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A PARKING SEARCH MODEL

RUSSELL G. THOMPSON
Department of Civil and Environmental Engineering, The University of Melbourne, Australia

and

ANTHONY J. RICHARDSON
Transport Research Centre, The University of Melbourne, Australia

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Abstract—Parking plays an important role in urban transport systems. However, there is currently a lack of understanding of how motorists choose car parks. This paper presents a model that represents the parking search behaviour of motorists. A search process was defined within a behavioural modelling framework and subsequently represented using analytical procedures. Relationships for estimating the utility of a car park incorporating access, waiting, direct and egress cost components were developed. Parameters were specified to represent the uncertain attributes of car parks, including queue sizes and departure rates. The size and composition of the choice sets of individual motorists were determined endogenously by the model. Searchers' perceptions of car park attributes based on their observations from previous and current searching experiences were represented. Applications of the model showed that long term experience does not necessarily lead to better choices. The effects of reducing duration limits were also investigated. © 1998 Elsevier Science Ltd. All rights reserved

INTRODUCTION

Parking plays an important role in the traffic system since all vehicles require a storage location when they are not being used to transport passengers. Due to the inherent uncertainty associated with many of the attributes of public car parks, including availability and location (Salomon, 1986; Polak and Axhausen, 1990) a high proportion of motorists travelling within central city areas must search for a car park. Car parks here refer to formal (off-street) organised parking as well as groups of on-street spaces with common attributes. Motorists have been observed spending a significant percentage of their total trip time searching for a car park (Huber, 1962; Axhausen and Polak, 1991). This can significantly affect the level of traffic congestion and environmental quality within an urban centre (Parker, 1973; Gillen, 1977; Feeney, 1989).

A recent review of parking models (Young *et al.*, 1991) identified a number of modelling approaches that have been used to understand and replicate parking choice behaviour, including utility (Van Der Goot, 1982; Hunt, 1988), optimisation (Goyal and Gomes 1984; Tsukaguchi and Jung, 1989), distribution (Ellis and Rassam, 1970; Florian and Los, 1980; Young, *et al.*, 1991) and assignment models (Nour Eldin *et al.*, 1981; Gur and Beimborn, 1984). More recently the CLAMP model (Polak and Axhausen, 1989; Polak *et al.*, 1990) has been used to investigate a wide range of parking policy analysis in European cities. Parking search within a car park has been represented by the PARKSIM model (Young, 1991).

There appear to be numerous behavioural deficiencies associated with the approaches that have previously been used to model parking choice. First, many approaches assume that the decision maker has perfect information, regarding the choice set and the attributes of alternatives. Furthermore, no allowance is made for learning or increasing knowledge about the system. Little attention is also given to explaining the relatively high level of sub-optimal decisions made. Previous models of parking choice have not considered it as a search, and subsequently have not incorporated many of the temporal and dynamic aspects of a choice process. Therefore, the development of a behavioural model of parking search is considered essential to understanding and explaining the choices being observed in central city areas. A sound understanding of parking choice behaviour is also a prerequisite for predicting the impacts of Parking Guidance and Information (PGI) systems.

This paper describes a model of parking search behaviour. An outline of the procedures used to represent the decisions and processes of motorists when searching for a car park are presented. A summary of the verification and application of a computer-based simulation model is also given.

THE PARKING SEARCH PROCESS

Parking choice can be considered as a search process, where drivers make a number of linked decisions based on updated knowledge gained from experience (Layzell, 1985; Polak and Axhausen, 1989). A conceptual representation of the parking search process was defined after analysing interview data from surveys undertaken in Wollongong and at The University of Melbourne (Thompson, 1993). This process consists of various stages, based on a series of decisions, linked in a temporal fashion (Fig. 1). Motorists examine individual car parks sequentially as they move within an urban centre. After an alternative is inspected, motorists can either select it or continue to search by travelling to another car park. The process is initiated when the first search (or trip) begins. Once searching has begun, the process of inspecting and evaluating car parks commences. The decision of whether or not to accept the current car park determines if the current search is terminated or continues. After parking, the process continues when the next search is undertaken.

The inspection of car parks is undertaken to identify their attributes and to determine the availability of spaces. After performing this task, an accurate assessment of a car park's attractiveness can be made. Evaluation involves comparing the level of satisfaction associated with the current car park with the expectations associated with other known car parks.

The decision of whether or not to accept the present car park determines the length of a search. If a car park is accepted and a space is available, the current search is terminated. This is usually well before all the feasible alternatives have been inspected. If the present alternative is rejected, searching continues. This generally involves moving to a new traffic link by choosing a turning movement. The turning movement selected usually determines the next car park encountered.

It is possible that a car park will be selected that currently has no unused capacity. In this case, a motorist must wait for a space to become available before parking. During this waiting period the current car park can be periodically re-evaluated in light of the observed departures of vehicles from the car park, with perceptions of waiting times being regularly updated.

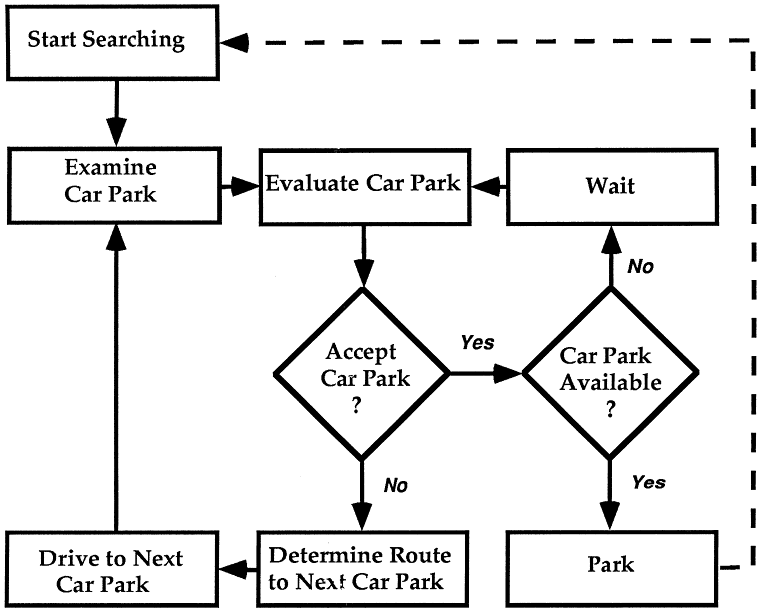

Fig. 1. The parking search process.

ANALYTICAL REPRESENTATION

Car park disutility

The model combines various costs associated with selecting a car park to estimate a generalised cost or disutility providing a numerical measure of a car park's attractiveness that is used to evaluate the current parking alternative. In order to capture the dynamic changes in the costs associated with searching for a car park, the total disutility is defined as consisting of three cost dimensions; access, native and waiting (Fig. 2). Each of these are represented in terms of cost attributes and are combined with relative importance weightings to form an overall measure of disutility.

Access costs are those costs incurred while travelling to a car park and include the in-vehicle travel time from the vehicle's current location to the car park as well as the time spent searching within the car park for a space. Native (or usage) costs associated with a car park, include the monetary cost of the direct fee and expected fine as well as the egress time (i.e. walking travel time from the car park to the final destination). These are the inherent costs of a car park which are incurred when it is selected. Motorists may also incur a waiting time cost before entering a car park which occurs when they have to queue at a car park before being able to enter it.

Disutility estimation

Procedures were developed for estimating the various cost components of a car park's disutility (Thompson, 1994). The in-vehicle travel time is estimated by computing the minimum travel time path between the vehicle's current link and the link adjacent to the car park. The egress or walking time is the time taken to travel from a car park to the final destination. The car park search time is the time a vehicle spends travelling within a car park in order to find a space. Probability analysis was used to relate this to the car park's occupancy and geometric characteristics.

The fee paid for parking is estimated by multiplying the fee rate by the intended parking duration, if payment is required (i.e. not optional) for using a car park. However, if a fee is legally payable, but it is not mandatory (e.g. on-street parking metres), the decision of whether or not to pay the fee involves consideration of the expected fine. The expected fine component of a car park's disutility is estimated by considering the type of infringement (i.e. non-payment or exceeding the specified duration limit) as well as the level of enforcement.

The expected waiting time depends upon the vehicle's current location with respect to the car park being considered. If the car park cannot be observed from the current position, the expected waiting time is calculated by estimating the perceived probability of a car park having at least one space available when it is inspected, as well as the mean waiting time. The mean waiting time for vehicles at car parks that have no spaces available is estimated by considering the number of cars already queued at the car park and the departure rate from the car park.

Parameter estimation procedures

Searchers have perceptions of the attributes and parameters associated with the disutilities of car parks. These are considered to be based on either their actual (objective) or subjective values.

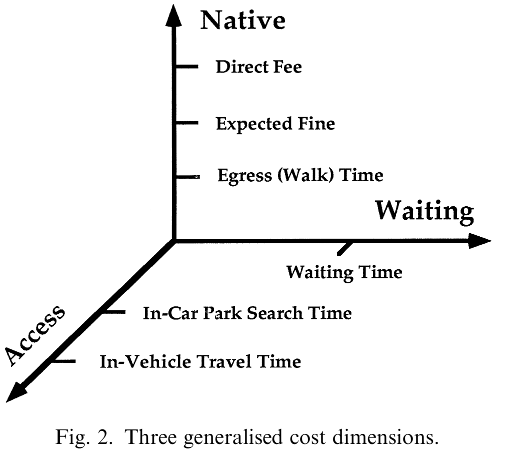

Fig. 2. Three generalised cost dimensions.

It is impossible for motorists to have perfect knowledge of several of the cost attributes and parameters of a car park, since they are stochastic (or uncertain) in nature (Polak and Axhausen, 1990; Salomon, 1986). Searchers, however, must base their choice on imperfect information, relying on their mental images, developed through their perceptual and cognitive processes. Motorists therefore, have at any point in time a mental image of a car park's attributes, developed by synthesising the initial perception with the additional information gained from previous as well as the current searching experiences.

Searchers' perceptions of several of the attributes and parameters of car parks are assumed to be based on their actual or objective values. These include capacity, fee rate and duration limit. Searchers are also assumed to have a mental image of several of the disutility parameters and attributes of a car park, which may be quite different than their actual value. A number of general subjective parameters within the model are specified as exogenous variables which are the same for all searchers and are assumed to remain constant throughout the simulation. These include the perceived probability of car park regulations being enforced and walking speed.

There are a number of car park characteristics and disutility parameters that are inherently stochastic in nature and are assumed to be variable for motorists depending on their current and previous searching experiences. These include the probability of a car park being available and the number of vehicles queued upon inspection. The values of these parameters are therefore, uncertain unless the car park can be directly observed from the vehicle's current location. Perceptions of these attributes are assumed to be formed from previous and current search experiences by combining perception and cognition. Various states were defined to represent the levels associated with the stochastic subjective parameters when they were observed. These are the initial conditions of the model.

Procedures were developed for estimating the subjective parameters of a car park's utility which were uncertain in nature, by focusing on the perceptions that individual searchers have and how these are formed. This procedure incorporates three separate input sources: initial perceptions, observations made on previous trips and observations made during the current trip.

The initial perceptions of the stochastic subjective attributes and parameters for on-street car parks, including the utilisation, were defined. A major influence in determining the mental image (or perception) of the variable characteristics of car parks is the information gained from direct observations made during previous searching experiences.

A trip is defined as a journey from an origin to a destination within the Central Business District (CBD) with a regular frequency. Observations of car parks from each trip are considered to be independent random variables. The perceptions of the attributes of a car park are considered to be a function of the observations gained from previous searches.

The values of the current perceptions of the car park attributes and parameters represented are based on the weighted averages of observations made during previous trips (searches). These weights represent the relative influences that recent and past observations of attribute levels have on current perceptions. This was performed using a weighted mean, which could be adjusted by a coefficient to reflect the relative weighting given to previous observations. This was represented using a function that has been used in modelling temporal relationships in route choice (Horowitz, 1984). This allowed the weights to increase or decrease exponentially from the past into the present.

There still exists considerable uncertainty relating to many of the characteristics of car parks even when they have already been observed during the current search. Modelling these attribute perceptions was therefore undertaken. The perceptions of the stochastic subjective attributes of a car park (when it has already been observed on this trip but can no longer be sighted from the current location) involves many factors. It is assumed to be a function of the status of the attribute of the car park at its last sighting (on this trip), the perceptions based on the previous trip sightings (including this trip's latest observation) as well as the elapsed time from when the car park was last sighted (incorporating the time it would take to return to it). A simple linear function was used to represent this relationship [eqn (1)].

$$\begin{aligned} p(t) &= S_L + (p_n - S_L) * \left(\frac{t}{t_{\max}}\right) \text{ for } 0 \leqslant t \leqslant t_{\max} \\ &= p_n \text{ for } t > t_{\max} \end{aligned} \tag{1}$$

where

$p(t)$ is the perception of an attribute given it has already been observed this trip
S_L is the state of car park attribute when last sighted (1 if available last sighting, 0 otherwise)
p_n is the perception of a car park attribute based on the number of independent trip observations, n (including the first observation of this trip)
t is the transition time (min), representing the elapsed time since the last observation of the car park plus the minimum travel time that it would take to return to it
$t_{\max}$ is the maximum transition time (min), after this time the perception of a car park attribute returns to that based upon the previous number of observations, n.

Stopping rule formulation

The parking search process (Fig. 1) assumes that motorists decide whether or not to stop searching after evaluating the current car park. This involves comparing the utility of the present car park with the utilities of other car parks in the choice set. After a detailed examination of numerous modelling approaches it was considered that an economic principle based on expected gain in utility could be adapted to represent the parking search process. That is, searching is assumed to continue until the expected gain is less than the cost of continuing to search.

However, the conventional economic search modelling approach based on the expected gain in utility (Richardson, 1982) could not be directly transferred to represent the parking search process since a large number of its general assumptions are violated (Axhausen and Polak, 1990). Common specifications of this approach assume that decision makers are risk neutral, have an unlimited time budget, face constant search costs, have full recall and possess a perfect knowledge of the utility distribution.

Various procedures were therefore developed for incorporating features of the parking search process into the overall concept of expected gain in utility. Since car parks may be only temporarily available, the rejection of a car park at any point in time means that it may not be available when and if the motorist decides to return to it at a later stage in the current trip. This general 'lack of recall' relating to the availability of previously inspected car parks, results in the current alternative being the most appropriate basis of comparison in the calculation of the expected gain in utility when deciding whether or not to continue the search. This is in contrast to basic economic search modelling where the maximum of all the previous alternatives inspected so far is usually used as the basis for comparisons. It is difficult to make general assumptions relating to the distribution of utilities or its parameters in parking search. Perceptions of the utilities of car parks are largely based on previous experience and network knowledge (those in the choice set) and hence do not generally conform to common statistical distributions. The costs of continuing searching have been internalised by including the travel time to a car park within the disutility of each car park. This component is represented by the minimum in-vehicle travel time to reach the car park being considered from the vehicle's current location. The expected values of the stochastic cost components were used to represent individuals' perceptions. The disutility was converted into a utility using an additive inverse transformation combined with a scaling parameter.

The net change in utility made by selecting another car park over the current one was estimated by comparing the utilities of respective car parks [eqn (2)].

$$\Delta U_k = U_k - U_{\text{current}} \tag{2}$$

$$U_k = -DU_k \tag{3}$$

$$U_{\text{current}} = -DU_{\text{current}} \tag{4}$$

where

ΔU_k represents the net change in utility by selecting car park k instead of the current car park
DU_k represents the disutility of car park k
DU_{current} represents the disutility of the current car park

U_k represents the utility of car park k
U_{current} represents the utility of the current car park
T represents the set of car parks in an individual's choice set, excluding the current car park.

Searching is assumed to continue if the expected gain in utility, by continuing the search, is positive. That is, searching continues if:

$$g' > O$$

where g′ represents the expected gain in utility.

A number of formulations for representing the expected gain in utility were evaluated. The Expected Selected Utility (ESU) was considered the most suitable for representing the expected gain in utility of car parks for searchers since it incorporates random choice and allowed a direct comparison with the current alternative to be easily performed.

The expected gain in utility from continuing to search from the current alternative is estimated by multiplying the change in utility associated with selecting alternative car parks, by the probability that they will be selected, assuming searching continues [eqns (5)–(7)]:

$$g' = \sum_{\forall k \in T} (U_k - U_{\text{current}}) * p_k \tag{5}$$

$$= \sum_{\forall k \in T} (U_k * p_k) - U_{\text{current}} \tag{6}$$

$$= ESU - U_{\text{current}} \tag{7}$$

where

p_k represents the probability of selecting car park k, $k \in$ T
ESU represents the Expected Selected Utility from continuing to search.

The probability of a car park being selected is estimated by using a logit type model, relating the probability of selection directly to its utility. To distinguish between types of car parks (i.e. on- street, garages and lots) separate (nested) models for each type are estimated (Hunt, 1988).

Direction of search

Motorists also select routes (i.e. series of turning movements) when searching for a car park which effectively determines the car parks encountered. Therefore, the direction of search is important, since numerous attributes of car parks are assumed to be updated upon direct observation.

A relationship between the likelihood of searchers selecting a particular turning movement and the quality of car parks the movement leads to, was developed [eqn (8)]. The expected maximum utility of the set of car parks on links directly accessible from each available turning movement was used to estimate this probability. This appears to be consistent with the stochastic nature of turning movement patterns. The Expected Maximum Utility (EMU) of car parks reached by selecting a movement is used to represent this:

$$P(m_i) = \frac{e^{\eta EMU_i}}{\sum\limits_{\forall k \in \mathbf{M}} e^{\eta EMU_k}} \tag{8}$$

where

M is the set of available turning movements, e.g. {Left, Through, Right, U}
$P(m_i)$ is the probability of choosing turning movement i, $i \in M$
η is the movement utility sensitivity coefficient
EMU_i is the Expected Maximum Utility of car parks reached by selecting turning movement i.

The EMU of the set of car parks relating to selecting a particular turning movement is estimated by considering only a subset of car parks — those on links reachable by two successive turning movements [eqn (9)]. Movements leading directly to significantly better car parks therefore have more chance of selection:

$$EMU_i = \ln\left[\sum_{\forall j \in \mathbf{R}} \exp(Uij)\right] \tag{9}$$

Where

Uij is the utility of the jth car park ($j \in \mathbf{R}$)

$\mathbf{R}$ is the set of car parks in the choice set reachable within two successive turning movements from turning movement i.

System representation

A range of physical and operational characteristics of the traffic and parking system were defined to represent the search environment (Thompson and Collins, 1992). Traffic volumes on the links and turning movements were assumed to be constant for the entire period being modelled. Travel times within car parks were used to schedule vehicles by estimating when they would reach the decision point to evaluate on-street car parks. It was assumed that motorists evaluate on-street car parks upon reaching the first unoccupied space. If there were no available spaces, this decision point was presumed to be after reaching the last space in the car park. For off-street car parks (i.e. garages and lots) it was assumed that these are evaluated at their entrances, before inspection, implying that motorists only enter off-street car parks with the intention that they will park there if a space is available.

Motorists were assumed to possess a set of characteristics that influence their search for a car park. These attributes relate to the utility of car parks and the level of knowledge of the characteristics of the system. Individuals were also assumed to possess a set of attitudes relating to the relative importance of the various attributes of car parks that were used to compare car parks when searching. In the past parking choice models have grouped individuals into trip purposes (Van Der Goot, 1982) and duration ranges (Axhausen and Polak, 1991) to estimate the importance weightings of the car park disutility components as well as the value of time.

Several assumptions were made regarding the nature of the initial choice set of car parks that motorists were assumed to be aware of. No off-street car parks were considered to be initially known by motorists, while full knowledge of all on-street car parks within the CBD was assumed.

In addition to the system and decision-maker characteristics described above, there are a number of factors relating to the trip that were also specified in the model. Trip attributes including the parking duration, the origin and the final destination as well as the arrival time were specified (Bates and Bradley, 1986).

VERIFICATION AND VALIDATION

The model was verified using a hypothetical CBD and parameter values adapted from previous studies. The choice set of motorists increased as off-street car parks were encountered while searching or observed when walking to the final destination after a car park had been chosen. A substantial amount of sub-optimal choices were simulated which is consistent with observed behaviour. Perceptions of the stochastic attributes of car parks also changed depending on the conditions which simulated motorists encountered. The model was able to replicate several of the observed parking choice strategies reported by Polak and Axhausen (1990).

Numerous parameters of the model were varied in order to test the sensitivity of the outputs and to check their relevance for inclusion in the model. Responses to changes in these parameters were reasonable and consistent with prior expectations. The turning movement utility sensitivity coefficient [eqn (8)] was found to directly influence the average in-vehicle search time. As this coefficient increased, searching time decreased. Coefficient values greater than 1 tend to increase the chances of the movement leading to the best alternative being selected, thus reducing in-vehicle travel time. Low values of this coefficient tend to dampen the difference between movement utilities, leading to a more random choice, thus increasing search time.

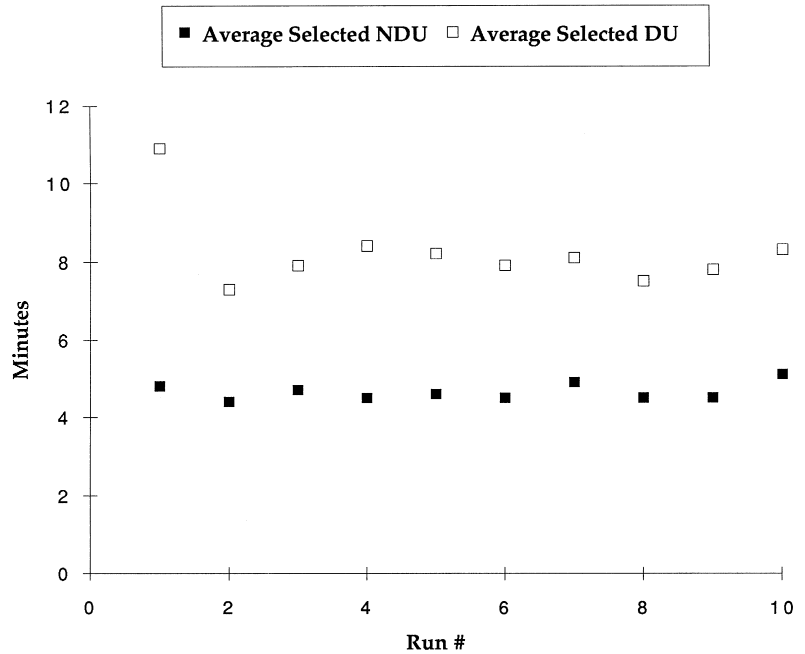

Fig. 3. Number of runs and selected car park utility.

The effect of experience gained by searchers over a number of successive runs representing independent daily trips was investigated. On average, the experience did not significantly influence the quality of the car parks selected — represented by the native disutilities of the selected car parks (Fig. 3). This appears to be largely due to the uncertainty associated with the availability of car parks. However, the overall utilities of the selected car parks (including waiting time) did improve dramatically after the first trip (run), due to the increased knowledge of the availability and departure rates at car parks. Motorists commonly waited to enter car parks on the first trip, but this was not so prevalent in subsequent trips. The variation in the average selected disutility seemed to stabilise as the number of trips incresed.

Details of a simulated trip (Table 1) are presented to illustrate the workings of the model. Figure 4 shows the layout of the traffic and parking components of the hypothetical CBD network.

Off-street car parks were classified as being either a lot or a garage. Lots are surface off-street car parks and are assumed to have a constant fee structure. Garages are multi-storey parking car parks (or stations) which are assumed to have a fee structure which is variable on the basis of the duration parked. The accumulation at car parks was determined using a procedure that randomly varied the initial levels in each run while representing a generally high pattern of demand. Link numbers of each leg of the routes taken to the selected car parks are presented in Table 2. The measures of performance for each run are shown in Table 3.

On the first run, the searcher proceeded directly to link number 28 and encountered on-street car park number 23 with no unused capacity. The searcher then waited for 6 min at this car park before moving to garage number 1, on the same link. This car park was then selected.

A similar search pattern was produced with the second and fourth runs (days), but garage number 1 was selected after waiting at on-street number 23 for only 2 min. On the third, fifth, sixth and seventh runs, on-street car park number 23 was available and was therefore selected. On the eighth, ninth and tenth runs, link 22 was inspected and lot number 4 subsequently chosen.

Table 1. Case study trip details

Trip Attribute	Value
Origin link number	58
Destination link number	28
Parking duration (min)	70

Figure 5 illustrates these effects on the utility of the selected car park. The selected disutility decreased after the first run as more information is gained on the availability and existence of car parks. The variation of the disutility of the selected car park decreases with the number of runs.

Table 3 shows that the waiting times incurred in the early runs were not maintained. It also shows that the cost of lot number 4 is free, which was traded off against the increased walking distance compared with garage number 1.

APPLICATION

The model was applied to predict the impacts on choice behaviour for a number of changes to the parking system, reflecting several contemporary parking policies (e.g. duration limit reductions and the elimination of enforcement practices). A small hypothetical CBD network was used to investigate the effects of these policies. The on-street parking network used in this investigation

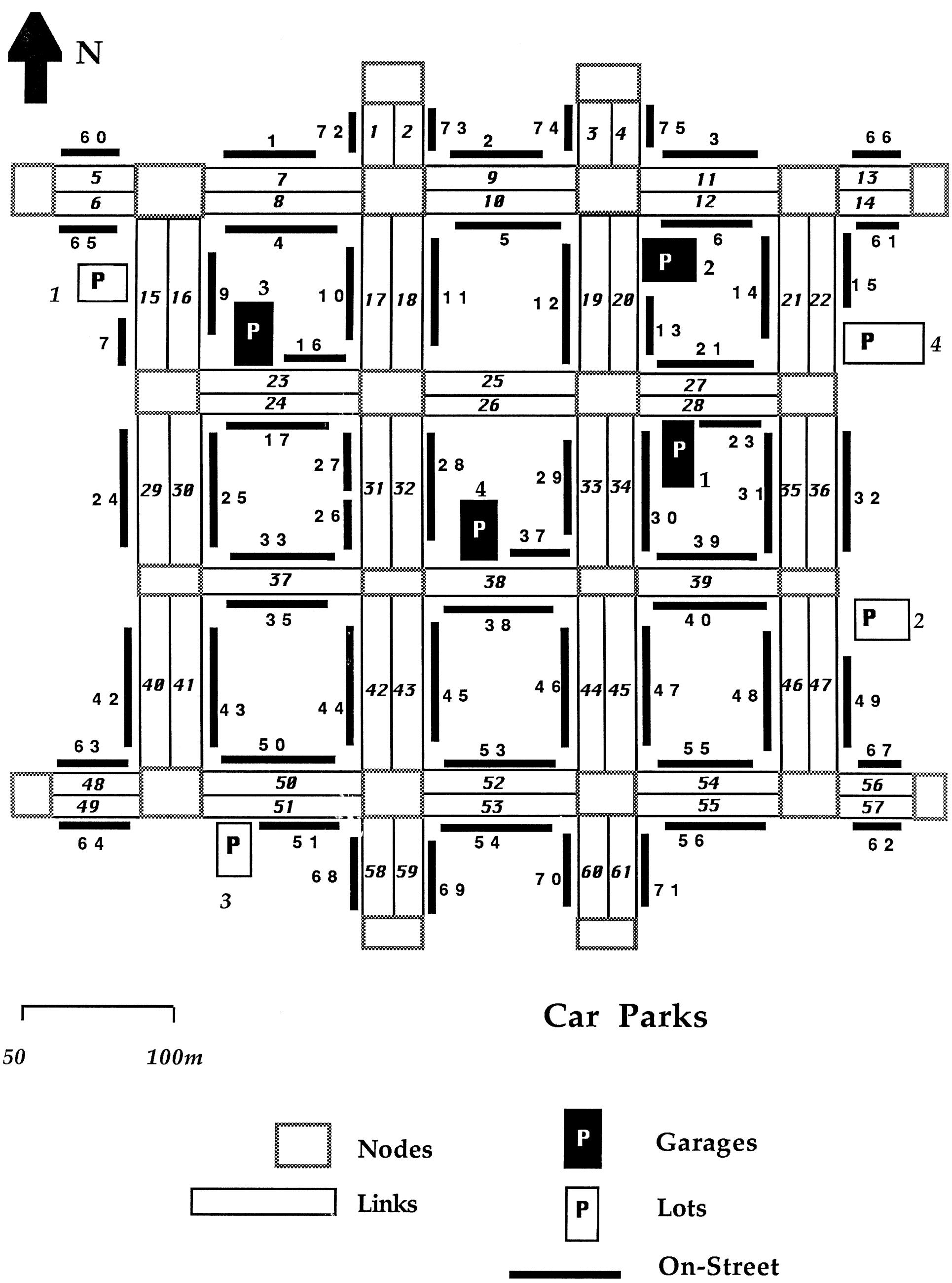

Fig. 4. Hypothetical CBD traffic, pedestrian and parking network.

Table 2. Link numbers of routes taken to the car parks selected

Run no.	Leg								
	1	2	3	4	5	6	7	8	9
1	58	52	54	46	35	28	—	—	—
2	58	52	54	46	35	28	—	—	—
3	58	52	54	46	35	28	—	—	—
4	58	52	61	60	54	46	35	28	—
5	58	52	54	46	35	28	—	—	—
6	58	52	54	46	35	28	—	—	—
7	58	52	54	46	35	28	—	—	—
8	58	52	54	46	35	21	22	—	—
9	58	52	54	46	35	21	12	11	22
10	58	52	54	46	35	21	22	—	—

Table 3. Case study measures of performance

Run no.	Selected car park		In-vehicle travel time (min)	Waiting time (min)	Fees paid ($)	Walking time (min)	Excess In-vehicle time (min)	Selected NDU (min)	Selected DU (min)
	Type	no.							
1	Garage	1	7.57	6.00	0.50	0.30	6.08	3.50	11.07
2	Garage	1	3.51	2.01	0.50	0.30	2.02	3.50	7.01
3	On-street	23	1.48	0.00	0.40	0.30	0.00	2.90	4.38
4	Garage	1	5.14	2.00	0.50	0.30	3.66	3.50	8.64
5	On-street	23	1.44	0.00	0.40	0.30	−0.04	2.90	4.34
6	On-street	23	1.56	0.00	0.40	0.30	0.07	2.90	4.46
7	On-street	23	1.48	0.00	0.40	0.30	0.00	2.90	4.38
8	Lot	4	1.78	0.00	0.00	2.29	0.30	4.10	5.88
9	Lot	4	3.02	0.00	0.00	2.29	1.53	4.10	7.12
10	Lot	4	1.71	0.00	0.00	2.29	0.23	4.10	5.81

was partitioned into three zones, based on duration limits. An inner zone (adjacent to the central traffic links) was designated as short term (up to two hours), while long term parking (up to 12 hours) was permitted alongside the outer (fringe) links. Medium term parking (up to four hours) was permitted at on-street parking adjacent to the other traffic links. Vehicle trips used to assess the impacts of these parking policies were assigned parking durations of between two and three hours with destinations on links in the inner part of the network.

Duration limit reductions

The effect on searching patterns by changing the duration limits of car parks within the CBD network was investigated. There exists a trend in many cities to reduce the on-street duration limits to encourage short and medium term parkers to shop and conduct business there. Short term

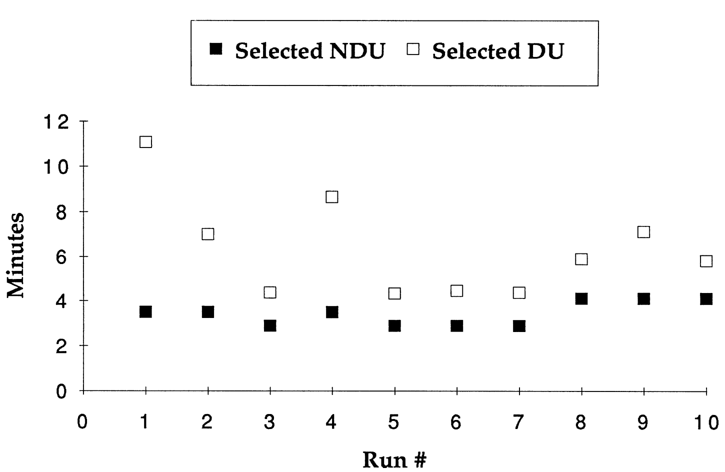

Fig. 5. Disutilities of selected car parks.

Table 4. Model results from reducing on-street parking duration limits

Averages (for fifth run)	Before	After
In-vehicle travel time (min)	3.76	1.35
Excess in-vehicle travel time (min)	1.98	−0.65
Walking travel time (min)	2.61	4.34
Selected native disutility (NDU)	9.07	10.39
Selected disutility (DU)	12.83	11.74

on-street parking was reduced to one hour within the inner area, while fringe parking was restricted to four hours. On-street limits adjacent to other links were limited to two hours.

The effects of changing the duration limits were estimated by running the model for both parking networks. The results produced show a significant change in parking search patterns. These have been summarised by considering the search characteristics of all trips for the fifth run (Table 4). The results show a substantial reduction in searching time as well as a significant increase in walking times due to the new policy. The trend after the duration limit changes was for vehicles to generally park on the outer (fringe) areas. The effect on the quality of alternatives selected was not significant as motorists traded off increased walking time for reduced searching.

Experience appeared to play a more positive role in the selection of car parks after the change to duration limits was introduced. This was attributable to motorists learning more about the location and details of off-street car parks after the initial search. Off-street facilities became quite attractive once they became known, particularly after the duration changes were made. This was confirmed by comparing the means of the disutilities from the first and fifth runs for before and after the introduction of the changes to the duration limits (statistically different at the 2.5% level).

A trip maker's origin, destination and duration have a large influence on their parking choice. Unfortunately, due to the limited computer resources available, large scale variation of these trip parameters reflecting the full range of trips into a central city area was not undertaken. The existing model has a number of limitations due to the simplifying assumptions made, many of which can be modified in the future if empirical studies suggest they are unrealistic. For example, the costs of continuing to search do not include any perceived money cost and are assumed to be constant, suggesting an unlimited time budget. There is also no account for various qualitative aspects of parking choice such as security and safety.

CONCLUSIONS

In conclusion, this paper has shown that parking choice behaviour in competitive situations can be described by a search process. The economic search principle of expected gain in utility was adapted to represent the searching patterns of parkers in congested city centres. Numerous characteristics of the parking search process were incorporated within this structure.

The application of the simulation model illustrated that experience in parking search does not necessarily lead to better car parks being selected. This is due to the inherently uncertain nature of the car parking system.

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