The Development of CENCIMM Parking Policy Model: Research to Meet a User's Need

Mike Taylor

Professor of Civil Engineering
University of South Australia

Lance Chambers

Manager
Operations Research & Information
WA Department of Transport

Bill Young

Associate Professor of Transport Engineering
Monash University

Abstract:

The CENtral CIty Movement Model (CENCIMM) is a simulation model combining the operations of the traffic network and the parking system in a central city area (or a regional centre). CENCIMM has been developed to meet the needs of the WA Department of Transport for a model that enables parking policy and operations to be included in metropolitan transport policy formulation. The application of the model has focused on the Perth CBD, but the model can be applied to any other area. It requires the construction of a traffic and parking supply database, plus trip pattern information by time of day. Disaggregation of vehicle trips is required, into the three broad classes of through traffic, tenant parkers and search parkers. The CENCIMM project is an excellent example of cooperation between transport researchers and users in developing a powerful tool for direct application in transport planning.

ontact author:

rofessor M A P Taylor
chool of Civil Engineering
niversity of South Australia
HE LEVELS S A 5095

elephone (08) 343 3330 Fax (08) 349 4284

In 1984 Hugo Wildermuth proposed the development of a multi-modal traffic network model for application the central city (Wildermuth, 1984) This model was termed CENCIMM, the *CEN*tral *CI*ty *M*ovement *M*odel The original CENCIMM model was intended to provide planners and analysts with a powerful tool capable of providing detailed information about travel behaviour and movement in CBD networks, covering all the available modes (e.g. car, foot, bus, light rail, ...) and the interactions between them Transport planning and policy decisions affecting central area travel would then be capable of indepth analysis In the event this model specification proved to be far too difficult, well beyond the capabilities of current technology and expertise (Pak Poy and Kneebone, 1988).

A revised specification for CENCIMM was then devised by WA Department of Transport, as a model of the road traffic and parking systems inside the CBD. The revised specification included the need for CENCIMM to be responsive to metropolitan transport policy and to reflect the influence of metropolitan-wide travel, whilst focussing on the central area parking system and the traffic performance of the CBD road network In particular, the influence of policies on the supply and operation of parking facilities was to be modelled explicitly.

This revised and sharpened focus stemmed from the emerging concerns about 'Traffic Demand Management', or specifically 'Road Demand Management', now more properly described as 'Sustainable Travel'. The concept of sustainable travel is for urban transport systems that function over the long term in keeping with community objectives of minimising congestion, energy usage, environmental degradation, social disruption, danger and risk The need for initiatives to encourage sustainable travel, and necessary research and development, were described by Wigan (1990) and Wayte (1991), and subject to open debate at an AUSTROADS seminar in early 1991 (AUSTROADS, 1991).

Parking provision is an important concern in sustainable travel, for parking policy and supply play major roles in the management of transportation systems in dense urban areas. The amount and the location of parking affect, in particular:

- the level of service and congestion on access roads and internal city streets
- the efficiency, effectiveness and financial performance of public transport
- the amenity, safety and environmental integrity of the city and its surrounds
- the form and functioning of the metropolitan region as a whole.

As a result, car parking policy and practice may present considerable conflicts between the sometimes differing objectives of local government, users, special interest groups such as owners and managers of office, retail and commercial properties, and state or national governments (Ker and Johnstone 1988) Although the policies that govern the provision and operation of parking facilities are recognised to have an important bearing on the operation of urban transport systems, decisions have often been made on an *ad hoc* basis, without proper integration with other elements of transport systems analysis Well-founded parking policy decisions can only be made when the analysis of parking behaviour and the effects of parking policies have been fully integrated with the other elements of the transport planning and analysis process.

Consequently the WA Department of Transport decided to pursue the development of CENCIMM as a parking policy-orientated model, and approached

Professors Taylor and Young to undertake the necessary research. CENCIMM development work commenced at the end of 1989, following an extensive review of previous research and development concerning combined parking and traffic network models (Young, Thompson and Taylor, 1991).

The role of CENCIMM

No one model can address all types of parking and traffic problems. Rather a set of models is required, where each model is suited to addressing particular problems at a particular scale. A useful way to picture this set of models is as a connected hierarchy, as described by Young, Taylor and Gipps (1989), and illustrated by Taylor (1989) with reference to an urban subcentre. One particular, simple hierarchy of models for use in parking policy analysis is the following:

(a) parking site or lot analysis;
(b) subcentre or regional modelling, and
(c) area-wide or metropolitan modelling,

noting that more detailed (and hence complex) hierarchical structures are also of use (Young and Taylor, 1991). Vehicle circulation at a metropolitan level in Perth is being modelled using the SPECTRUM model. This model provides level (c) in the hierarchy. Level (a) can be modelled using PARKSIM (Young 1985) CENCIMM provides the modelling capability at level (b).

The hierarchical concept requires the existence of direct communications links between models at the different levels, so that information from one model (level of interest) may be sent to another. In the present discussion, where the impacts of central city parking policies on metropolitan travel are of interest, the most important link is between CENCIMM and the metropolitan-level model, SPECTRUM.

The particular concerns for Perth that CENCIMM must address include the following:

- road congestion at intersections and the impact of the extra provision of parking on this congestion This is particularly of concern in the north west corner of the city where significant parking facilities are under construction;
- the impact of the transfer of short term parking to long term tenant parking on the performance of the traffic system;
- the impact of parking cost structure on parking preference and the traffic system;
- the impact of parking opening time (9:00 am) and closing time (5:00 pm) on traffic system performance;
- the utilisation of short term parking spaces;
- capacity problems caused by vehicles accessing or leaving a parking lot;
- the impact of the alteration of existing floor space to parking;
- consideration of the permissible level of parking in each of the three rings of central city development, and
- the impact of the removal of on-street parking and the introduction of clearways on traffic flow and parking use

In this way CENCIMM provides a tool for policy development in sustainable travel It can estimate the impacts of parking system operation and the parking search process on central city traffic congestion, and can model the distribution of chosen parking locations in response to alternative policies for parking charges, parking durations, and the provision of public transport feeder services from parking lots distant from trip destination sites. The model also allows exploration of the impacts of the removal or provision of on-street parking spaces The model hierarchy permits a wider study of impacts of policies at the metropolitan-wide level, e.g for the investigation of the effects of parking policies on destination choice A modelling framework allows investigation of the scenarios generated by alternative policies before their implementation in real world situations

CENCIMM specifications

The main aim of CENCIMM is to provide assistance in the assessment of alternate CBD parking policy. The decision to park is, however, affected by the provision of transport infrastructure and its access to the parkers' final destinations Further, different parkers require different parking attributes. A first step in the model development was the determination of the *types of users* of parking facilities Wildermuth (1986) divided the users into:

- city car commuters with a (free) tenant parking space
- all other work trips
- home-based school trips
- other home-based trips for 'business' purposes (short stay)
- other home-based trips for non-business purposes (medium stay)
- non-home-based trips for 'business' purposes
- non-home-based trips for non-business purposes
- commercial vehicle trips

Each of these parking users has different parking durations, needs (e.g desire to park close to the destination) and willingness-to-pay It is, however, difficult to obtain behavioural data for each group and modelling of each group (at least initially) may result in too much complexity given the likely restrictions on available data A simple binary breakdown that encapsulates the basic differences between the user groups is:

(1) the parker with a provided space (*tenant* plus *business*), and

(2) the choice parker with no provided space (*long term* and *short term*)

In addition, through traffic in the central city must be accounted for Thus the travel demand data required by CENCIMM needs to be disaggregated into the three categories of through traffic, tenant parkers and search parkers As will be seen later, temporal variations in demand must also be included

CENCIMM handles different user groups by taking a set of (up to ten) origin-destination matrices in its input These matrices are separated in terms of parking type (basically through trips and tenant parkers - i.e. those with fixed vehicle destinations -

and search parkers - who must find a suitable space Within this general scheme so different trip types can be accommodated, e.g. trip purpose and parking duration.

Network model specification

The CENCIMM model belongs to the class of 'dense network' traffic assignment models A dense traffic network is one in which each link in the network represents a real road or street section, and which includes most of the streets in the study area Further properties of dense networks that distinguish dense network studies from conventional strategic network studies include:

(1) the basic unit of flow is the turning movement rather than the total link flow, for the dense network model must consider through, left and right turning traffic separately;

(2) trip generation can take place along the links of the network rather than at designated 'zone centroid' nodes This is particularly relevant to the modelling of on-street parking. The 'zonal destination' of a trip is then a broad target for the destination of the vehicle trip component of the journey. The actual destination of the vehicle occupants is some land use site within the zone, while the precise destination of the vehicle trip is an available parking place. The driver may need to undertake a search process in and around the destination zone to find that precise destination. The inclusion of on-street and off-street parking places within the network description is ostensibly of great importance in a realistic parking system model, and

(3) the development and dissipation of levels of congestion within the network, over the hours of the day, is important in dense network modelling. For example, different traffic management strategies (e.g. turn bans, parking prohibitions and limits) may be imposed at different times of the day, thus altering the ways that a network can be used.

In the particular case of CENCIMM, there is a further complicating factor on the level of detail required in the model output As CENCIMM models the search process for parking spaces, it must know the composition of its flows (stored as elemental units, i.e. turning movement flows) in terms of through traffic, tenant parker traffic, and search parker traffic. Then it can be used to predict the amount of central city vehicular travel (e.g. vehicle-hours of travel) that is consumed by the parking search process. CENCIMM also needs to record car park occupancy levels, by time of day.

CENCIMM model operation

Models can be run in either *steady state* or *transient* modes (Young, Taylor and Gipps 1989). Most transport network models seek to find a steady state (e.g. an 'equilibrium' condition). For a parking system, however, this may not be an appropriate strategy. Parking occurs over most, if not all, hours of the day, and the demands for and use of parking facilities vary widely with time of day The model should therefore be run in dynamic mode over a specified period of the day (e.g. 7:00 am - 7:00 pm). This enables the build up of parking to take place and to be studied, and allows the variations in parking accumulation to be determined as well as investigation of the interaction between short and long term parking

To allow the development of the model, information on the arrival and parking duration characteristics for the entire day is required. For Melbourne, this information has recently been extracted from the 1978/79 Home Interview Survey database (Young and Thompson, 1989). Data obtained from the 1986 Perth metropolitan travel survey (WADoT 1986) can provide similar information for Perth.

CENCIMM works at the dense network level, and thus needs to collect travel demand information from an urban-wide model (e.g. SPECTRUM). It can also work independently of other models, given sufficient information about the subset of metropolitan trips that will use the CBD network, to investigate the level of parking along streets, the use of parking lots or the use of park-and-ride systems. This level of detail is best modelled using a time-update macroscopic simulation model, where the time updates are relatively small (e.g. of the order of 15 minutes when the total study period is of several hours duration). This aggregation provides the level of detail required while still enabling realistic computer run times. Users have different parking durations, needs (e.g. desire to park close to the destination) and willingness-to-pay. The user demand interacts with the parking supply which is constantly changing, and the reconciliation of the changes in supply and demand is a key element of the model. The investigation of this interaction required a dynamic search procedure, by which groups of vehicles (packets) move through the system looking for the most appropriate parking place. If appropriate parking places are available at the best location the parker is likely to park. If a parking place is not available or the parker chooses not to park, the driver will continue the search. The decision to park is probabilistic because of the stochastic nature of choice.

The method used to simulate parking choice in CENCIMM is the 'QP - Quick Parking' procedure described by Taylor (1991). This procedure provides a reasonable simulation of traveller behaviour in a computationally efficient framework, a necessity for the intensive computations required in execution of the CENCIMM model.

Transient (terminating) models

An important finding from previous research on parking systems and parking behaviour is that the systems are in a continuous state of change. There is no equilibrium condition (Young 1985). Thus a parking model should not search for an equilibrium state, as no such state will exist within the time frame (the 24 hours of a day) of application of the model. This is quite different to much of conventional traffic network modelling. The CENCIMM model therefore considers the state of the parking system over several hours of a day. It starts by generating traffic early in the morning when there is little or no traffic on the network: if necessary, data can be input into the existing arrays to represent vehicles in the system at the start of modelling.

Variations in network conditions over time: First consideration in each time slice is for through traffic and public transport. This yields a set of base traffic flows on the network, on which parking traffic can be superimposed. The groups (or 'packets') of search-parker vehicles arriving at the outskirts of the network are generated, for each time slice, from the search parker O-D matrix and the proportion of that travel generated in the time slice.

Travel time on the network is a function of the link and junction types and the traffic flows in a particular time slice. The travel time on a vehicle link is determined using the volume-capacity relationships developed for MULATM. Bus travel along links acts as a kerbside impedance affecting the volume-capacity relationship. The delay at intersections is determined using the junction approach leg capacity and delay functions from MULATM. The impact of parking on travel times must also be included. Travel time in parking lots is related to the level of utilisation of the lots: the higher the utilisation, the longer the search time. The travel time on the pedestrian links is a direct function of the walking speed and the distance travelled.

The modelled parking and vehicle movements replicate the individual trip patterns discussed above.

Traffic routing: Through vehicles are assigned to the appropriate path to their destinations, using the equilibrium assignment method. The location and composition of each packet of choice parkers at the end of a time slice is monitored. If the packet has broken up in any way new packets are generated to represent each unique group of vehicles from the original packet (e.g. where some vehicles in the packet can park, but others cannot).

The route choice of the tenant parkers is considered in similar fashion to the through traffic. The final destination for the route choice of the tenant parkers is the parking destination. If the tenant parkers park during the time slice, the model estimates their departure times from the parking station, by convoluting the arrival time and duration of parking. The division of parkers into tenant and choice parkers cannot be carried out easily from the existing data, and appropriate assumptions had to be made in the development of CENCIMM.

Parking search process

Choice parkers consider all possible routes to their final destinations (a land use site). The modelled route is determined on a minimum disutility criterion and the vehicles travel the relevant distance over the duration of each time slice. The travel times are weighted in the determination of the disutility of each total trip. The initial weightings are 1.0 for vehicle travel time and public transport access travel time, 1.5 for search time and 2.5 for pedestrian walk time and public transport waiting time. These weightings are being refined as more information on parker preference becomes available (Young, Thompson and Taylor, 1991). Total disutility is recorded in terms of money units, so that parking charges and public transport fares may also be included, as these are obviously important questions for transport policy formulation.

When the vehicle is within an acceptable access time from the final destination, the packet of vehicles starts to search for parking places. If appropriate spaces are available the vehicles park and departure times are calculated. Any vehicles from the packet that cannot park form another packet and select one of three alternatives:

(1) wait for a few minutes in case a space is vacated. If no spaces become available within a set time the parker moves off. The acceptable waiting time can be changed by the user;

(2) accept a space that has a shorter time limit. If this occurs the extent of parking meter feeding is assessed and output to provide the analyst with an indication of the inappropriate use of short term parking space, or

(3) move to the next destination.

Different trip types may be introduced (through CENCIMM's multiple O-D matrix input facility) to allow for trip type, parking duration and level of prior knowledge.

A probabilistic model determines which choice is taken. For those vehicles that move to the next parking place any appropriate parking places passed on route to the next destination can be selected. This process of determining an optimal parking place and searching for a parking place while moving towards it is continued until all vehicles in the group are parked. If some vehicles do not find a parking space within some predetermined time (say 25 minutes) they move back to their point of entry. They continue to look for a parking place but leave if no place is found before they reach the start origin. The proportion of vehicles not finding a parking location is monitored.

Individual perceptions of the parking system by choice parkers are considered by sampling random variations about the mean utility for each parking lot.

Residential and illegal parking are not seen as problems of great concern in Perth and are not modelled explicitly. Similarly, parking information systems have not been used greatly in Perth. Thus CENCIMM does not explicitly include these systems at present. The modular structure of the CENCIMM program code will allow such factors to be incorporated at a later date.

The departure time of all parked vehicles in the system is also considered by the executive routine. If any vehicles leave during the time slice, they are routed towards the appropriate destination (the original point of entry), using the equilibrium assignment method.

Data needs

The data needed as input to CENCIMM may be divided into two main groups: network inventory information, covering the layout of the road system and the locations of parking lots, and traffic demand data defining the travel patterns in space and time of through traffic, tenant parkers and search parkers. These items must be specified by the user. Information on the distribution of parking durations is also required, and this has been built into the model for the present time, given the limited availability of such data (Young and Thompson, 1989).

Network specification

The transport network used by CENCIMM consists of traffic links, traffic nodes (intersections) and parking locations. The links allow for vehicle movements. Parking may or may not be provided on each link, and the allowable durations may also vary between links. The intersection presents the opportunity to move from one link to another, via the permissible turning movements at each intersection. The nodes (intersections) include options for signalised and unsignalised control. The prices, capacities and speeds of the system are incorporated. Off-street parking facilities is also represented in the network. The CENCIMM traffic network database is compatibility with that developed for MULATM and PARKSIM.

The parking system is represented by capacity, prices, maximum parking time and parking lot capacity/search time relationships. Off-street parking lots are connected to the network using the same node-link structure as for the road sections, except that CENCIMM can recognise the links representing the parking lot as off-street facilities. On-street parking is provided along the links representing those streets.

The pedestrian system is represented by links and impedance measures. Pedestrian walking distances (e.g. for access trips from lots to destinations) are measured as grid (or 'Manhattan') distances. The impedance measures enable the volume of pedestrians and the interaction with the transport system to be studied.

The public transport system in the existing version of CENCIMM is limited to on-street bus operations, with routes along specified roads, although a future development will be the inclusion of public transport in separate rights-of-way (e.g. light rail transit).

The MULATM software package provided an existing traffic network database 'shell' that already includes most of these elements, with extensive data input, editing and display facilities for physical network inventory and traffic demand data. It was used as a base for the development of CENCIMM. The connections between MULATM and CENCIMM were described by Taylor (1990).

Parking lot specification

The following information is required about each parking station in the study area network:

- its location in the network, and the type of parking provided (on-street or off-street);
- the number of parking stalls available;
- the time limit (if any) applying to the station;
- the cost ($/h) of parking in the station, and
- any time of day limits on parking (e.g. 'clearway' restrictions that might apply to on-street parking).

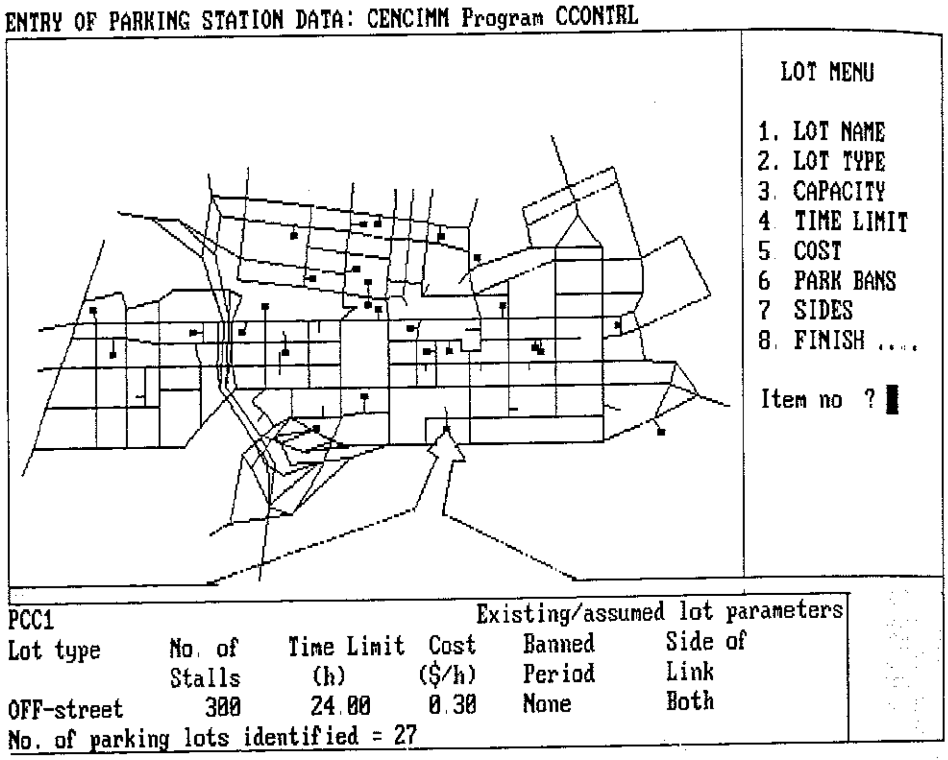


Figure 1 CENCIMM graphics display of parking facilities, highlighting one parking lot

CENCIMM holds this parking inventory in a customised relational database, in conjunction with the network inventory, traffic flows and travel demand databases. The package can then use its extensive graphical display capabilities to highlight selected elements of the total database. Figure 1 is a CENCIMM graphics screen displaying the data held for a selected parking lot in the Perth CBD. The total traffic-parking systems database provided by CENCIMM is a most powerful advisory tool for the transport planner. Thus the package has a useful role as an information source, besides its unique modelling capabilities. Chambers (1990) and Lister and Ratcliffe (1990) discussed the importance and application of databases systems for planning and managing central city parking systems.

Vehicular traffic

The demand information required by CENCIMM consists of origin-destination matrices by time of day and trip type (through, tenant, searcher). The origins are the entry points into the study area provided by SPECTRUM. The ultimate destinations vary depending on trip type, as given in Table 1.

Table 1 Destinations of CENCIMM trips by trip type

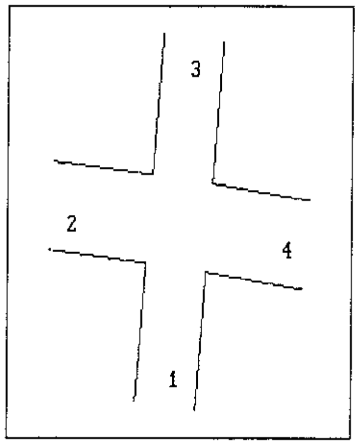
Trip type	Destination
Through vehicle	boundary link
Tenant parker	parking location
Search parker	final land use site

The demand information must also be specified by time of day. The scheme adopted for the present version of CENCIMM is to provide an overall O-D table for each trip type, and then nominate the proportions of those trips that will arise in each of the time slices representing the time period for analysis. This was deemed necessary as more specific data about travel demand patterns by time of day are not commonly available. Reverse direction trips are made from the parking areas to the initial origins, starting at times set by the parking duration curves. CENCIMM determines these reverse trip movements and their timing internally, the user does not have to specify them.

An additional feature of CENCIMM is that the specified travel demand can be superimposed on other traffic flows. For example, if present day flow volumes are known, then the effect of a new parking station could be assessed by estimating the additional traffic demand to be generated or attracted by that station, and superimposing it on the existing flow.

Outputs

The outputs of any model must be related to the needs of its users (Young, Taylor and Gipps 1989). CENCIMM needs to be sensitive to the impacts of parking provision on he operation of the traffic system in the central city, and to be capable of estimating the impacts of central city parking on metropolitan travel demand. It can provide base information that will provide a network-wide perspective and allow analysts to make higher-quality decisions.



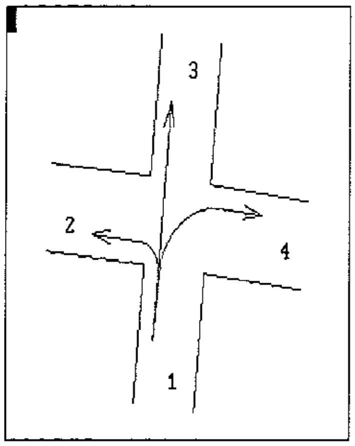
CENCIMM Prog CCTMFLOW: JUNCTION FLOWS

1 FITZGERALD STREET
2 NEWCASTLE STREET
3 FITZGERALD STREET
4 NEWCASTLE STREET

		LEG OUT				
		1	2	3	4	TOTAL
LEG IN	1	0	36	221	28	285
	2	211	0	146	680	1037
	3	614	82	0	133	829
	4	37	307	81	0	425
TOTAL		862	425	448	841	2576

FLOWS DISPLAY OPTIONS
1 all flows leaving a leg
2 all flows entering a leg
3 single flow
4 select flow type
5 select new time interval
6 try another node   Option

* = missing data
OBSERVED traffic flows at node 303
Time interval 08:00-09:00



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Press any key to continue

Figure 2 CENCIMM holds traffic flow data at the basic level: the turning movement

Further, the model output must permit the user to synthesise the performance of the system at the required level of detail. The use of 'exploratory data analysis' techniques to provide a view of the overall performance of the system and the highlighting of link performance indicators for the network provide the analyst with useful information for making quality decisions.

The initial set of criteria to be considered in assessing the performance of the combined traffic and parking system are:

- utilisation of the parking system and its component parking stations;
- total time taken to find parking places;
- proportion of drivers who do not find a parking place;
- total vehicle travel demand on the study area road network;
- pedestrian, vehicle and public transport flow patterns as related to parking;
- traffic volume/capacity ratios on links, and degree of saturation at intersections;
- mean walking distance for parkers;
- parking vehicle search times, and
- parking revenue.

Many of these performance measures can be presented in a graphical form using interactive computer graphics, to help analysts in assessing the impacts of different parking strategies. Some of the types of output incorporated in CENCIMM are:

- pedestrian, vehicle and public transport flow patterns for parkers;
- turning movement flows at intersections (Figure 2);
- link-based traffic parameters such as volume/capacity ratios, congestion coefficients and delay times;
- network-based traffic parameters such as vehicle-km of travel, vehicle-hours of travel and vehicle-hours of delay, categorised by trip type (through traffic, tenant parker, search parker);
- mean walking distance for parkers;
- utilisation of parking system by time of day (Figure 3), and
- parking revenue.

Application

In 1987 the Perth CBD had 41 169 car parking spaces, of which 33 077 were long term bays (see Table 2), servicing employment of around 83 000. For purposes of comparison Brisbane, with central area employment of about 61 000, had around 15 000 tenant and long term parking spaces. Long term bays constitute about 80 per cent of the total parking capacity in central Perth, and the number of such bays has been growing rapidly (e.g. there were 26 700 bays in 1977).

A limit of 40 000 long term (commuter) parking spaces was recommended by the Central Area Parking Policy Review (CATAC, 1986) as the maximum capacity that was compatible with the peak capacity of the road system. The rapid growth in the provision of long term parking means that this limit will be approached in the very near

Table 2 Car parking in Central Perth, 1987

Type of parking	Perth City Council	Private Operators	Total	Remarks
Tenant	0	21 729	21 729	33 077 long term
Public long term	8456	2892	11 348	
Public short term	2834	1545	4379	8092 short term
Kerbside	3713	0	3173	
Totals	15 003	26 166	41 169	

future, if current trends continue CENCIMM has an important role in the assessment of car parking policy, particularly parking allowances for new developments. The situation also needs to be addressed by strategies that integrate the planning of the Perth CBD with regional and metropolitan transport planning.

The following transport issues are important for the central area of Perth, and will find many common elements with the issues affecting other Australian cities, especially in the light of the debate on sustainable travel for our cities:

- the need to ensure that an adequate level of service is provided to the central area, especially in view of the problems associated with car access by increasing numbers of CBD workers;
- car parking policy and provision need to be consistent with overall objectives for the central city, including considerations of the supply of parking spaces, the distribution of the spaces between long term and short term parking, the split between public and private parking provision, parking on the periphery as opposed to the central area, and the use of pricing as a demand management tool
- there is a need to identify the appropriate means of providing accessibility and mobility within the central area This includes the provision of special transit services within the central area, the utilisation of existing radial transit services that pass through or terminate in the central area, and the provision of pedestrian facilities;
- achieving conditions of sustainable travel requires that limits be placed on levels of road traffic congestion (see, for example, AUSTROADS (1991)) The means to achieve such limitations include

    car pooling, as a means to increase car occupancy and hence increase the trip carrying capacity of the road system,

    peak spreading, as an attempt to increase the effective vehicle carrying capacity of the road system,

    road or *congestion pricing*, as a formal pricing mechanism for regulating road travel demand by location or time of day;

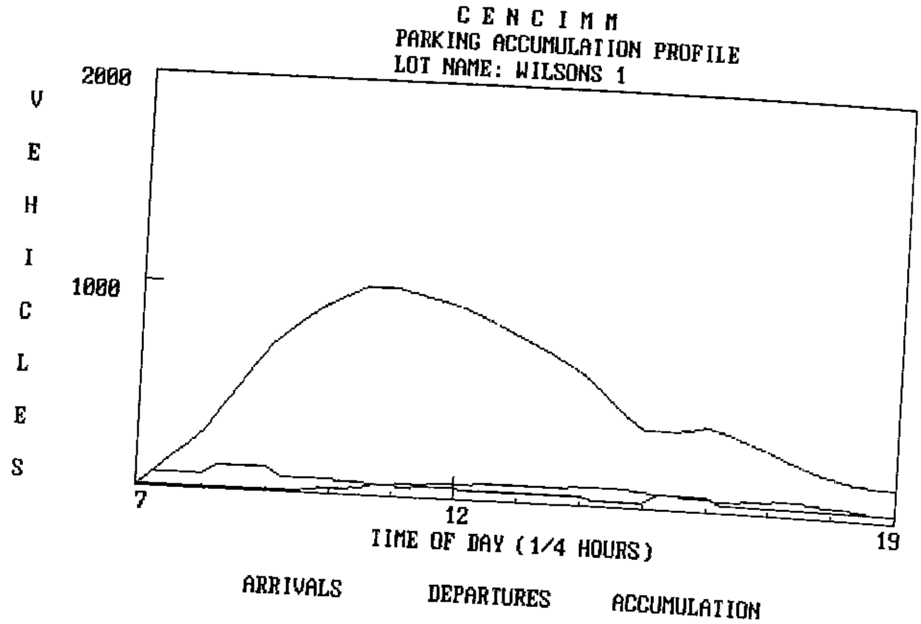

Figure 3 CENCIMM outputs include parking lot occupancies, by time of day

- assessment of the impacts of transport systems on the amenity and economic viability of the central area, noting that the impacts may be both *beneficial* (e g by promoting accessibility) and *detrimental* (through congestion, visual intrusion and air pollution), and
- monitoring and predicting the operation of the road traffic and parking systems, with emphasis on traffic management, impacts of through traffic, goods delivery, and access to commercial developments.

The development and application of CENCIMM is providing a powerful analytical tool for use in transport policy making and planning to address these issues The interplay between the central area and the metropolitan area is a vital consideration.

Further model developments

The CENCIMM model is the subject of intensive ongoing research and development, and a number of new developments are proposed for it. These include:

(a) a lifting off the present restriction that parkers must enter and leave the area through the same cordon node, perhaps through the use of a probabilistic model to take account of linked trips. The need for such a facility must be determined from linked trip travel behaviour as revealed in metropolitan travel demand databases (e.g. the 1986 Perth database);

(b) the implementation of a set of submodels of parking charges over time, as opposed to the simple hourly rate submodel in the prototype CENCIMM package, and

(c) output of performance measures that include fuel consumption and vehicle emissions indices (as in MULATM)

A further important consideration is for the systematic definition and specification of data needs, data types and data collection practices that will permit the assembly of the required travel demand data (e.g. origin-destination matrices by parker type, trip purpose and parking duration).

Conclusions

The development of CENCIMM provides an excellent example of the cooperation and collaboration that can occur between a research team and the users of the research. User specification of the requirements and capabilities of the model, and the knowledge of the particular city areas for application of the model, provide the researchers with the trajectory that the research and development work should follow to achieve the common goals of a powerful modelling tool that can assist directly in transport policy formulation and the assessment of transport and development plans. This is not to say that there are no difficulties arising in the development of CENCIMM, but the strong links between the researchers and the users means that these difficulties can be used constructively, to extend, refine and improve the developing model system

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