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Modelling the Choice of Car Parks in Urban Areas and Managing the Demand for Parking

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ABSTRACT

Car parks are an essential piece of infrastructure associated with the road networks, yet commonly available traffic assignment models do not to explicitly integrate them into the modelling process. This research attempts to integrate the choice of car parks in urban areas into the travellers' route choice and incorporates both the route and car park choice in a joint modelling framework of traffic assignment based on equilibrium approach. This paper illustrates the implementation of the model in a commonly used standard suite of traffic assignment software. The proposed method considers multiple user classes - commuter and non-commuter flows, and involves modelling the demand for short stay and long stay car parks over multiple departure periods. A special search time delay function has been developed to represent the disutility in searching for a place in a car park, which is integrated further into the function of generalised cost of travel. This technique has been successfully applied to study the choice of car parks in the case of a simple hypothetical network. Another larger numerical example illustrates the case of managing the demand between two car parks in Leeds, England.

INTRODUCTION

Town centre parking facilities usually range from simple unorganised on-street type facility to a very well organised multi-storey car park and include surface off-street parking, private non-residential facilities, etc. Many of the organised car parks may have restrictions on the duration of parking, such as short stay (e.g., up to 2 hours), or long stay allowing for up to half-day/full day or even multiple days, etc. In addition, organised car parks may charge a fee for parking depending on the location of the car park, day of the week and duration of parking. In a typical day-to-day situation, drivers make choices between car parks, perhaps usually associated implicitly with route and departure time choice. This implicit choice of car parks is important to understand as it is needless to emphasise that adequate provision of parking for cars and managing them efficiently, is a critical element in the overall success of any transportation plan. However, traditional transportation modelling frameworks do not seem to attempt explicitly model the car parks in urban areas, nor the commonly available traffic modelling software programs address this issue, although some independent models (*1, 2*) were developed in the past. The first aim of this paper is, therefore, to incorporate the choice of car parks into the standard assignment modelling framework and to investigate the resulting impacts. Moreover, this approach will also facilitate testing the sensitivity of drivers towards varying car park pricing structures and hence could prove a potential tool in planning and managing the car park facilities. Hence the other aim of the paper is to set up an example to illustrate the choice of car parks with varying parking fees.

Many studies in the past (*3, 4*) involving parking considered the behavioural aspects of drivers, but very few (*5, 6*) considered the impact of location of the parking on the route assignment. For example, (*3*) estimated the demand for car parks in the town centres based on choice modelling approach using nested logit structure. The estimation was based on revealed preference information concerning the behaviour of drivers. The study included both on-street and off-street parking facilities, in addition to considering the private non-residential car parks, usually provided by the employers at work places. Although the study considered various attributes of the drivers in choosing the car parks, it ignored some of the important criteria such as the delay in the car park. The study also ignored the influence of the location of the car park on the route choice of the drivers, although a coarse representation of the location relative to work place has been considered.

(*6*) studied the parking location choice using equilibrium approach, however, their model completely ignored the element of time thus leaving the dynamic aspects of the problem unattended. Although they attempted to predict the parking allocations by varying the demand levels, it was limited to a uniform factor method, which increases or decreases the demand by a pre-defined factor. As a result of such an approach, the impact of varying levels of demand over a period of time could not have been studied.

More recently, (*7*) reviews the evidence based upon which parking policies for commuter, leisure, shopping and residential purposes based. This research recommends that analysis of the impact of the parking practices on the accessibility to work places/ shopping areas should be studied in greater detail.

(*8*) formulates an equilibrium model which solves for user equilibrium flows based on a time dependent approach with multiple user classes and multiple parking facilities. It is assumed that the drivers initially make a joint choice of departure time and parking duration before deciding on the route which minimises the over all disutility from origin to destination, thus following a hierarchical choice structure. The main finding of this study is that the parking behaviour of drivers is significantly influenced by factors such as the quantum of the demand, size of car parks, parking charges and the distance of car park to ultimate destination. Although some illustrative examples using hypothetical networks are provided, the main limitation of this research is that the model has not been tested on larger realistic networks. Thus, by far, (*8*) represents research work similar to that of ours and hence, as part of our study, we aim to make comparisons with the results given in (*8*). In addition, we also extend our work to a large real network and illustrate the principles laid out with some interesting examples based on parking demand management.

METHODOLOGY

Notation

Consider a network of directed links $a \in \mathrm{A}$ serving O-D demand represented by $\boldsymbol{Q} = \{....,q_k,...\}$ where q_k is the O-D demand for a particular commodity *k*, each commodity defining a combination of origin, destination and (discrete) departure period. Definition of the commodity could be even more general including the purpose of trip, e.g. commuting, non-commuting, activity duration such as half-day or full-day for commuters and even shorter for non-commuters etc. Therefore, in the most general case a given commodity could be identified by a combination of origin, destination, departure period, trip purpose and activity duration. It is assumed that the total period of analysis is divided into several departure periods contained in a vector of length L. Each commodity k is served by a set of routes R_k with $|R_k|$ elements; the full route set across all commodities thus has dimension, $\rho = \sum_{k=1}^{K} |R_k|$. Let $\boldsymbol{f}$ be the ρ- vector of commodity route flows and $\boldsymbol{C(f)}$ is the vector of commodity route costs. The link travel time is given by a traditional BPR style cost-flow function as below:

$$\tau_a^t = \alpha_a + \beta_a \left(\frac{x_a^t}{P_a} \right)^{\gamma} \qquad \forall\, a \in \mathrm{A} \quad and \quad t \in L \qquad (1)$$

where,

τ_a^t = travel time on link a during departure period t

x_a^t = flow on link a during departure period t which is given by the link path incidence relationship, i.e.,

$$x_a^t = \sum_r \delta_a^r\, f_a^r \qquad (2)$$

$$\delta_a^r = \begin{cases} 1 & \text{if route r uses link a} \\ 0 & \text{otherwise} \end{cases}$$

P_a = capacity of link a

α, β and γ are link-specific parameters.

The path travel time is given as the summation of the link travel times along the route.

Model Formulation

It is assumed that the drivers are rational in their choice of routes and would choose a route that cost them lower compared to the alternative feasible routes. It is also assumed that a number of car parks of varying capacities are available nearer the destination zones which are well connected to the road network. The car park management may be charging different fees depending on the duration of parking and its relative location, for example, the city car parks may charge slightly higher compared to those which are slightly away from the town centre. Hence, the choice of car park depends on factors such as the size of the car park/its occupancy, parking charge and the distance of the car park to the ultimate destination. This can be formally expressed in the generalised time equation as below:

$$C_r^{kt} = \tau_r^t + \theta_s^k S_p^{kt} + \theta_z^k Z_p^{kt} + \theta_w^k W_p^{kt} + \eta_p \qquad (3)$$

where,

τ_r^t = path travel time along route r during the departure period t
S_p^{kt} = search time in car park p for commodity k during departure period t
Z_p^{kt} = parking charges at car park p for commodity k during departure period t
W_p^{kt} = walking time from car park p to the ultimate destination for commodity k during departure period t
θ_s^k = value of search time relative to the path travel time
θ_z^k = time value of parking charges
θ_w^k = value of walk time relative to the path travel time
η_p = unobservable preference to car park p, if any.

In equation (3), the search time term merits some explanation here. In a car park, the search time depends on the physical size of the car park – usually the bigger, the more time it needs to find a place to park. The search time also depends on the occupancy of the car park relative to its capacity. It is easy to see that partially filled car parks are preferred compared to nearly full car parks. Following (*8*), the search time function can be written based on a BPR style function as below:

$$S_p^{kt} = s_p^t + \beta \left(\frac{x_p^t}{Y_p} \right)^{\gamma} \qquad (4)$$

where,

s_p^t = minimum search time in the car park p

x_p^t = net flow into car park p during departure period t

Y_p = Capacity of the car park p

β, γ are the parameters.

Net flow into the car park is computed as the difference between the inflow and outflows during the departure period. Following the principles of user equilibrium (*9*), it can be stated that the network system is in equilibrium if all the used routes along with the car parks on them have equal and minimum costs while all the unused routes have greater or equal costs. This statement can be represented as the following complementarity condition:

$$\begin{aligned} &\left[C_r^{kt} - C^{*kt}\right] f_r^{kt} \geq 0 \\ &C_r^{kt} \geq C^{*kt} \\ &f_r^{kt} \geq 0 \end{aligned} \qquad (5)$$

where, C^{*kt} = minimum cost of travel for the commodity k in departure period t.

Equation (5) means that the route flows are positive definite if the route costs are equal to the minimum route costs, alternatively they are equal to zero if the route costs are greater than the minimum possible route costs, thus satisfying the equilibrium requirements.

Conditions in (5) can be transformed to a minimisation problem, following (*10*) as below:

$$\begin{aligned} &Min\ Z = \sum_a \int_o^{x_a^t} \tau_a^t(\omega)\, d\omega \\ &\text{subject to } \sum_r f_r^k = q_k \\ &\qquad f_r^k \geq 0 \end{aligned} \qquad (6)$$

Solution to (6) can be obtained by following the standard algorithms such as Frank-Wolfe or the Method of Successive Averages.

Modelling of Search Time in Car Parks

Car park search time described by equation (4) which when applied to multiple departure time periods, throws out the options of potentially two different approaches that can be followed while implementing the model. The first approach could be based on the intuition that the available car park capacity reduces at the end of each departure period as the time progresses, and the other approach could consider the accumulation of the vehicles in the car park over the departure periods, although both approaches seem similar, their implementation procedure and the implications could be quite different from each other. The following paragraphs describe the two approaches in detail and the numerical examples given later illustrate the methods and discuss the results.

Method 1: Reducing Capacity Method (RCM)

This method is based on the rationale that if the car park is partially occupied (e.g., at the end of a given departure period), then during the immediately subsequent departure period the minimum search time s_p^t in the car park will be relatively higher compared to the case of an empty car park perhaps in the previous departure period. It is also important to note that the available car park capacity Y_p in the current departure period should be reduced by an amount equal to the accumulated demand until the end of the previous departure period, to ensure that the car park is not overloaded during the current departure period. The expression for search time function can be expressed as below:

$$S_p^{k\,t} = S_p^{k\,(t-1)} + \beta \left(\frac{x_p^t}{\left(Y_p - \sum_{i=1}^{t-1} x_p^i \right)} \right)^{\gamma} \qquad (7)$$

where, $S_p^{k\,(t-1)}$ = search time at the end of the previous departure period (t-1), which is equal to the minimum search time s_p^t when t = 1 . Although the expression in (7) is intuitively reasonable, it is important to note that the shape of the search time function changes significantly in each of the successive departure periods. On the flip side, equation (7) effectively restricts the inflow into the car park, especially, when it is nearly full to its capacity.

Method 2: Cumulative Occupancy Method (COM)

This method has been devised to address the drawback on changing shape of the search time function in various departure periods from the previous method. It is aimed at cumulating the flows into the car park in all the previous departure periods so that their effect is taken into account by the new arrivals in the current departure period. In this case, unlike the previous method, the minimum search time remains constant throughout the analysis period and so does the car park capacity. On the contrary, occupancy of the car park is cumulated over time and the expression for the search time is as given below:

$$S_p^{k\,t} = s_p^t + \beta \left(\frac{\sum_{i=0}^{t} x_p^i}{Y_p} \right)^{\gamma} . \qquad (8)$$

The search time in (8) may be less effective in restricting the inflow into the car park when near the capacity and is likely to overload the car park. This is because the joint route and car park choice is based on relative costs between alternative routes, which means, that if a route has been found quicker even with the car park on that route is over capacity, then it will still continue to attract flows into it compared to an alternative slower route. Therefore, in the implementation some strict constraint may be needed to avoid the over loading when using equation (8).

NUMERICAL EXAMPLES

The search time functions described in the previous section can be easily incorporated into the generalised cost function specified earlier. Equilibrium assignment flows can be solved using established procedures following algorithms, such as Frank-Wolfe, Method of Successive Averages, etc. Then the joint car park location choice with assignment modelling using equilibrium approach can be set up with any standard transport modelling software such as TRIPS, EMME/3, SATURN, OmniTRANS, etc. In this case study, SATURN has been used to set up numerical illustrations of the principles described. SATURN (*11*) was originally developed as a simulation and traffic assignment tool to analyse the traffic congestion in urban areas, but ever since underwent significant addition to its functionality, the newest being the origin based assignment which is currently being tested. In addition to its mathematically sound methodological aspects, wider availability of SATURN networks and the associated demand data makes it a popular choice in many traffic modelling studies.

Six Link Network

On the supply side, a simple six link network serving a single OD pair (Figure 1) has been assumed which is identical to that given in (*8*). On each link, a Bureau of Public Roads (BPR)-type travel time function for each departure period of the form in equation (1) has been assumed. All the links are assumed to be one-way with the link attributes as shown in Table 1. It is important to note that all the drivers are assumed to complete their journey during the period in which they departed from the origin, which means that the inflows to each link are modelled based on a static approach rather than based on a dynamic network loading of flows in space and time.

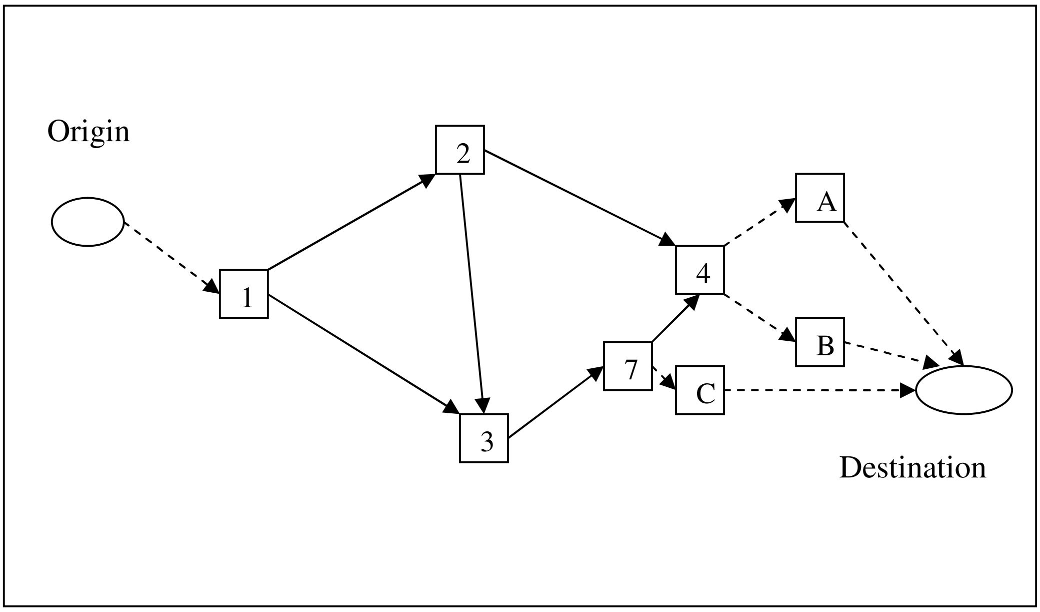

FIGURE 1 Schematic of Six Link Network

TABLE 1 Network Link Attributes

Link	Free flow time, τ_a^0 hours	Capacity, P_a veh/h
1-2	0.30	800
1-3	0.45	800
2-3	0.15	500
2-4	0.50	800
3-7	0.20	800
7-4	0.10	700

It is assumed that near the destination, there are three car parks – two for the joint use of commuters and non-commuters, and one exclusively for use by non-commuters. The two mixed-use car parks are designated A and B and have a capacity of $Y_{A,B}$ = 2000 vehicles each, and the non-commuter car park C has $Y_C =$ 350 spaces. The searching time delay for a space in a car park depends on the size of the car park and its occupancy at any given point of time. In order to compute the search delay, a BPR-style function as shown in (4) with parameters as below is used:

$$S_p^{kt} = s_p^t + 0.31\left(\frac{x_p^t}{Y_p}\right)^{4.03} \qquad (9)$$

In this exercise, s_p^t is assumed equal to 0.1 hour for car parks A and B and 0.05 hour for car park C. The search time delay in the overall generalised cost is assumed to be weighed higher relative to the in-vehicle travel time, and hence the values obtained from (9) are multiplied by a factor of 1.4 for both commuters and non-commuters. Walking time from the car parks to the ultimate destination is weighed slightly lower for the commuters and is multiplied by a factor of 1.8, whereas for the non-commuters it is assumed to be 2.0. It is easy to see that the modelling framework can also accommodate car parking charges, if any, without needing any structural changes to the model. It is also assumed that the car parks A, B and C are located respectively at 1.0 km, 0.75 km and 0.5 km short of the ultimate destination and the average walking speed is equal to 5.0 kmph.

In this exercise, the demand between a single OD pair is assumed to be given in each departure period in a typical multiple time period context. It is also assumed that the demand is disaggregated into commuter and non-commuter categories, which are further sub-divided into sub-classes (also called user classes), depending on their parking duration. For example, the commuters are divided into two sub-classes of 4 hour and 8 hour parking duration, and the non-commuters are further sub-divided into three sub-classes of 1 hour, 2 hour and 3 hour parking duration. Therefore, in all, there are five user classes of demand in each departure period and the modelling has been carried out over four consecutive departure periods of one hour each. Figure 2 shows the commuter and non-commuter demand at origin in multiple time periods. Commuter demand peaks during the departure period between 7am and 8am whereas, the non-commuter demand picks up with the time of the day. Comparatively, the commuter demand is quite intense over the non-commuter demand initially, but by about 10am, the non-commuter demand occupies a significant proportion of the total demand.

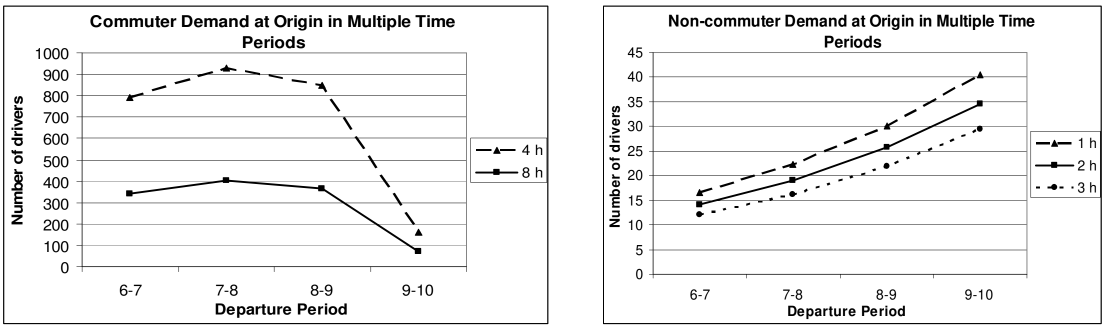

FIGURE 2 Commuter and Non-commuter Demand in Multiple Departure Periods

In this illustrative numerical example, we computed the car park search time by both the methods as specified by equations (7) and (8). Table 2 compares the car park allocations by RCM and Time Dependent Flows (TDF) modelled by Lam et al. for various commodities. While the first departure period allocations compare well with each other, the other departure period flows are not. This is true especially for the commuter flows in departure periods 2 and 3. On the contrary, in Table 3, which compares the results by COM (i.e., Method 2), the convergence between the COM allocations and Lam et al. is significantly better, especially in the final departure period, the commuter and non-commuter allocations to various car parks are almost identical.

TABLE 2 Comparison of Car Park Allocations by RCM and TDF

Departure Time	Model	Commuter Flows				Non-Commuter Flows#		
		Parking for 4hr		Parking for 8hr		Parking for 1 hr	Parking for 2 hr	Parking for 3 hr
		A	B	A	B	C	C	C
06:00-07:00	RCM	0	787	0	340	16	12	12
	TDF	0	790	0	341	17	14	12
07:00-08:00	RCM	553	376	240	163	21	12	12
	TDF	684	245	295	106	22	19	16
08:00-09:00	RCM	693	159	294	68	26	26	26
	TDF	561	289	242	124	30	26	22
09:00-10:00	RCM	109	53	48	23	40	34	30
	TDF	88	75	38	32	40	35	29

Almost all non-commuter vehicles have been allocated to car park C, hence no entries shown for A or B.

TABLE 3 Comparison of Car Park Aoolcations by COM and TDF

Departure Time	Model	Commuter Flows				Non-Commuter Flows#		
		Parking for 4hr		Parking for 8hr		Parking for 1 hr	Parking for 2 hr	Parking for 3 hr
		A	B	A	B	C	C	C
06:00-07:00	RCM	0	790	0	341	17	14	12
	TDF	0	790	0	341	17	14	12
07:00-08:00	RCM	703	226	304	97	19	16	14
	TDF	684	245	295	106	22	19	16
08:00-09:00	RCM	534	314	230	136	30	26	22
	TDF	561	289	242	124	30	26	22
09:00-10:00	RCM	85	78	37	33	40	35	29
	TDF	88	75	38	32	40	35	29

Almost all non-commuter vehicles have been allocated to car park C, hence no entries shown for A or B.

In order to differentiate the nature of the car park search time function in each of the two methods described, and to understand its impact on the overall assignment process, a graph comparing the search time functions has been drawn which is shown in Figure 3. It can be noted that the capacity reduction method has a 'step' profile while the cumulative occupancy method has a uniform profile through the analysis period. This is an important observation in that the capacity reduction method has a varied effect of search time on the over all assignment process in each departure period. It is assumed that the departure periods are discrete with their starting and ending points clearly marked. The cumulative occupancy method has a uniform effect of search time function on the assignment process through all the departure periods. These observations explain the difference between the two sets of results. While comparing with TDF by Lam et al., they seemed to have modelled the flows on links using more sophisticated dynamic assignment techniques as opposed to simple static assignment approach. Given these differences in approaches, the results obtained by in this case study, especially by the COM, have been found satisfactory. In order to confirm further the above observations, car park allocations by COM have been subjected to further tests of validation, which are explained in the ensuing paragraphs.

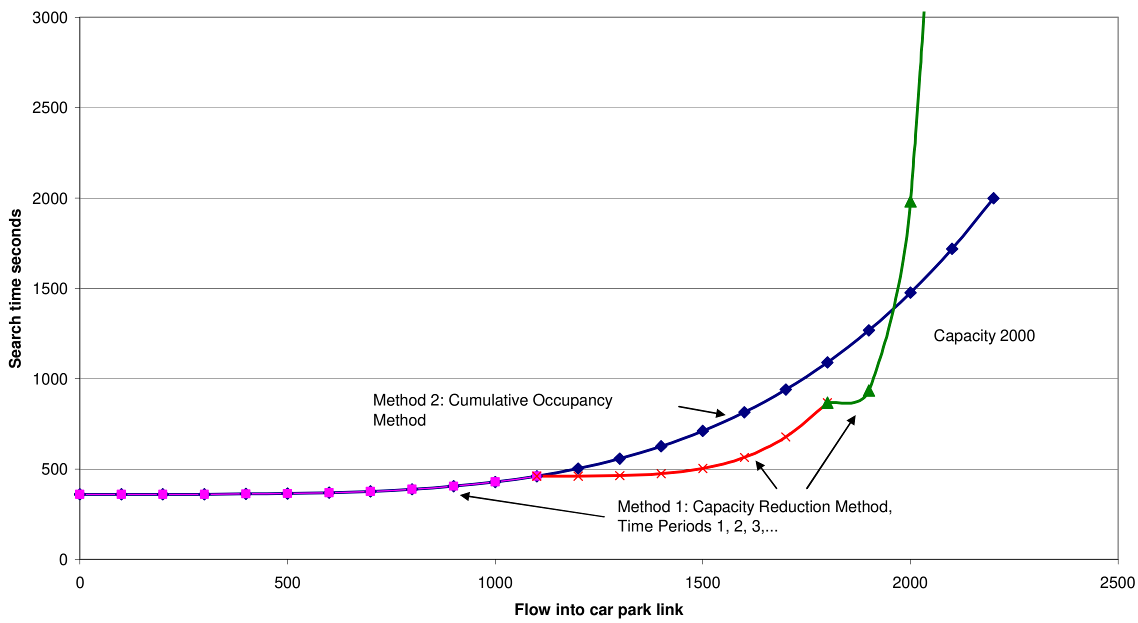

FIGURE 3 Parking Search Times

Table 4 shows the validation of the flows by COM with TDF of Lam et al. as the basis for comparison. GEH statistic has been created to reduce the bias towards higher base values, in the sense that when smaller differences over smaller base values are compared, they should not appear as a very high percentage difference. In general, GEH values of less than 5 are considered satisfactory and it may be noted that the allocations to all three car parks in all the departure periods are well below the recommended level.

TABLE 4 Comparison of Car Park Occupancies and GEH Statistics

Departure Period	Car Park	TDF	COM	Capacity	Difference	% difference	GEH
06:00-07:00	A	0	0	2000	0	0	0
06:00-07:00	B	1131	1131	2000	0	0	0
06:00-07:00	C	43	43	350	0	0	0
07:00-08:00	A	979	1017	2000	38	3.86	1.2
07:00-08:00	B	351	321	2000	-29	-8.54	1.64
07:00-08:00	C	57	49	350	-7	-13.64	1.07
Cumulative	A	979	1017	2000	38	3.86	1.2
Cumulative	B	1482	1452	2000	-29	-2.02	0.78
Cumulative	C	100	92	350	-7	-7.78	0.79
08:00-09:00	A	803	757	2000	-45	-5.75	1.65
08:00-09:00	B	413	457	2000	44	10.7	2.12
08:00-09:00	C	78	78	350	0	0	0
Cumulative	A	1782	1774	2000	-7	-0.46	0.19
Cumulative	B	1895	1909	2000	14	0.75	0.33
Cumulative	C	178	170	350	-7	-4.49	0.61
09:00-10:00	A	126	121	2000	-4	-4.06	0.46
09:00-10:00	B	107	112	2000	5	4.78	0.49
09:00-10:00	C	104	104	350	0	0	0
Cumulative	A	1908	1895	2000	-12	-0.69	0.3
Cumulative	B	2002	2021	2000	19	0.95	0.43
Cumulative	C	282	274	350	-7	-2.84	0.48

Note: GEH = Sqrt{ (x2 – x1)^2 / [(x1 + x2) / 2]}, which is useful to reduce the bias towards higher base values

Finally, this discussion will be inadequate without commenting on the ways to calibrate the model. It is easy to see that the parameters, s_p^t, β and γ in car park search time in (4) will need to be calibrated to reflect the observed situation at a car park. In addition, the demand if known, in various departure periods along with their parking duration, will be ideal to set up the joint parking location choice and assignment model described so far. However, in practice, the availability of data in fine resolution may be a critical issue. Therefore, in the following section, we aim to illustrate the method with data which is commonly available to practitioners. In particular, a real network of Leeds and peak hour O-D matrix with a single user class were used. Indeed, if the data were available to even better resolution, then the numerical example can easily be extended to benefit from the detailed analysis.

Leeds City Network

Leeds is one of the major cities in England and has transformed into the biggest financial centre outside London. Leeds urban area is located in Yorkshire region and has extensive road transport network. Leeds transport network is spread over an area of 20 km X 15 km approximately covering the entire Leeds district (Figure 4). This research work adopted the latest version of the available network, which is continually being updated.

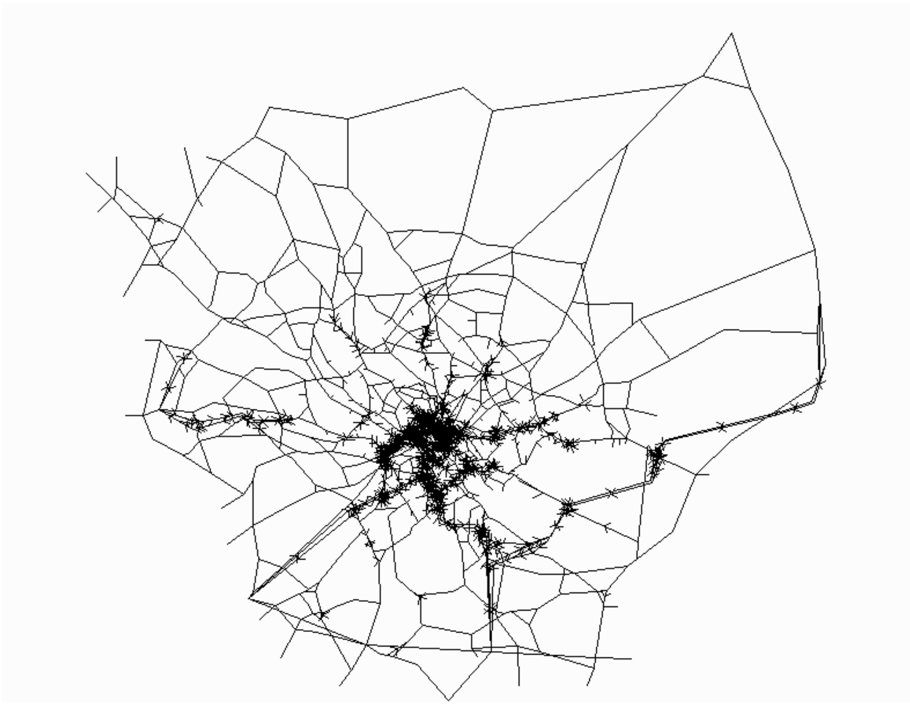

FIGURE 4 Leeds Morning Peak Network

Travel demand is represented in the form of an O-D matrix with about 478 traffic zones including the external zones outside Leeds district. Total quantum of travel in 2007 is over 106,000 pcus during the morning peak hour. The demand pattern indicates that a large volume of travel takes place between down south and up north and even between the north and the east areas.

In this research, out of several car parks in and around the town centre, two closely located car parks near the city centre have been identified and incorporated into the modelled network. The first one is an off-street facility located along Woodhouse Lane and the other is located along Elmwood Road off Wade Lane (Figure 5). In this illustration, the first car park is assumed to have similar characteristics as that of car park C in the five link example and the second one is assumed to be with identical features as that of car park B. Closely located car parks allow the drivers to choose from them along with the associated route to be followed and further allow the testing of the principles described in this paper.

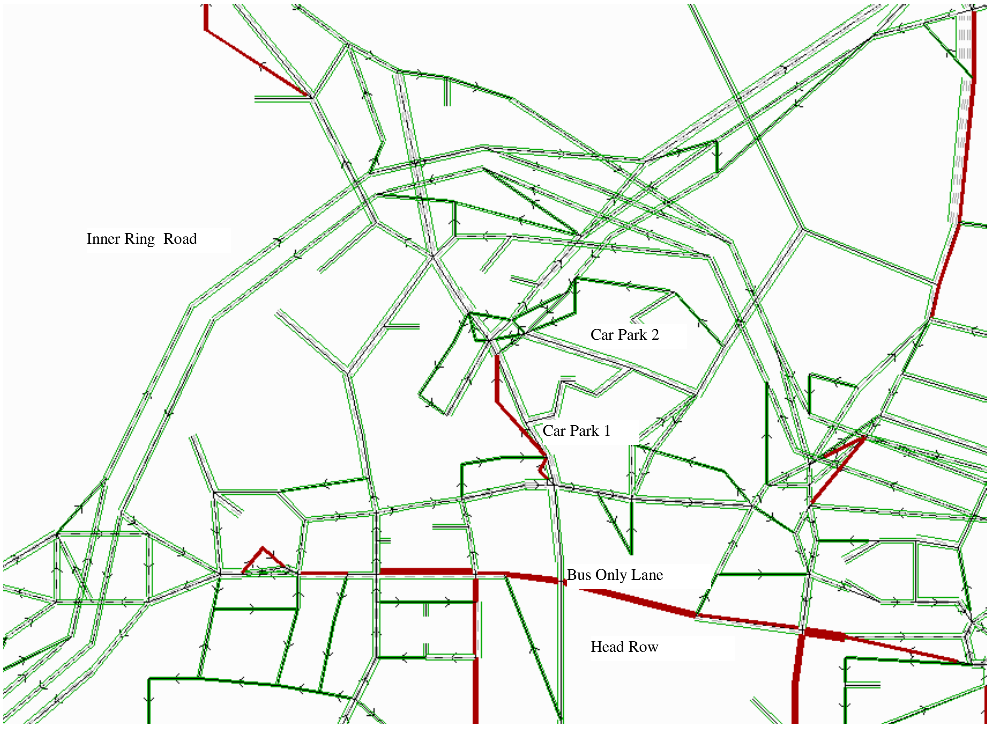

FIGURE 5 Location of Car Parks in Leeds City Centre

Incorporating the car park into modelled network is fairly straight forward and all it needs is to create a link between the centriod connector of a zone and the first real link to which it is joined to represent a car park. The car park links need to be connected by walk links to as many possible destinations as appropriate. This will allow the drivers a choice of car parks. The car park link needs to be associated with the properties such as capacity, minimum/capacity search time etc. This can be achieved by editing the link properties using network edit facilities. Figure 6(a) shows that out of about 440 cars, 240 drivers choose car park 1 which is smaller but cheaper, and the rest going to car park 2 which is bigger but expensive.

The model is very sensitive to the capacities of the car parks. As a test of sensitivity, the capacity of car park 1 has been reduced to 100 vehicles and then the assignment process has been repeated. Figure 6(b) shows that the demand for car park 1 has dropped to about 70 in the light of the reduced capacity. The assigned number of drivers can be interpreted as the long term average demand for each car park. The sensitivity of the model makes it a useful tool to test the parking policies such as demand management under various pricing structures.

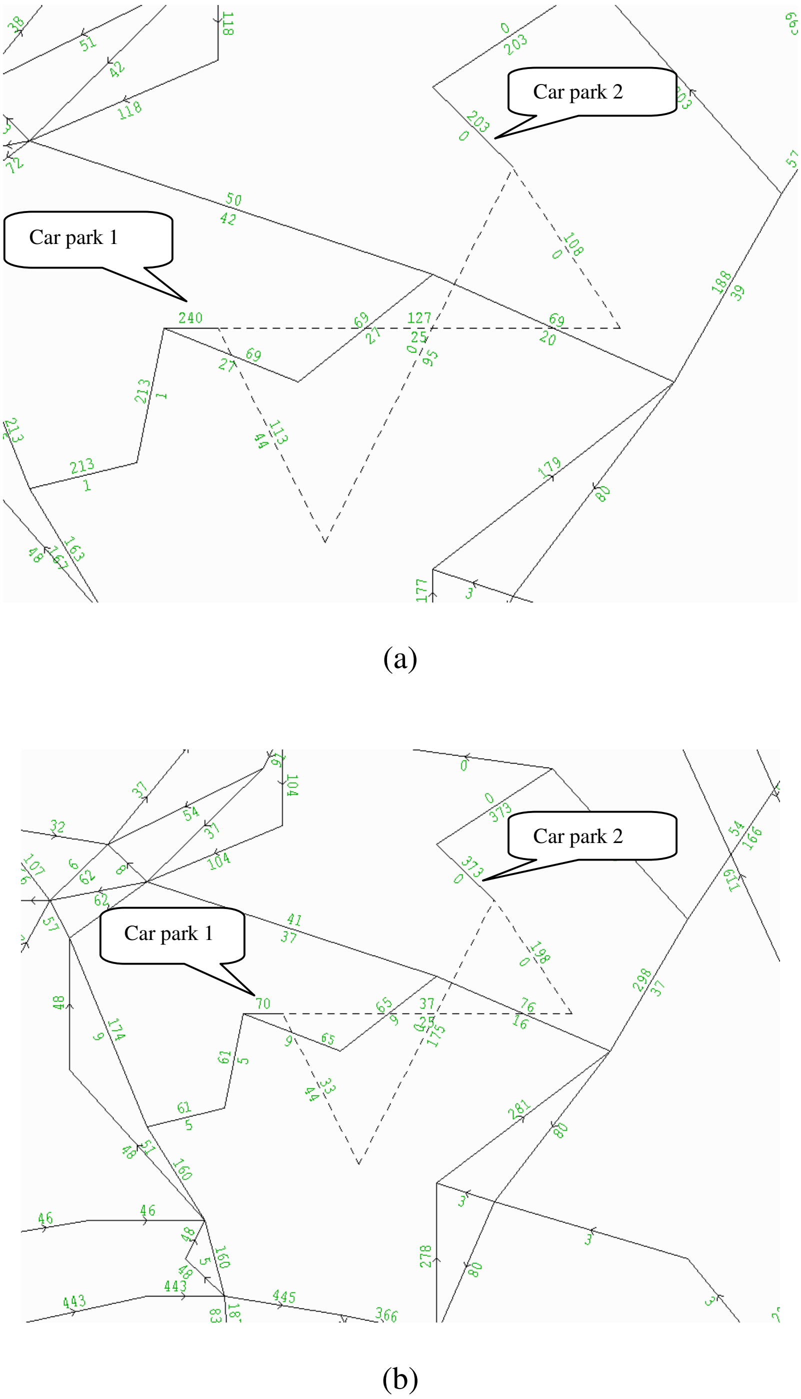

FIGURE 6 Demand for Car Parks 1 and 2

Parking Demand Management

Consider the situation where an off-street multi storied car park remains considerably under utilised compared to a nearby at-grade car park. This situation forces many drivers keep moving around in search of a car park space which escalates the congestion around the busy car parks. Assume that city council plans to remedy the situation by attracting some drivers to the multi-storey car park. In this section, we illustrate with a simple example, how to analyse the impacts of managing the demand for parking.

Let us assume, from our previous example, car park 1 represents an off-street at-grade parking facility while car park 2 represents a multi-storied car park. Imagine that the city council wants to attract more shopper drivers to the multi-storied car park by charging some differential fee equivalent to 300 seconds at car park 1. The fine sensitivity of the model allows the testing of this scenario quite easily. The parking fees have been implemented as an add-on charge to car park 1 as a penalty and the assignment has been repeated. Figure 7 shows that the demand for car park 2 has dramatically increased by about 40% to 330 vehicles, whereas the demand for car park 1 has dropped to about 112 vehicles. In this illustration, the capacity of car park 1 has been reset to 350 vehicles as in the original case. It is important to note that the method developed in this research can be extended easily to the cases of multiple user classes having different characteristics.

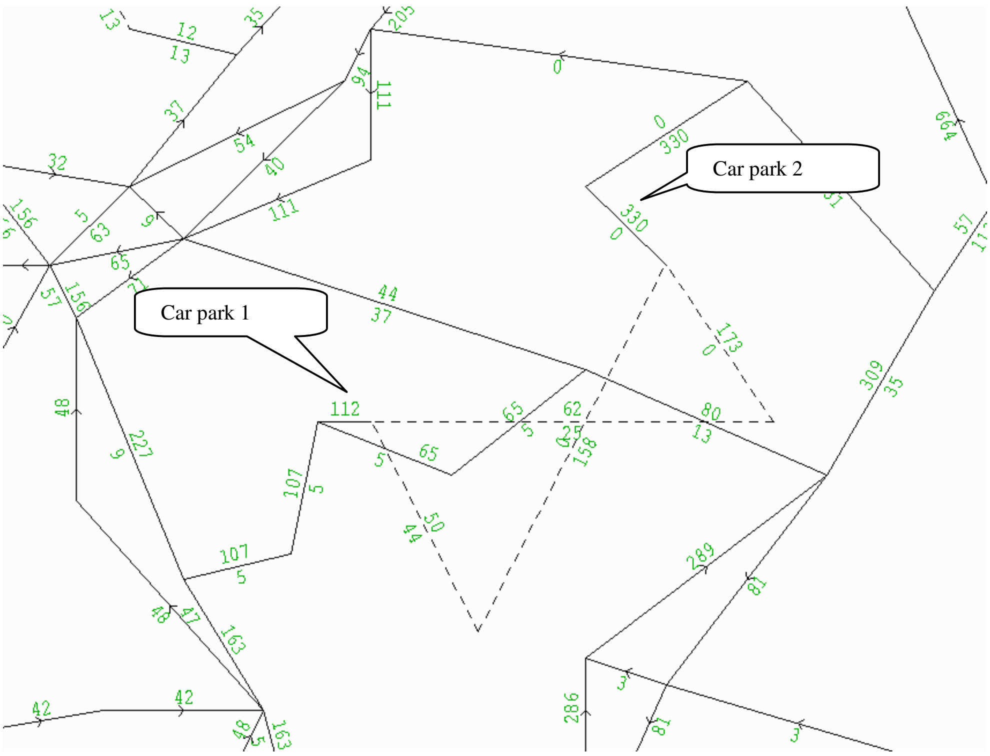

FIGURE 7 Parking Demand Pattern with a Charge at Car Park 1

CONCLUSIONS AND FURTHER WORK

This research paper specified a joint model for parking location choice and traffic assignment using equilibrium approach. An important addition to the work done in this field is the method for modelling the car park search time by two different approaches described, besides the implementation procedure using a commonly available suite of traffic modelling software. Another important feature of this work is that it has been illustrated with practically available data, and it is believed that the method and the solution procedure described here will be of immense help to the practitioners in real life. The main conclusions from this research include that the capacity reduction method is quite effective in controlling the loading to the car parks, although with a changing search time profile. On the contrary, the cumulative occupancy method adopts a uniform search time profile throughout the analysis period and is more suitable for situations when the car parks are less busy. As a planning tool, this method can be applied to study the impact of car park pricing structures. However, as the numerical values for the parameters in search time function have been adopted from elsewhere (*8*), the authors are planning to calibrate and validate the models based on real data. In the meantime, it may be worth considering carrying out some sensitivity tests with varying values of the parameters to ascertain the quality of the conclusions. An important further extension to this work is to incorporate the departure time choice with elastic demand, so that the users can actually choose to depart at a suitable time and in the extreme, some drivers may choose not to travel at all. More tests also can be conducted in association with the other transport modelling software to investigate the efficacy of the search time functions.

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