

Planning urban car park provision using microsimulation

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In three different locations around the world, city planners have sought to investigate the effects on the road network of car park planning policy and

accessibility. All have looked for methods to minimise urban congestion caused by drivers searching for a car park space. All have used an S-

Paramics microsimulation model to test the design options. This paper describes how they went about it and what they achieved.

INTRODUCTION

The provision of available car parking is one of the most contentious issues for city drivers. Car park spaces can be hard to find and expensive to use. There may be queues to get into the most convenient car parks which require drivers to move on to alternative car parks. Some city centre traders regard the lack of suitable car parking as a significant reason for shoppers to prefer out of town shopping centres. In New Haven Connecticut, Gov. Rowland at a ceremony celebrating the renovation of the city's largest car park in 2002 declared: 'if you don't have parking, nothing else works'. [1]

Car park hunting, the circulation of drivers looking for a parking space, can be a major contribution to city centre congestion. The proportion of cars searching for a space was found to be 26% when surveyed in Manhattan in 2006, while in Brooklyn it was 45%. The situation is not new. In 1927, a similar survey in Detroit found the figures to be 19% and 34% in separate locations [2]. This long standing problem may at last be assisted by technology. While iPhone users can now notify each other as spaces become available [3], traffic planners can now take advantage of recent developments in traffic modelling, which demonstrate that car park access can be included in road traffic simulation models to support the design process.

Car park location in urban planning policy is largely concerned with optimising the relationship between car parks, drivers and their destinations. Charging regimes may be used to reduce localised inconvenience caused by parked cars and to favour one class of driver over another in allocating spaces. The perceived benefits include improvements to a city's commercial centre through better accessibility for the target consumer. Policies may be supply-led by actively managing spaces or demand-led by simply increasing the number of spaces [4]. Increasingly, active management policies are used to ration spaces and encourage sustainable travel patterns [5].

Urban planning policy considers the charging regimes for car parks. Transport planning policy complements this and considers access to the car parks. It is concerned

with the relationship between car parks, the road network and congestion.

Accessibility of car parks is addressed in road design guidelines. UK Department for Transport advice on parking guidance and information systems includes reports of case studies that show that there are quantifiable benefits to be derived from installing variable message signs indicating car parking space availability [6]. Benefits are described as quantitative, in terms of time saved, and qualitative in terms of public image and driver safety. WebTAG [7] guidance touches on the subject briefly in discussion of travel costs by including 'parking "costs" (which notionally include time spent searching and queuing for a space and walking to the final destination)'.

The authors' perception is that car park accessibility is normally considered after the urban design is complete and car park policy has been determined. The missing link is in the transport planning policy contribution to the initial design of urban areas with respect to car park provision and accessibility. This apparent deficiency has recently been addressed in three different locations reported here. Each has sought ways to investigate the effects on the road network of car park planning policy and accessibility. All have looked for methods to minimise urban congestion caused by drivers searching for a car park space. All have used an S-Paramics microsimulation model to test the design options.

A study in Nieuwegein (The Netherlands) modelled a large expansion in travel demand and the provision of car park spaces for a major town centre redevelopment, where Saturday afternoon shopping was the critical period. It incorporated ITS within the microsimulation model to deliver information to drivers on availability of spaces and routes to car parks. Another study, in Rochdale (England), models the distribution of spaces in conjunction with major town centre development plans. The goal is to optimise the provision of car parks with respect to adjacent land use and to minimise town centre congestion by considering car park access early in the design process. The third study, in Takapuna (New Zealand), is also investigating the effect of city centre expansion. It

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NIEUWEGEIN PLANNED DEVELOPMENTS

Nieuwegein is a town just to the south of the city of Utrecht in the centre of the Netherlands with good economic prospects. To make the most of this, the municipality wants to restructure their city centre to include new developments. New multi-story car parks are planned to cope with the increased demand for parking spaces and a system for dynamic parking advice will attempt to minimise queueing at the car park entrances. Grontmij was asked to build an S-Paramics model of the city centre to review the effects of the new developments on the city's road network including the parking advisory system.

The results of the simulation showed congestion at the three car parks closest to the city centre. This was in accordance with the city manager's expectations. To bring the remaining capacity of the two other car parks into use, a parking advisory system was implemented in the simulation to redirect vehicles to the available parking capacity and gain insight into the effect of the system.



KCAP architects

uses bespoke software to model the car park demand and a microsimulation model to assign the demand to the network. Once again the goal is to understand the effect of car park policy and minimise city centre congestion.

CAR PARK MODELLING IN MICROSIMULATION

Typical design option tests for a microsimulation model include changes to road layout, public transport priority schemes, optimisation of signals, or changes in demand. Each individual vehicle in the simulation will react to these changes, and the congestion they cause, as it moves to its destination.

When testing the effect of car park policy decisions, the emphasis moves from examination of the effect of changes to the road network to examination of the effect of changes in the destination for that part of the trip undertaken in a car. The simulation model must now

include the capability to distinguish between the driver's destination and the vehicle's parking location and make dynamic choices between these locations.

Arrivals

Car parks are an entity within the microsimulation model, and are linked to zone destinations and car parks may serve more than one zone. Allocation of vehicles to car parks is undertaken by limiting car park access to specific trip purposes.

The model includes car parking charges and the distances between car parks and associated zones as components of the generalised trip cost. As each vehicle type may have different cost coefficients, the modeller may differentiate between drivers who will accept a longer walk and those who will accept a higher charge.

If a car park is full then vehicle drivers within the simulation wait at the entrance for a predetermined time, after which they re-assess their choice of car park and possibly proceed to another. Using an external software controller it is possible to monitor car park occupancy within the simulation and change a vehicle's destination before it reaches the queue.

As an example of how this methodology can be used to implement a car park policy model, consider a city centre zone with a mix of retail and commercial use with several car parks available within reasonable walking distance. Drivers will have a preferred location based on their proposed length of stay and the car park charging structure. Some drivers may have a contract for permit parking. A car park may have multiple adjacent entrances, each coded with a restriction to force vehicles to accept the appropriate parking charge.

The effect in the simulation is that short stay vehicles enter car parks closer to their destination or with a lower charge. The long stay vehicles enter via the entry links with the higher charges or accept a longer walk time. The modeller can test responses to car parking changes by adjusting entry charges for different car parks or by varying the level of permit parking. Land use changes may be modelled by adjusting the proportion of driver and vehicle types using a particular zone and related car parks.

Departures

The assignment of all vehicles to an S-Paramics road network is controlled by a detailed (5 minute) time release profile. In its simplest form of use, the journey origin car

Figure 1:
Rochdale city centre
carparks



park is determined by finding the minimum journey cost, which includes the walk time, or vehicles may simply be released in proportion to the size of the car park.

If more control is required, such as the ability to match departures to arrivals at the same car park, the release may be triggered by an external software controller linked to the simulation model which uses an algorithm to determine when to release vehicles and where they originate on the network. This may be associated with a car park occupancy monitoring system and be used to match vehicle arrivals with a subsequent departure.

MODELLING SOLUTIONS

Data collection

Travel demand matrices for the Nieuwegein model were derived from a pre-existing macroscopic model and refined with survey data. Further surveys were undertaken to determine the usage of the main car parks, the average length of stay and the residual numbers after the shops were closed.

Because of the complex requirements of the Rochdale and Takapuna studies, more extensive data collection was necessary. Demand matrices for Rochdale were developed primarily from roadside interview data which identified the true destination of the journey. The interview data was used to determine the parking type (eg long/short stay, on/off street, contract), and the likely parking duration (based on journey purpose).

A full parking inventory of the town centre and occupancy data provided input to a car park location model, used to link car parks to destination zones. The time to walk to each destination from each car park was initially estimated from simple geometry and later used as an important calibration parameter.

Parking inventory data was essential to provide accurate capacity estimates categorised by: short or long stay, on or off-street; public or private, and charged or free. This included all car parks within, or adjacent to, the town centre. Residential parking areas adjacent to the town centre, were also included as these provided free parking, with longer walk distances, and were often used by commuters. Areas with high drop-off trips were modelled as a private parking type at their destination but could have been improved by having both the inbound and outbound legs of the drop-off trip in the matrix.

The car park data also provided charging information for each car park. When combined with the car park interview data it was found to be possible to group charges into a single short stay and long stay charge. This simplification was appropriate in Rochdale, but it would have been possible to use a car park specific charge if the variation was more significant.

Parking data in Rochdale was limited to peak car park occupancy and the model would have benefited from a comprehensive survey of vehicles entering and leaving throughout the day. In Takapuna, and Nieuwegein, arrival time, dwell time, and occupancy data was available and this was used, with the charging information, to model driver's choice of car park

Demand matrix segmentation

Matrix segmentation enables the modeller to control departure time demands for different classes of vehicles. The degree of segmentation must be supported by the data. Similarly car parks should be grouped to a level commensurate with the detail of model input data.

In Rochdale, matrices were derived for cars categorised by commuter, non-commuter and work. The interview



ROCHDALE KEY DEVELOPMENT AREAS

Rochdale is a historic market town in East Lancashire, now a metropolitan borough of Greater Manchester. The town centre contains a central retail and business area that not only competes with other local centres but also with Manchester City Centre and the Trafford Centre. To help improve Rochdale's competitiveness as a centre for retail and commerce, Rochdale Development Agency plan a major redevelopment of the south east area of the town centre. Comparative assessment of the town centre masterplan proposals on the highway network and car park operational performance require an objective scoring method only available via a transport simulation model. Providing parking of acceptable size, location and type is considered critical to the attractiveness of the town centre retail and commercial environments and hence formed a major part of the modelling exercise.

data enabled the commuter and work matrices to be subdivided into private non residential (PNR) parking and contract parking. PNR parking supply, which is notoriously difficult to estimate, was assumed to be unlimited in the model as the matrixes were explicitly defined. For areas outside the town centre all drivers were assumed to park at their destinations.

Takapuna adopted a similar approach, with demands segmented into 'long stay' and 'short stay' parking types. Long stay was further split into 'on site' or 'general' depending on access to workplace car parking. Long and short stay demands were estimated from the purpose matrices of a strategic transport model, with adjustments based on car park number plate and turn count data.

Trip linking

In order to model vehicles arriving and leaving from the same car park, trips in and out of the city centre area must be linked, with origin car parks and departure times selected based on prior arrival car parks and times. This requires more sophisticated control over the departure time and the departure location than is available from conventional OD matrix methodologies.

In Nieuwegein, the study period covered the main shopping peak period on Saturday afternoon and included a warm up period to populate the car parks and initialise the ITS controller within the microsimulation model. To model the linked trips, all traffic departing from the city centre was deleted from the OD matrices. An external software controller monitored the car park occupancy in the model to determine the arrival profile and, after a suitable dwell time typically one hour, released matching vehicles on return trips.

For Takapuna, before the PM simulation was run, a separate demand model was used to generate a profile of releases in the PM peak based on car park occupancy derived from the AM peak. This was to be subsequently used in the PM model run.

Matrices were generated based on the profiled

Figure 2:
City centre model of
Nieuwegein



demands derived for each zone within Takapuna. When selecting from which particular car park the vehicle should depart, the demand model matched its outbound zone with that of a parked vehicle. The match was made based on the parking duration (long/short), and the expected departure time estimated from the arrival time distribution. If this process found a vehicle within 20% of its expected departure time, then one was added to the profile to be released. If no match was found, then the release was carried forward to the next profile period and the search repeated.

The Rochdale model was also divided into AM and PM peak scenarios. The choice of car park for departure in the PM peak was modelled using the generalised cost of travel combined with an exit cost to help bias car park selection. Comparison with observed data showed the use of exit costs could successfully calibrate the model.

Car park searching

As the primary goal of all three models was to study the impact of car parking on urban traffic congestion, the strategies for allocating vehicles to car parks within the model and subsequent car park hunting were key to the success of the studies.

The Nieuwegein study was specifically designed to test the effect of a proposed car park advisory system. VMS signs were positioned on all approaches to the town centre (Fig 2) and provided information on which car park to select (Fig 3). Based on the experience of the Town Parking Manager, the ITS system was configured to make only 20% of drivers follow the advice of the parking advisory system. This left the remaining 80% to proceed to their first choice car park, and re-route from there if it was full.



Figure 3:
Car park Advisor
Variable Message Sign

The Rochdale and Takapuna models focussed on accessibility more than guidance. In Rochdale, policy decisions were used to determine car park choice, which restricted the allocation of car parks to zones, eg contract parking areas were linked to work-related, rather than shopping-related zones. In Takapuna, parking was less constrained by policy and all car parks were linked to all zones with less predetermined allocation of spaces. Vehicles arriving at a car park would queue for a fixed time then move on to the next best car park based on the vehicle trip cost, walk cost, and parking cost. The Takapuna model augmented this selection process with a car park availability control and a search limit implemented through an external software controller.

The search limit reflects drivers' willingness to circulate through numerous car parks in order to find a parking space, by setting a limit on the number to be tried before giving up, and looking for something 'highly likely' to have spaces. The availability control monitors car park occupancy any car parks that have been full for 10 minutes are removed from the list. As soon as a vehicle leaves a car park, it is reintroduced into the selection procedure.

ISSUES

First choice car park

The first choice car park issue arose in both Rochdale and Takapuna. This occurred when the first choice car park for a vehicle was small and quickly filled. Most vehicles that selected this car park to minimise journey costs would have to re-route to their second choice. In reality many drivers make the same trip regularly and learn that this car park is usually full. They discount it as a first choice and select a larger car park with a better chance of finding a space.

Two solutions were developed to address this problem. Takapuna used their car park availability controller to overwrite the driver's choice, to provide a proxy for the driver learning process. The second solution was to group smaller car parks, typically those with less than 50 spaces, to avoid excessively large demand being allocated to a specific car park as first choice. Car park destination catchments and walking times were adjusted in parallel to prevent too many vehicles having the same first choice car park.

A high level of matrix segmentation is in use for Rochdale to allocate car parks. This methodology offers a solution through further segmentation by driver 'familiarity'. Drivers with knowledge that the smaller car parks are full tend to avoid them and make their first choice the larger car parks.

THE MODELS IN OPERATION

Nieuwegein

The base model was calibrated for a typical Saturday afternoon. The test scenarios included planned new developments in the city centre.

Two future year simulations were compared. In the first, without the advisory system, large queues formed at the most attractive car parks. With the parking advisory system, the vehicles were more equally distributed over the available parking capacity with spaces available in most car parks. This resulted in fewer vehicles searching for a parking spot and fewer queues in the city centre. This was achieved with just 20% of drivers taking heed of the parking advisory system. Future tests will extend the range of the ITS system and redesignate some roads as pedestrian areas.

As the model simulated a future year scenario of 2015 and the detailed design of the town centre will probably differ from that which has been simulated, the predicted benefits were conservatively interpreted in evaluating the scheme. Despite that, the conclusion was that an investment in a parking advisory system to make the best use of the parking capacity in Nieuwegein is justifiable.

Rochdale

The Rochdale model has been used to test part of a major town centre redevelopment planned for 2012. Key features include relocating the town centre bus station and council offices, removing the main town centre multi-storey car park, and redesigning key junctions on the A58 through the town centre.

Further developments in the modelling process may include a similar external software controller as implemented in Takapuna and Nieuwegein. This could include explicit car park guidance at route decision points as well as a car park space 'opportunity cost' which would be added to the generalised cost associated with each car park before the first choice is allocated. This cost would bring the likelihood of space availability at each car park in to the destination choice although more survey data would be required to help calibrate this.

Takapuna

The S-Paramics model for Takapuna is to be the operational transport assessment tool for all significant planning applications and district plan change proposals within central Takapuna. In this way, all assessments will be made under a common and consistent modelling framework as has previously been successfully achieved in two other developing areas of North Shore City.

With the recent economic downturn, some landowners in the area have ceased trading or sold their holdings, while others have delayed their planning and assessment work. Takapuna has a calibrated car park model incorporated into the traffic simulation model, both of which are part of an assessment framework that is ready to be used as soon as economic growth returns.

6 SUMMARY AND CONCLUSIONS

Car parking strategy is crucial to reducing the problem of traffic congestion in urban centres. The Nieuwegein study has demonstrated how effective even a partial take up of a particular solution can be. Tests undertaken with the Rochdale and Takapuna models show that the ability to include car parking strategies within the analytical framework can significantly influence the outcome of design solutions.

Each study has identified the necessity of linking ar-

TAKAPUNA DEVELOPMENT PROPOSALS

Takapuna is the major business district in North Shore City, New Zealand. Growth has remained relatively static over the past 10-20 years. One of the principle problems is poor accessibility, with only three roads leading in to Takapuna, each of which is congested during commuter peak times. Now, however, there are plans for residential and employment growth over the next 10 - 20 years, complemented by a new major connection to one of the three access roads, and planning for bus priority lanes, bus stations, and other transport infrastructure.

Much of the car parking within the wider Takapuna area is unrestricted on residential streets. During weekdays these areas are full from the early hours of the morning with all day commuter vehicles while the existing centralised pay car parks are often under utilised. People are prepared to walk up to a couple of kilometers from the residential streets to avoid paying for parking.

There are current proposals to enforce car park policy to redress this balance by building further centralised car parking and adding time restrictions to on-street parking.

However, much of the existing long-term parking is located on rough ground where older buildings have been demolished, and many of these areas are expected to be re-developed in the next few years.



rival and departure trips from the same car park, but developed three distinct solutions for this. The way in which simulated drivers select a car park has also varied, but has been consistently based on matrix segmentation, enabling charges and restrictions to be applied to reflect charging policies. The issue of identifying a sensible first choice car park was also addressed by each study.

The three city centre studies discussed here address different aspects of car park modelling and have shown some innovative solutions to a common set of issues, particularly the congestion caused by drivers hunting for spaces. They have demonstrated that transport modellers can confidently use microsimulation to examine the effects of car parking strategy on urban traffic.

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