and duration of stay;

- definition of parking capacity for combinations of parking site, arrival time and duration of stay;

- definition of the relationship between levels of car park occupancy and time spent searching and queuing for a space; and

- allowance for additional highway vehicle kilometres generated by traffic searching for parking spaces.

2.3.3   The details of the comprehensive approach to parking modelling are now considered under the following headings:

- person and vehicle trip ends;

- role of the demand model;

- the need for tours;

- numbers and definition of time periods;

- time of travel choice;

- parking choice;

- accumulation of demands;

- parking capacity restraint.

Person and Vehicle Trip Ends

2.3.4   An essential requirement for modelling of parking in urban central areas is for person and vehicle trips ends to be clearly distinguished. This is because, in urban central areas, it is frequently the case that the zone in which parking takes place and the location of the activity undertaken by the trip maker are different.

2.3.5   The process of establishing a base year model with this distinction is quite complex. Important points to note are:

- at the data collection stage, it is desirable that both the parking location and true origin and/or destination are requested from interviewees;

- assignment models work on the basis of vehicle trip ends, and traffic counts also relate to this definition of trip-making; and

- any count-based matrix estimation applied in assignment model calibration will act on the vehicle matrix, but the changes will have implications for the person trip matrices as used by the demand model, and appropriate adjustments will need to be made.

2.3.6   For a base year model calibration, it may be necessary to iterate between application of an early version of the parking model and application of matrix estimation in the development of the highway assignment model.

Role of the Parking Element of the Demand Model

2.3.7   The primary role of the parking element of the demand model is to change the relationship between person and vehicle trip ends in response to changes in parking and highway access conditions. A further role is to allocate car park access and egress modes between the available alternatives, which in general will be walking and bus.

2.3.8   Figure 1 shows the location of the parking sub-model within a transport demand model with a hierarchical logit formulation, the approach assumed in the description of parking choice modelling as described in this Unit. In this example, the TAG default choice hierarchy is assumed, with trip frequency as the least sensitive choice, followed by main mode and macro-time period choice with the same sensitivity, followed by destination choice (or trip distribution) with greater sensitivity than main mode choice (see TAG Unit M2).
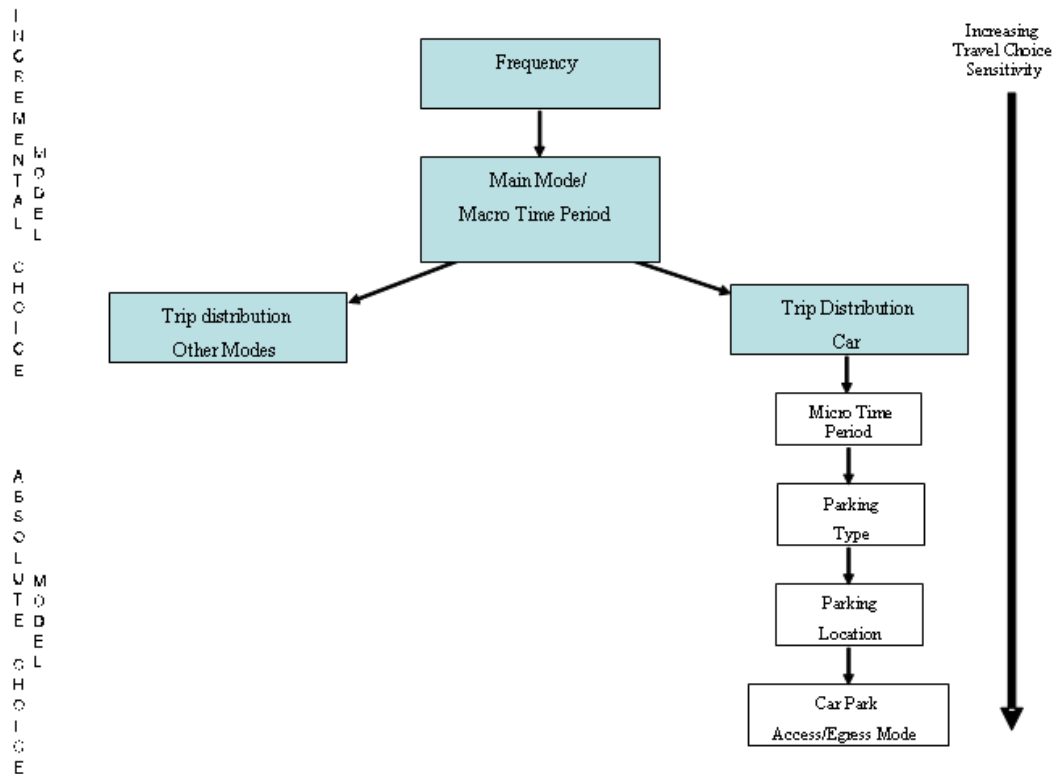
Figure 1 Parking Element within the Travel Choice Hierarchy

2.3.9 Also in line with the TAG default hierarchy, micro-time period choice is shown below destination choice in Figure 1. Micro-time period choice relates to the choice of time of travel within the periods subject to the macro-time period choice stage.

2.3.10 The parking choices are generally assumed to be more sensitive on the car travel side of the structure. An incremental approach requires a sound base position to be established, from which to pivot in forecasting. In the case of parking choice, there is rarely sufficient information to establish a robust base position and an incremental approach is not therefore feasible. Consequently, choices related to parking are normally defined in the model structure as absolute choices.

2.3.11 The structure shown assumes public transport sub-mode choice (e.g. bus versus rail) would take place within the assignment model, but this is not a requirement for the modelling of parking. See TAG Unit M2 for a discussion on the alternative ways of representing public transport mode choice in transport models.

The Need for Tours

2.3.12 While it is generally accepted that the different trips made during the course of a day by any given traveller are not independent, the complexities of modelling this dependency are sufficiently great that the majority of models represent individual trips. While for most applications this can be considered an acceptable simplification, for interventions such as parking and road pricing, with their potential for significant differentials in costs between time periods, it is unlikely to be satisfactory.

2.3.13 For a comprehensive treatment of parking, the outward and return legs of home-based journeys should be linked together to form 'primary destination tours'. This linkage preserves the integrity of the 'travel out, undertake activity, travel back' sequence, and enables the effects of transport policies to be represented consistently across the whole day. With tour-based modelling, responses to policies are modelled on the basis of the total cost of travel for the outward (from home) and the return (to home) journeys combined, including any parking costs incurred.

2.3.14 The tours approach does not apply to non-home-based movements, which, in principle, may also be affected by decisions relating to the outward and return portions of the 'primary destination tour'. However, to handle this a full-scale 'trip-chaining' model would be required; this is a highly complex alternative not considered in this Unit and for which specialist advice should be sought.

2.3.15 In most models, non-home-based trips should therefore be excluded from this trip-linking process and treated as individual trips, in the traditional manner. These trips generally occur between the outward and return legs of home-based tours. On this basis, they can be assumed to have no **net** effect upon **total** parking demand in any one modelled period, as arrivals and departures tend to be broadly in balance. They can therefore be excluded from the supply/demand modelling of parking, although this approach presents problems for the reporting of the details of the occupancy of individual parking sites. Alternatively, the parking of non-home-based demand can be modelled on a trip basis, with assumptions made about appropriate durations of stay.

Number and Definition of Time Periods

2.3.16 The parking modelling process works in the most optimal way when the duration of most parking events (an arrival and a subsequent departure) is longer than one time period. It is then possible to make an assumption that arrivals and departures occur at the mid point of each time period in terms of their impact on available spaces. Where tours are within a single time period, their impact upon available parking spaces becomes more approximate, with assumptions having to be made about length of stay. If a time period is long, this approximation governs the dominant part of the demand. In response, an increase may be considered in the number of time periods required for modelling parking compared with the time periods used in a conventional transport model. A further requirement for larger than normal numbers of time periods arises in order to represent:

- charging structures which can vary by time of day (in both base and forecast situations);

- car park opening and closing times;

- the peak hours that are calibrated and validated in detail within highway supply models; and

- the effects of parking on micro-time period choice.

Macro-Time Period Choice

2.3.17 The relevant components of a parking tour are illustrated in Figure 2.
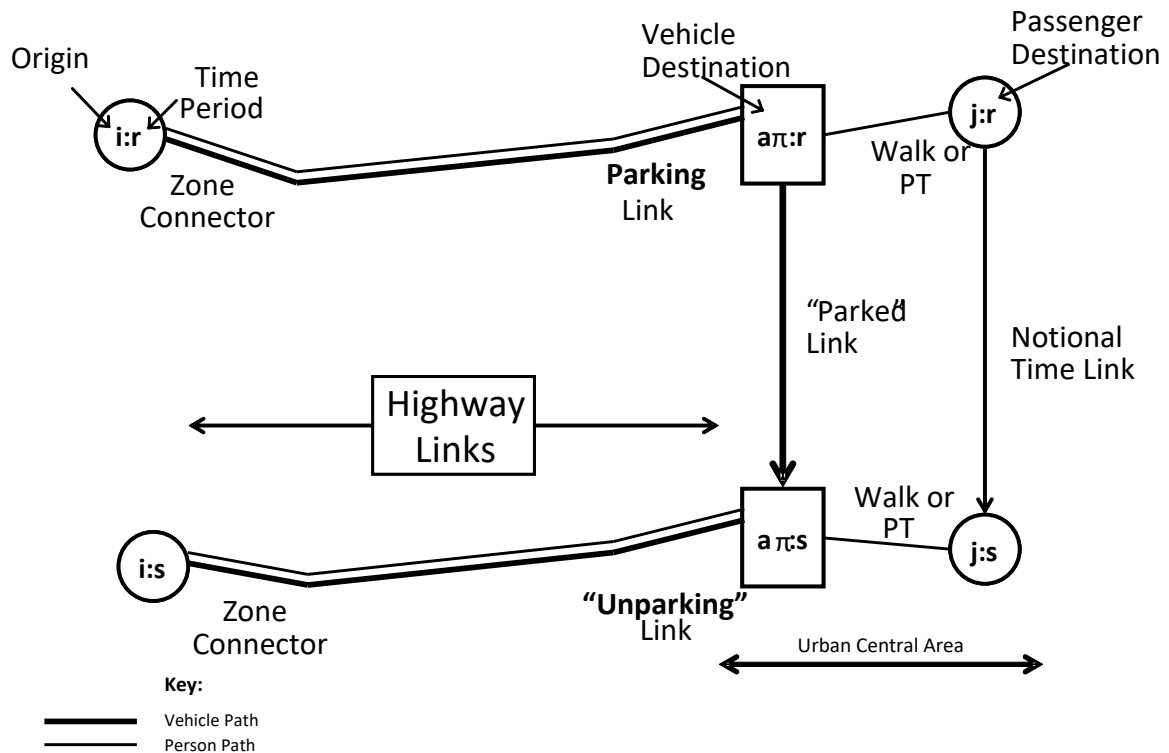
Figure 2 Example of a Parking Tour

Figure 2 Example of a Parking Tour

2.3.18   The purpose of the parking choice model is to allocate car tours to the various possible parking sites, given home origin in zone i, non-home 'primary destination' in one of the parking zones j, departure from home in period r and return home in period s.

2.3.19   Parking sites are combinations of area, a, which in practice is treated as being synonymous with a zone, and the parking type, π (on-street and off-street by permitted duration, private non-residential (PNR), etc.).

2.3.20   The use of tours implies that the choice of when to travel must relate simultaneously to the choice of outward and return periods (r,s). In order to keep time-switching within sensible bounds, the combinations {r,s} may be grouped, separately for each home-based purpose, into a set of mutually-exclusive combinations (R,S). Time-switching would only be modelled to take place within each combination.

Parking Choice

2.3.21   Parking choice should generally be applied only to the car mode[1], and should only be modelled for the designated central area parking zones, although it is possible for a model to have more than one urban central area, with geographically separate groups of parking zones (e.g. within a model of a conurbation).

2.3.22   A data set of walk times between parking locations and zone centroids is required. These could usefully reflect anticipated delays of significance such as those imposed by road crossings, subways and pedestrian congestion, etc. Each urban central area should normally have its own discrete set of walk links.

2.3.23   As stated earlier, it is not essential to model urban centre parking for non-home-based trips. Similarly, for a model with a reasonable degree of spatial disaggregation in the urban centre, the

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[1] Goods vehicles, particularly light goods vehicles, do make some use of available parking spaces in urban central areas. It may therefore be appropriate to represent the parking of these vehicles in the same way as for non-home-based person trips. Appropriate questions on roadside interviews can serve to identify the scale of this issue.

number of intra-zonal car trips is normally sufficiently low to avoid the need for the representation of their parking demand.

2.3.24   A proportion of car demand arriving in a central area will not park in a recognised space or will do so for only a very short time, and this proportion will vary by trip purpose. Trips made escorting children to and from school are a good example of short duration parking. Estimates of these proportions need to be made and they should be excluded from the parking choice process and hence from the calculations of parking accumulations.

2.3.25   All traveller segments should be assumed to have access to on-street and public off-street parking, but only user specified segments should be allowed to access PNR. It is reasonable to assume that PNR can only be used in the attraction zone. In addition, the underlying **preference** for different types of parking may be varied by traveller segment.

2.3.26   The choice between parking site is based on a comparison of generalised costs. Different parking sites can have different monetary costs, search time and egress time. The monetary costs should reflect the duration at the destination, as well as employer subsidies. For a given parking site and duration, money costs are fixed; egress times to the final destination can vary according to network conditions (if for instance bus is used); and parking search time is calculated as a function of accumulation as a percentage of capacity in each car park in the period concerned.

2.3.27   Enforcement should be dealt with in the calculation of the money cost. For those parking types that are limited to a maximum duration (e.g. on-street meters) or are classified as illegal, the cost (in addition to any legal payment for meters, etc.) is the penalty multiplied by the probability of being apprehended. These probabilities of being caught are externally estimated to reflect both the enforcement effort **and** the duration of parking (in other words, different values are appropriate to different combinations of r and s): they remain fixed within any one model run, so that they are independent of the actual amount of illegal parking that would be modelled as occurring.

2.3.28   Note that, since the parking cost for each site may be individually specified, it is possible to allow for spatial variation in the enforcement effort.

2.3.29   In order to reflect available parking spaces for each πa combination, the relevant terms in the parking choice logit formulation may need to be multiplied by a 'size variable'. As demand groups are modelled in turn, accumulations of parked vehicles by site should be calculated, and the size variable recalculated as the minimum number of spaces available over the periods between time periods r and s. The availability of parking types π should be controlled with reference to the demand group, pk. The same device should be used to restrict availability of specific sites for vehicles arriving in later periods when the capacity has already been used by vehicles arriving in prior periods.

2.3.30   As a car park nears capacity, the 'modelled' cost of parking increases. However, in an initial allocation of demand to available spaces, significant overloads might occur. As a result of the first pass allocation, there will most likely be a number of parking sites that have been assigned more demand than can be accommodated in the available supply. The parking model may therefore need to iterate so as to redistribute the excess demand in each parking site into other, available, parking sites. As this process is carried out, the total amount of excess demand should decrease. The sites to which excess demand can redistribute are those which are not over-capacity in the previous iteration.

2.3.31   The excess demand in a given parking site is made up of a mixture of trips with different journey purposes and different desired destinations. The redistribution should be carried out as if the excess were once more headed for the desired destination zones, as in the first pass allocation, though now with a restricted set of sites being available.

2.3.32   Redistribution of excess demand should continue until one of the following stopping criteria is met:

- the total excess demand across all modelled parking zones is less than some specified tolerance; or

- the change in the total amount of excess demand across all modelled zones has changed since the last iteration by less than some specified tolerance, i.e. the parking model is not able to redistribute sufficient excess demand at this point to make any difference to the result; or

- all parking sites associated with all desired destinations are full to capacity, or contain excess demand, so that no excess can be redistributed at all (note that this criterion is in some ways equivalent to the second, above).

2.3.33   If none of the above criteria can be met, the parking model iterations should be terminated when some predefined maximum number is reached so as to ensure that the model does terminate, regardless of the attributes of the input data. In these cases, realism of the case being modelled should be reviewed and amendments considered to the input data, relating to either the demand or the supply. Results from a model run which terminates after a pre-determined number of iterations should be treated with caution.

2.3.34   The above explanation relates to model developed in the Department's **Study of Parking and Traffic Demand**. Other methods of achieving equilibrium may also be feasible.

2.3.35   It should be noted that, for a base year model, there should be no residual excess if the definition of supply and demand is accurate.

Aggregation of Demands

2.3.36   As a result of the various choice processes, a highly-structured matrix of demand, which can be generally written as $T_{pkijmrs}(\pi a)$, is obtained. However, it is only necessary to **store** demand at a level of disaggregation sufficient to calculate generalised costs of travel in the highway assignment model. Hence, there is a need for an aggregation procedure which gathers together estimated demands.

2.3.37   For the most part, information about purpose and person-type is not relevant to the operation of the highway assignment model. A notable exception is the variation in the value of time, which can affect routeing. For this reason, it is necessary to define 'flow groups', representing groups of travellers having common values of time. Demand should, therefore, be aggregated by flow group.

2.3.38   Additionally in the aggregation process, tours for home-based purposes should be split into their constituent trips and allocated to their respective time periods, and car person trips converted to vehicle units (and are given vehicle trip ends, that is car park zones). On input to the highway assignment model, demand is therefore by flow group in the conventional form as numbers of unlinked vehicle trips, by vehicle origin and destination, and time of day.

2.3.39   As a result of the above, the highway assignment model used with a demand/parking model can be largely conventional. An exception would occur if parking search mileage is to be forecast explicitly. The demand model would need to store total road mileage for each zone in order to calculate a link and turn vehicle pre-load based upon an estimate of the total search mileage.

2.3.40   Where public transport is considered as an access/egress mode for car parks, the aggregation process will need to allocate the public transport leg to the public transport demand matrices when undertaking public transport assignments.

Parking Capacity Restraint

2.3.41   For each zone where parking supply is represented, definitions of capacity and price are required for each parking type. The parking supply model has two main functions. The first is to modify parking search time in relation to capacity utilisation. The second function is to keep a check of the availability of spaces at each parking site. The search time functions should be derived from

available empirical evidence, supported by some underlying theory related to queuing processes. Different functions are appropriate to different parking types, π.

2.3.42   In many towns and cities, it will be necessary to include residential areas on the periphery of the urban centre within the area over which parking is modelled, as these areas might be used by urban centre trip-makers, particularly commuters. The ideal approach would be to include this limited area of residential parking demand within the overall parking model, representing its from-home and to-home demand within the tours matrix. Thus, the departures and arrivals across the day would allow the available spaces for other demands to be calculated. However, the complexity may not be warranted and, where this issue is not critical, an estimate of available spaces on the urban periphery for trips bound for the urban centre can be derived from surveys (e.g. a cordon of roadside interview surveys) and input to the model as an exogenously derived value.

2.4   Approximate Treatment of Parking

2.4.1   The methodology for comprehensive treatment of the demand and supply modelling of parking as set out above is complex. Its implementation would add significantly to model complexity, development times and run times.

2.4.2   Simpler approaches can be taken, which essentially involve the removal of some of the levels of detail from the ideal specification. Examples of simplifications are:

- demand modelling using trips rather than tours;

- independent modelling of time periods;

- omission of income segmentation;

- high levels of spatial aggregation of the parking modelling process;

- omitting urban centre periphery parking issues;

- reduced numbers of parking types; and

- exogenously derived parking cost changes.

2.4.3   These simplifications are discussed in this section.

Trip-Based Modelling

2.4.4   Modelling of tours is an overhead that can be generally avoided when there are no plans for policies that have significant time of day impacts (e.g. peak period road pricing). With appropriate caution and caveats to the outputs, modelling of parking could be undertaken on a trip basis.

2.4.5   Note that, for parking models working on a trip basis, it is necessary to halve the money costs of parking, as this by definition relates to the tour (i.e. the out and return trip combined).

2.4.6   It is assumed that any demand model encompassing a parking model will operate on a production/attraction (PA) basis. Derivation of occupancies for all parking sites at the beginning and end of each time period is, in principle, straightforward, even with a trip-based model, because the proportions of trips that are from-home and to-home are known and an estimate of both demand into and demand out of a car park can be made. However, the use of from-home and to-home factors does not guarantee, as a tour-based model would, that the total demand into and out of a parking site over the day will be equal.

2.4.7   However, assuming the to-home/from-home factors are sensible, demand-in and demand-out should be quite close for each site. It should therefore be straightforward to correct for the discrepancy prior to calculating search times. The model should be based on the assumption that

car park occupancy at midnight is zero. Occupancy throughout the day should then be built up, calculating occupancy at the end of each modelled period. In general, the occupancy at the end of the day will not be zero (and is as likely to be positive as negative). Occupancies at the end of each time period may then be estimated by:

$$Occ_{AM} = Occ'_{AM} - 0.25Occ'_{OP}$$
$$Occ_{IP} = Occ'_{IP} - 0.50Occ'_{OP}$$
$$Occ_{PM} = Occ'_{PM} - 0.75Occ'_{OP}$$
$$Occ_{OP} = 0$$

where:

Occ_{AM} Occ_{IP} Occ_{PM} Occ_{OP} are the final modelled occupancies (by car park) in the morning peak, inter-peak, evening peak and off-peak, respectively, corrected for discrepancy; and

Occ'_{AM} Occ'_{IP} Occ'_{PM} Occ'_{OP} are the occupancies calculated by building up occupancies throughout the day with no correction, in the morning peak, inter-peak, evening peak and off-peak, respectively.

2.4.8   The deficiencies arising from this simplification are as follows.

- Where policies which imply materially different conditions or costs between time periods are to be examined, tours modelling is preferred. In particular, for the modelling of time of day choice on a trip basis to be valid, this choice ought to be at the bottom of the hierarchy, which is (rightly) not the case for most models. Thus, modelling parking policies which differ materially between peak periods, inter-peak periods and the off-peak could be problematic with this simplification.

- Whilst, in the base year model, the adjustments to make arrivals and departures balance over the day are likely to be quite modest, it would seem reasonable to expect that that this will not remain the case with fairly radical parking policy tests, e.g. a major increase in morning peak charges to free spaces for off-peak arrivals.

2.4.9   Therefore, modelling of parking responses on a trip basis is most likely to result in acceptable forecasts where it is used to reflect, in a broad brush way, the impact of parking conditions on:

- traffic growth to the urban centre over time; and

- the impacts of transport policies other than parking (supply and money cost) itself.

Independent Modelling of Time Periods

2.4.10   Whilst not employing tours modelling, the above still anticipates sequential modelling of time periods (as is the case with a tours-based approach) to allow car park occupancies at the end of one time period to be an explicit input to the next. An alternative would be to define exogenously the starting occupancies for each time period and hold these fixed within each run of the overall model.

Omission of Income Segmentation

2.4.11   Income segmentation for consumer travel is highly desirable for a model of parking, as money costs can be a major element of the overall parking costs. However, income segmentation will greatly increase model dimensions and the effort required to set up a model. There can often be competing requirements for segmentation within the demand model, such as the desirability of distinguishing the education or shopping trip purposes. Omission of income segmentation is probably acceptable for models where the representation of parking is required to assess the impacts of capacity

constraints on demand or in order to test policies related to car park opening hours, etc. The results from tests of parking charge strategies using a model without income segmentation are likely to be approximate.

Spatial Aggregation

2.4.12 Parking is most accurately represented in a model with a reasonably high degree of spatial detail in the central urban area, particularly the network and parking location detail. This facilitates the accurate representation of parking locations and hence walk distances to/from the attraction trip ends. However, this spatial detail adds to model setup costs and to model run times (particularly where large numbers of zones are required to represent individual parking sites).

2.4.13 Parking models can be set up with very limited spatial detail, perhaps only two zones (inner and outer) representing the urban central area. Such models might have value in representing the impact of overall capacity and price constraints. However, as demand changes from the parking model would be applied to large parts of the urban centre, the model would only be useful for broad policy analysis rather than analysis of the impacts of changing the precise location of parking supply and/or person trip ends.

Omitting Urban Centre Periphery Issues

2.4.14 Earlier reference has been made of the need to consider urban centre parking close to but outside of the centre itself, typically in residential areas and derelict industrial locations. Where such factors are not significant they can be omitted from the model. This is especially the case if the urban centre is in the base year surrounded by areas of controlled parking, dedicated to residents.

2.4.15 Similarly, for many areas, it may be appropriate to discount the possible use of bus services from peripheral parking areas to the urban centre, and therefore to omit this functionality.

Reduced Numbers of Parking Types

2.4.16 A wide variety of parking types can be included in a parking model. However, for models where the details of parking impacts are not critical, and particularly for models with a high degree of spatial aggregation in the area of parking modelling, a reduction in the number of parking types may be appropriate. It is recommended that, as a minimum, two categories be employed, private non-residential (PNR) and publicly-available spaces.

Exogenously Derived Parking Cost Changes

2.4.17 A fully specified demand model along the lines advised in TAG Unit M2 should be able to make use of exogenously derived cost changes alongside those provided by the supply models. The simplest form of parking modelling is therefore to calculate exogenously the costs (time and money) imposed on urban centre trip makers by a change in parking policy (or static parking supply over time). The weakness of this approach should be quite evident from the description of the complexities of modelling parking in a comprehensive way given earlier in this Unit, which explained the numerous trade-offs that a traveller can make in response to a change in parking costs. There will generally be a tendency for any costs derived exogenously to exaggerate impacts of policy changes. For example, an apparently simple change, such as a 20% increase in all parking charges for the urban centre, may not translate into a 20% increase in average price paid, as trip-makers may tend to move to lower price car parks where the absolute increase would be less, and to free locations peripheral to the urban centre if available.

2.5 Treatment of Parking Within the Highway Assignment Process

2.5.1 The modelling of parking choice wholly within a highway assignment model is appropriate where changes in the location of available parking spaces can substantially affect choice of highway route in and around a central area. In these circumstances, a link to a demand model is not a primary

requirement. A highway assignment model of only the urban central area and its immediate approach roads may be all that is required.

2.5.2   When choosing their parking location, motorists are understood to make a trade-off between walk distance, parking price and estimates of search time. There are a number of ways in which parking choice based on these factors can be represented in a highway assignment model. In such an approach, the trip matrix should be subdivided, for example, as follows:

- short-stay trips requiring a publicly-available car parking space;

- long-stay trips requiring a publicly-available car parking space; and

- all other trips (trips with access to private spaces and goods vehicles).

2.5.3   The network structure should reflect this sub-division, with separate links representing short-stay and long-stay charges to which only appropriate segments of the matrix are permitted access. Parking capacity links should be provided with cost/flow curves that impose search time delays as capacity is approached. Highway route choice and parking choice are thus carried out as a single process. Note that vehicles leaving car parks are also explicitly represented.

2.5.4   The assignment-based methodology is most suitable for morning peak modelling, where arrivals at car parks vastly outnumber departures. Departures from urban centres in this time period are fairly trivial and can be ignored in terms of their effect on available parking capacity. Hence, available capacity in the modelled time period can be assumed to relate only to arrivals. It is necessary to have a measure of occupancy at the beginning of the modelled period (normally of one hour duration for an assignment model). An exception is where residential areas surrounding the urban centre are being modelled to reflect the use of these spaces by urban centre arrivals. In these circumstances a measure of the extent to which residents vacate the spaces is required in order to set the availability for incomers.

2.5.5   In the inter-peak, the weakness of the assignment approach is exposed by the fact that both arrivals and departures need to be considered in order to have a measure of available spaces for arriving vehicles. This can only be defined approximately as there can be no explicit linkage between the arrival and departure 'links' in an assignment network as shown in Figure 3. If arrival and departure demand are roughly equal in the inter-peak period, then the problem is circumvented. All that is required is an estimate of occupancy for each link at the start of the modelled time period.
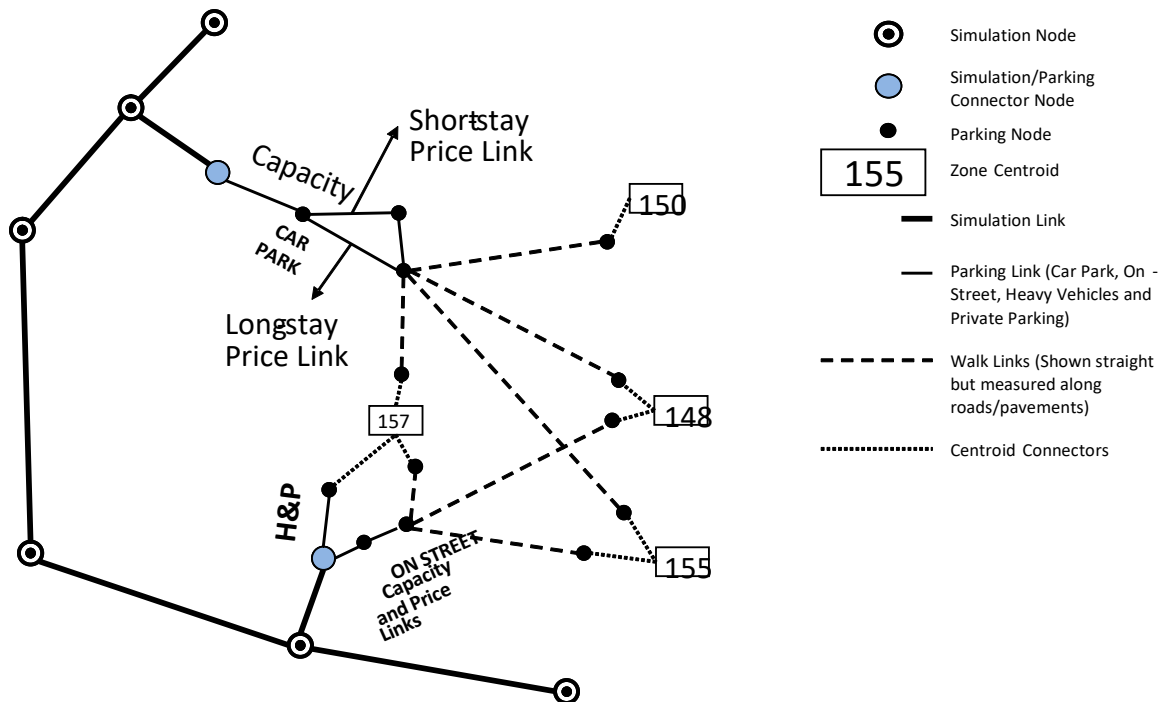
Figure 3 Parking Choice and Pedestrian Movements in a Road Traffic Assignment Model

2.5.6   For the evening peak, the modelling of 'unparking' is the crucial factor. The capacity for the link needs to be set so that it represents parking availability for the trips at the time of their arrival. This is difficult to estimate precisely, but can roughly be equated to capacities for incoming vehicles in the morning peak.

2.5.7   The deficiencies noted above would not be resolved by distinguishing 'from home' and 'to home' trips in the assignment model user classes. The problem of there being no connection between the supply treatment of arrivals and departures would remain.

2.5.8   The highly detailed representation of parking in a central area is probably not appropriate in an urban area-wide variable demand model because model run times are likely to be prohibitively long. In any event, a process based upon a demand model changing the relationship between person and vehicle trip ends is inherently superior to one based on the assignment process, for reasons discussed above relating to the impact of both earlier arrivals and departures upon available spaces for incoming traffic.

2.6   Data Requirements for Urban Centre Parking Modelling

2.6.1   The data specifically required for modelling parking cover the supply of parking and the ways that the supply of spaces are used.

Supply Data

2.6.2   For both treatments of parking described earlier, a more or less complete inventory of the parking supply is required, which should include:

- the numbers of spaces by type – on-street, off-street, private non-residential, and contract – and specific car park locations;

- the charges which apply to each of the types of space in each location at each time of day (including any penalty charges); and

- the opening hours and restrictions on duration of stay which apply to each of the types of space in each location.

2.6.3   Most of this information, with the exception of the supply of private non-residential (PNR) parking, is relatively straightforward to assemble, primarily from local authority sources but also from information published by private operators. On-street capacities can be estimated from marked spaces or an assumption about the number of vehicles that can be parked within a unit length of kerb.

2.6.4   For PNR spaces, surface level and aerial photography and/or satellite imagery can be used to estimate the number of spaces by model zone. Specifically commissioned aerial photographs can be used to define PNR surface level occupancy in a specific time period (say between 1200 and 1400). Aerial/satellite photographs can also be used to identify buildings likely to have underground car parks.

2.6.5   Mail-shot surveys to the building management can then be used to obtain further details of capacity and utilisation. Given that not all locations would respond, some means of expanding the sample of responses to represent the complete picture will be required. It may be possible to use judgement to categorise the non-respondents by size and then expand within size category.

2.6.6   For PNR spaces which are below ground or, indeed, embedded within a building so that they are not obvious from the air, approaches would probably have to be made to the building management, either by direct interview or by mail-shot[2]. Again, it is quite possible that information for only a sample of PNR car parks would be obtained and so some means of expanding the sample to represent the complete picture will be required.

Car Park Usage Data

2.6.7   The information required about parking space usage includes:

- durations of stay by trip purpose; and

- numbers of vehicles entering and leaving each modelled car park in each modelled time period.

2.6.8   At the data collection stage, it is desirable that both the parking location and true origin and/or destination are requested from interviewees. On this basis, a cordon of roadside interviews around the urban centre for which parking modelling is to be undertaken is highly desirable. This cordon should be positioned such that all major walk movements between car parks and urban centre person destinations are within the boundary. However, the cordon should not be more distant than absolutely necessary from the urban centre, in order to avoid diluting the sample with trips that do not have an urban centre destination.

2.6.9   The demand data collected by roadside interview cordons will be of some value in determining the number of PNR spaces, on the assumption that the peak occupancy calculated from this data equates to a value close to the limit of the PNR supply. Sample sizes may not permit capacity by individual zone to be estimated, but a sector value would be a useful check on estimates derived for other purposes.

2.6.10 Specific parking questions for a roadside interview should ideally include:

- parking type;

- parking location;

- journey purpose;

- duration of stay; and

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[2] It is possible that the Valuation Office Agency has collected some useful information and this should be ascertained before embarking on a survey.

- charges paid.

2.6.11 For the purpose of modelling parking, it may be preferable to conduct roadside interviews in the direction of travel away from an urban centre, rather than in the direction of travel towards the urban centre, so that 'actual' rather than 'intended' data, such as choice of car park or duration of stay can then be recorded.

2.6.12 Whilst valuable demand information can be obtained from roadside interview surveys, it is also desirable to carry out sample interview surveys of drivers at the more significant parking locations (preferably in the exit direction), particularly where this can be done economically. Duration of stay and trip purpose would be a key question for such surveys.

2.6.13 A primary source of usage data should be the electronic parking payment machines used by parking operators, providing a 100% sample over a significant period (e.g. two weeks). While these data provide no information about journey purpose, they can be useful for deriving overall average durations. These are used for off-street public car parks and on-street spaces where charges are levied. Available data usually includes arrival time and price paid, and from the latter a reasonable estimate of duration of stay (but not by trip purpose) can normally be made. Where a barrier system operates with payment on exit, accurate duration of stay data can be obtained.

2.6.14 Contract parking can form part of the spaces within an otherwise publicly-available car park. These spaces are not available to the general public. Capacity and usage should be separately identified. This capacity can effectively be classified as another form of PNR.

2.6.15 For parking spaces that are free at the point of use, it is desirable to obtain some arrival/departure count data and duration data. However, it should be noted that there is no requirement for all parking locations to be observed in terms of the scale of their usage. A reasonable sample with a good spread across parking types and locations is all that is required as a source for calibration and validation of a parking module[3].

2.6.16 Areas surrounding urban centres, particularly residential areas, that tend to be used by central area commuters should be included within the parking model and data are therefore needed on capacity and usage[4]. There is a complication here in that some (but not all) of the parked vehicles owned by residents will tend to leave in the morning peak and be replaced by incoming commuters and a simple occupancy count will not distinguish between residents and commuters. An outbound roadside interview cordon as recommended above, that encompasses the relevant residential areas, will provide data on the departure numbers for trips from home.

2.7 Forecasting using Urban Centre Parking Models

2.7.1 The process of applying a parking model in forecasting is essentially similar to that for changes to the highway or public transport supply definition. Assumptions need to be made about future capacities, charges, opening hours, levels of enforcement ,etc., for each parking location or zone in the central area. Large scale urban centre land-use changes can make the process of defining future parking supply a complex process.

3 Modelling Park-and-Ride

3.1 Introduction

3.1.1 Park-and-ride is often seen to be a major component of transport plans for urban areas, sometimes the dominant intervention within a local transport strategy. It is therefore necessary to be able to model demand for park-and-ride with a reasonable degree of accuracy. Park-and-ride cuts across

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[3] This is analogous to highway and public transport model validation, where only a sample of links are included in the process.

[4] An exception here would be residential areas that have been subject to residential parking schemes where compliance is enforced. These could reasonably be left out of the model's representation of parking.

the clear distinction between main modes within transport demand and supply modelling, and therefore presents a significant challenge to the analyst.

3.1.2 Park-and-ride can usefully be considered under the following headings:

- rail based park-and-ride using rail station car parks, where spaces may be limited;

- rail based park-and-ride using available parking spaces in the area surrounding rail stations (which may or may not have a car park of limited capacity);

- rail based park-and-ride at large scale 'parkway' stations with substantial car parks able to cope with projected demands, and with little opportunity for off site parking; and

- formal bus based park-and-ride schemes with dedicated services and substantial car parks able to cope with projected demands.

3.1.3 The modelling of these cases is considered in this Unit, along with the modelling of choice between alternative park-and-ride sites/services.

3.1.4 In any of the above forms of park-and-ride, charges for parking may be levied (either specifically or as part of an overall parking/ public transport fare charge). Car park capacity can also influence the usage of a particular site/service combination, as can available on-street parking in the area surrounding the parking site. These factors are addressed in this Unit.

3.1.5 A variant of park-and-ride is where a lift is given to a public transport stop. This variant is frequently termed 'kiss-and-ride'. This travel option is out of scope of this Unit as no parking event occurs at the public transport stop.

3.1.6 As with the modelling of urban centre parking choice, a comprehensive approach to park-and-ride modelling is described first followed by an approximate treatment of park and ride and the consequent limitations they introduce.

3.2   Full Treatment of Park-and-Ride Modelling

3.2.1 Park-and-ride has the potential to attract users from both the car and public transport modes. It can also bring about a simultaneous mode and destination transfer (e.g. from a car trip to an urban fringe location to a park-and-ride trip to the town centre). Comprehensive treatment of park-and-ride therefore requires a travel demand model in which all the main modes and travel demand responses are represented.

3.2.2 Park-and-ride choice should be positioned at a level in the demand model choice hierarchy which is commensurate with the relative sensitivity of this choice to changes in generalised costs.

3.2.3 In the absence of evidence from a local estimation, it should be assumed that the choice of park-and-ride should be positioned below destination choice and therefore with a sensitivity parameter value which is greater than that used for destination choice. Given the scarcity of evidence to support this advice, tests of the robustness of the forecasts to variations in the parameter values should be conducted, as advised in TAG Unit M2.

3.2.4 Because park-and-ride has been shown to extract users from both car all-the-way and public transport all-the-way, park-and-ride choice may, in principle, be either a sub-mode of car or a sub-mode of public transport. If park-and-ride choice is positioned on the car side of the choice hierarchy, the main mode choice would be between car plus park-and-ride, public transport, and walk and cycle. Thus, extraction from public transport all-the-way would be forecast at the main mode choice stage and extraction from car all-the-way would be forecast at the park-and-ride choice stage. If park-and-ride choice is positioned on the public transport side of the choice hierarchy, the main mode choice would be between car, public transport plus park-and-ride, and walk and cycle. In

this case, extraction from public transport all-the-way would be forecast at the park-and-ride choice stage and extraction from car all-the-way would be forecast at the main mode choice stage.

3.2.5   For models where evidence from a local estimation is not available, the positioning of park-and-ride choice as a sub-mode of either car or public transport may be based on the following:

- where park-and-ride is dominated by relatively short car legs in order to gain access to a substantial public transport leg, then positioning as a sub-mode of public transport is likely to be the more appropriate; and

- where the park-and-ride site is located so as to attract relatively long car trips to change mode on the edge of the urban area, and where public transport mode share is low for the movements of interest, then treatment as a sub-mode of car is likely to be the more appropriate.

In either formulation, the model would allow the transfer of existing car available[5] public transport trips to a new park-and-ride service.

3.2.6   The park-and-ride choice model should be validated by comparing base year forecasts of park-and-ride patronage with counts of cars parked at existing park-and-ride sites. Clearly, if no park-and-ride sites exist in the base year or at the time that the model is used for forecasting, no validation would be possible. In these instances, the need for tests to establish the robustness of the forecasts to variations in the sensitivity parameter values is even more important.

3.2.7   Attribute (site) Specific Constants may be introduced to ensure that the base year forecasts of park-and-ride patronage match the car park usage counts. However, these constants are largely cosmetic in an incremental model and may mask significant discrepancies between modelled and observed data. It is important, therefore, that the comparisons are reported prior to application of the constants.

3.2.8   Usage of the park-and-ride sub-mode by non-home-based trips is very low[6]. Consequently, tours modelling would encompass almost all of the relevant demand.

3.2.9   Where park-and-ride is to be modelled, the following requirements should be accommodated:

- the need to represent the balance between out and return trips across the day, in particular to ensure that park-and-ride is used for both the out and return leg; and

- the need to track car park occupancy, and hence model the availability of spaces, for each time period that is represented.

3.2.10   Income segmentation is not an important requirement for the modelling of park-and-ride because money costs would generally be at a scale intended to keep the facility attractive to a high number of users and to be competitive with the overall costs of travel wholly by car or alternative public transport modes. However, where park-and-ride is to be modelled alongside a policy of significant price-based demand management in an urban centre, the inclusion of income segmentation may be desirable.

3.2.11   Public transport and highway cost components for park-and-ride are generated from the relevant assignment models. In this respect, the definitions of the zoning systems for highway and public transport models should be considered simultaneously. A common practice to facilitate appropriate cost skims is to define an interchange zone representing the park-and-ride car park and public transport stop location. These interchange zones should be referenced in the zone system for both highway and public transport assignment models.

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[5] Here the term car available denotes trips from car owning households as opposed to trips for which are car was necessarily available.
[6] Usage of park-and-ride parking capacity by goods vehicles can be assumed to be zero.

3.2.12 In the development and use of a multi-modal model, greater efficiency is achieved by adopting a common representation of bus services in both the highway and public transport assignment models. With this arrangement, bus service definitions in the base year and future year scenarios need only be considered once, rather than separately for highway and public transport assignment models. The bus service definitions are usually established for the public transport model, with the results then being mapped to the highway model to provide the representation of fixed bus flows.

3.2.13 The costs associated with the act of parking at the park-and-ride site itself should also be included, and these need to be held, and where necessary calculated, in the demand model. The variable cost relates to parking search time as the capacity of the car park is approached. The process here is essentially the same as the representation of car parks in an urban centre parking model. Available parking capacity needs to take account of any opportunities for on-street parking that might arise in the event of car park capacity being approached (noting that park-and-ride can be significant in some locations where there is little or no formal parking).

3.2.14 Figure 4 provides an example structure for a transport demand model that includes park-and-ride, in this case as a sub-mode of public transport. The box labelled "Public Transport Access" represents the trips or parts of trips by public transport. Access to public transport would be by either walk (labelled "Walk Access" or by car (labelled "Car Access"), which is park-and-ride.
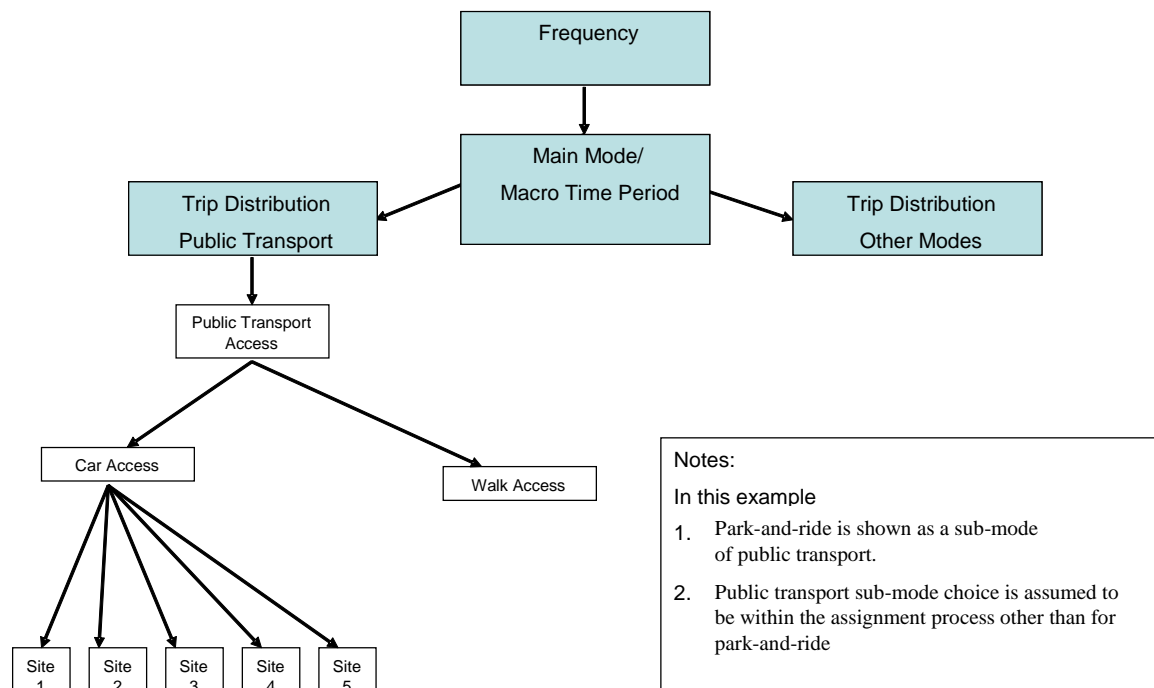

Figure 4 Example Structure of a Transport Demand Model including Park-and-Ride

3.2.15 In many urban areas, there will be a choice between alternative park-and-ride sites (and their associated bus or train services). All costs for alternative highway and public transport legs should be skimmed from their respective assignment models. Through experimentation, it should be possible to restrict the number of park-and-ride opportunities represented for each origin to destination pair, e.g. the demand model might only consider the five alternatives with the lowest generalised cost. A limited set of zones for each park-and-ride site should be defined, from and to which park-and-ride trips may be made, so that the processes of skimming costs from the two separate networks and combining them for the demand model can be made easier. This approach also facilitates the construction of the appropriate trip matrices for assignment.

3.2.16 As with urban centre parking, the demand model should include an accumulation process by means of which individual highway and public transport legs of a full park-and-ride trip are allocated to the correct assignment matrices.

3.3 Approximate Treatment of the Modelling of Park-and-Ride

3.3.1 The methodology for comprehensive treatment of the demand and supply modelling of park-and-ride as set out above is complex and its implementation would add to model development times and costs and model run times.

3.3.2 Simpler approaches may be taken, which essentially involve removal of some of the levels of detail from the ideal specification. Examples of simplification are:

- use of trips rather than tours as the behavioural unit;

- independent modelling of time periods, bearing in mind that time-period choice modelling is better done on a tours basis, which is more complicated than trip-based modelling;

- geographic restriction of park-and-ride, more so than might be the case in the full treatment;

- manual allocation of origin and destination pairs to the individual park-and-ride sites;

- use of highway assignment and simple mode choice models;

- base year park-and-ride representation within a public transport assignment model; and

- exclusion of base year park-and-ride from the choice process.

Trip-Based Modelling

3.3.3 As noted in paragraph 2.4.4, modelling of tours is an overhead that is generally avoided in transport modelling when there are no plans for policies that have significant time of day impacts.

3.3.4 It is assumed that generally any demand model which includes park-and-ride choice will operate on a production/attraction (PA) basis. Derivation of occupancies for all parking sites at the beginning and end of each time period is, in principle, straightforward, even with a trip-based model, because the proportions of trips that are from-home and to-home are known and therefore both demand into and demand out of a car park can be estimated. However, the use of from-home and to-home factors does not guarantee, as a tour-based model would, that the total demand into and out of a parking site over the day will be equal.

Geographic Restriction of Park-and-Ride

3.3.5 In a comprehensive approach to the modelling of park-and-ride, a very wide variety and number of origin to destination pairs would have the opportunity to make use of car as an access mode to public transport. However, where it is known that the vast majority of park-and-ride trips involve (or would involve) only a single public transport leg with an urban centre destination, it would be reasonable to exclude other movements from the process.

3.3.6 It is therefore possible to restrict the park-and-ride choices in the model to tours/trips that are to/from an urban centre attraction. For the comprehensive approach, this restriction may not be worthwhile, as it would not materially affect the overall model dimensions. However, for the simplifying assumptions as set out below, it could greatly influence the problem size to be dealt with.

Manual Allocation of OD Pairs to Individual Park-and-Ride Sites

3.3.7 The comprehensive approach to park-and-ride modelling assumes that the demand model will handle the choice between competing park-and-ride sites. An alternative is to allow the user to specify for each origin to destination pair a single park-and-ride site that will be used by all demand. This can be done on the basis of network maps and local knowledge. In some respects, this approach may be superior to explicit modelling of choice of site, as it may capture the 'intuitive'

response to park-and-ride possibilities, rather than being based purely upon generalised cost. The analyst should record their justification for the assumptions made.

Highway Assignment and Simple Mode Choice Models

3.3.8   Where only a highway assignment model is available, it is possible to obtain some useful information about potential demand for new park-and-ride operations, particularly in terms of the merits of alternative sites and the way multiple sites might interact with each other.

3.3.9   Without a full demand model, the process implicitly assumes that the impact of park-and-ride is purely upon choice of mode (i.e. a choice between use of car all the way or of park-and-ride).

3.3.10   Two simplified approaches to park-and-ride modelling are possible in this context:

- representation wholly within the assignment process; and

- use of a simple logit model.

3.3.11   Representation wholly within the assignment process is illustrated graphically in Figure 5. In this case, it is assumed that all park-and-ride destinations are in the urban central area. A special public transport link is assumed in the model from the park-and-ride site to the urban centre zone. The bus travel time assumed should reflect modelled highway speeds and the presence of any bus priority measures. The bus speed could be made variable with passenger flow in order to reflect the impacts of crowding. Additional links are required to represent waiting times and fares. Within the urban centre, walk links should be provided that represent the walking times within the urban centre in order to reach final destinations.
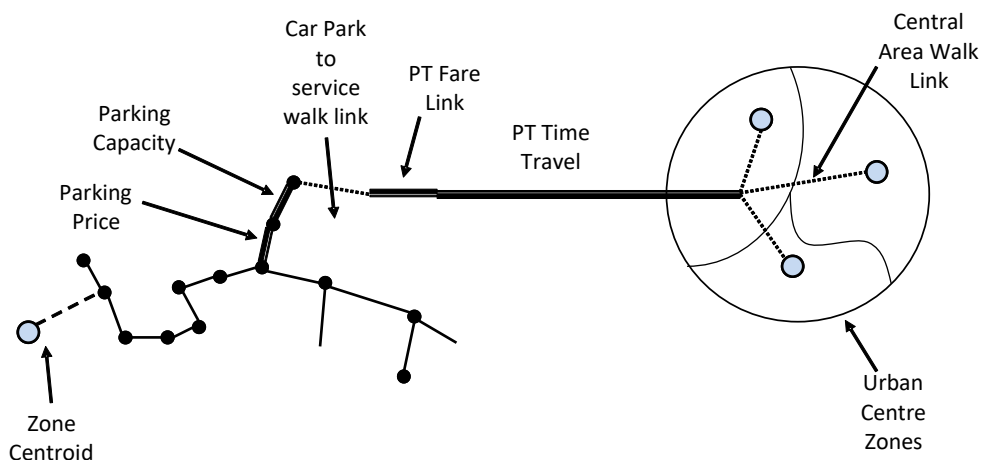

Figure 5 Representation of Park-and-Ride in a Highway Assignment Model

3.3.12   The park-and-ride site should be represented using links to represent both capacity and any parking charge. A link can also be provided to represent any interchange penalty.

3.3.13   As with any model in which time periods are not linked, forecasting of park-and-ride patronage using a highway assignment model would be most appropriate for morning peak appraisal; this is because, in the morning peak, it can be assumed that the influence of return trips upon available parking capacity is effectively zero.

3.3.14   The logit model approach would use similar data inputs to build up the costs for the park-and-ride alternative. A significant difference is that a zone would need to be defined for each of the park-and-ride sites. Iteration between the highway assignment model and the logit model would be required until an equilibrium had been reached. The modelling procedure could be further simplified through omitting the variable elements of park-and-ride costs, such as public transport crowding.

3.3.15   For both of the approaches, it is desirable to model an existing park-and-ride operation in order to calibrate the process. Site Specific Constants can be introduced to aid the calibration process. However, some allowance should be made in the calibration for the potential transfer from existing public transport which is not captured by either approach.

Base Year Park-and-Ride Representation within a Public Transport Assignment Model

3.3.16   If formal modelling of park-and-ride within the base year of a travel demand model is considered to be too onerous, there remains the issue of how to treat the car legs of mixed mode trips. A commonly-used practice is to include such trips wholly within the public transport assignment model. For the majority of origin to destination pairs, representation of public transport trips as a mixture of public transport modes (bus, train or tram) plus walk legs will be appropriate. Exceptions will include origin to destination pairs:

- using urban rail stations for which there are parking opportunities;

- existing bus based park-and-ride operations; and

- larger external zones for which the majority of trips could only gain access to a relevant public transport service by car or a local bus service.

3.3.17   The importance of the above circumstances can often be determined from the base year public transport demand surveys.

3.3.18   For all of the above, direct and fairly long connectors can be provided from zone centroids to the relevant public transport stop. The speeds on these connectors should be estimated on the basis of the likely access modes that would be used. As public transport assignment models generally work with a single user class which includes trips both with and without some degree of access to the car mode[7], this estimate is often very approximate. This is particularly the case for the third item in the above list, as both car and local bus services (not represented in the model network) are available. For the first two items, an assumption of car access can reasonably be made. Car speeds for the connector can, in the base year, be approximated from a highway assignment model, and a similar process can be made to adjust speeds for forecast years.

3.3.19   By default, the process set out above would encompass both kiss-and-ride and park-and-ride trips, though in the former case only the 'passenger' trip would be included. Similarly, the process implicitly includes, in an approximate way, both formal parking within designated car parks and parking in areas surrounding public transport stops.

Exclusion of Base Year Park-and-Ride from the Choice Process

3.3.20   Assuming a public transport model is set up as suggested above, forecasting changes in patronage of existing park-and-ride operations would be handled in an approximate way by a transport model without an explicit park-and-ride module. Similarly, if base year park-and-ride is trivial or non-existent, no facility needs to be provided. On this basis, explicit modelling of park-and-ride could be restricted to new facilities.

3.4   Data Collection for Park-and-Ride Models

3.4.1   For a model representing base year park-and-ride, the following data items are required for model setup, calibration and validation:

- car park capacities (including where appropriate an estimate of any additional capacity available on street in the vicinity of the stop);

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[7] Separate assignment by a measure of car availability may help in this respect, but there is no certainty that a trip made from the 'car available' category would be using car for any part of the trip being made.

- public transport frequencies and capacities (assuming the service is exclusive to the park-and-ride operation);

- monetary charges (car park and public transport fare);

- link passenger counts;

- car park inbound and outbound flows by time period; and

- existing demand segmented by trip purpose and trip duration.

3.4.2   Supply information is generally readily available. Passenger interview surveys at park-and-ride stops or on-vehicle will provide the necessary demand data. They can also be used to determine usage of informal parking sites and to distinguish kiss-and-ride activity, to understand what would be the reserve mode if the park-and-ride facility was not available and to gain a measure of duration of stay. Data from automatic barriers or ticket machines at park-and-ride car parks can also be used for the latter purpose, and can provide multiple day observations as opposed the single day commonly provided by passenger surveys and counts.

3.5   Forecasting

3.5.1   The process of applying a park-and-ride model in forecasting is essentially similar to that for changes to the highway or public transport definition. Assumptions need to be made about future car park and service capacities, prices, operating hours, for each park-and-ride operation.

4   References

Study of Parking and Traffic Demand: The research programme, by Denvil Coombe, Peter Guest, John Bates and Paul Le Masurier, Traffic Engineering and Control in February 1997.

Study of Parking and Traffic Demand: A Traffic Restraint Analysis Model (TRAM), by John Bates, Andy Skinner, Graham Scholefield and Richard Bradley, Traffic Engineering and Control in March 1997.

Study of Parking and Traffic Demand: The effects of parking control strategies in Bristol, by Denvil Coombe, Peter Guest, Graham Scholefield and Andy Skinner, Traffic Engineering and Control in April 1997.

5   Document Provenance

This Unit consists of restructured and edited material from **TAG Unit 3.10.7 Modelling Parking and Park-and-Ride** that existed in the previous TAG structure at August 2013.