Forecasting parking demand from new developments in central Sydney

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Abstract:

The central business district of the City of Sydney is the major centre for government, tourism, international business, specialist retailing and cultural attractions in New South Wales. The City has been experiencing an unprecedented construction boom that has placed great pressure on the City planners in respect to maintaining their strict parking code. This paper describes research undertaken by the Department of Transport to develop a forecasting technique that will quantify the impact that additional off-street parking will have on the City's street system. The model developed is capable of responding to changes in the workforce, the supply of parking and the price of parking within the City.

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Introduction

The City of Sydney is the location of the first European settlement in Australia having been settled in 1788. The City is located on the shores of Port Jackson at the eastern extremity of the Sydney Metropolitan region. The City's Central Business District (CBD) forms an elongated rectangle with its main axis north/south, it is approximately 2.5 kms. long and less than 1 km. wide. The original street system of the City was oriented towards the port area and designed to cater for horse and carriage. Thus the street pattern in the northern sector of the City is narrow and circuitous making access by motor vehicle difficult.

The City has 38 per cent of Australia's tourist support jobs and 60 per cent of the head offices of the country's top 100 companies. The CBD of Sydney continues to be New South Wales' major centre for government, tourism, international business, specialist retailing and cultural attractions.

Over the last 7 years there has been an unprecedented construction boom in the City. This has resulted in the use of scarce road space for heavy vehicles, equipment and the delivery of construction materials.

In April, 1987 the City Council closed Pitt Street, between Market and King Street,to traffic to create a pedestrian mall. This had been a long term pedestrian planning project of the City Council and was part of the 1971 City Plan. The street closure introduced a major change to the traffic circulation patterns within the City. It also resulted in major delays to buses operating through the City, as one of the principal bus routes was closed to buses in the City.

The Pitt Street closure and increased construction activities have caused traffic congestion and severe delays to buses. Increasingly, government agencies have become concerned at the traffic implications of current and foreshadowed redevelopment projects in and adjacent to the CBD. In particular, there are inherent conflicts from a traffic management perspective between government sponsored projects and government's desire for improvement to the pedestrian environment of the city. This concern was heightened by the speculation that there could be a 50% increase in off-street parking within the CBD by 1992

When a new building project is evaluated in isolation it can be shown to add only marginally to the total level of traffic congestion in the City. However, a major issue arises when incremental increases reach a magnitude that cannot be addressed by local traffic management because of the aggregation of traffic from new developments. Unrestrained commercial office development, which has severely peaked travel patterns, may choke certain sectors of the City potentially sterilising future development opportunities. It is also inconceivable that the community would wish to see the City's development governed by an overly restrictive transport strategy. The need for a government-endorsed strategy within which development, operational and environmental objectives can be addressed is clear and pressing.

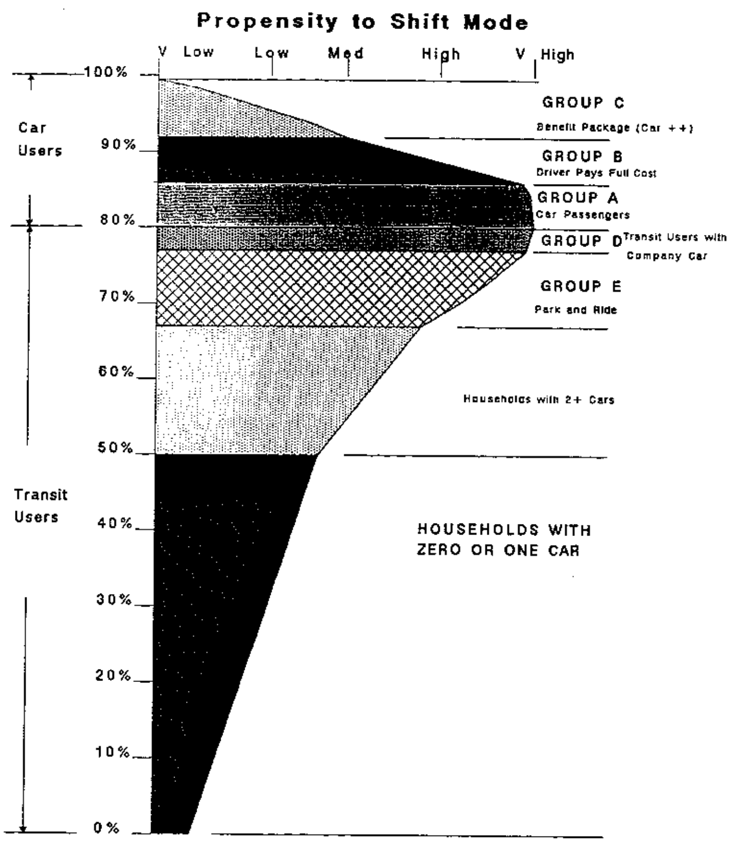
This paper describes the research undertaken to develop a forecasting technique that will assess the impact new developments will have on the City's public transport and street system. The main concern is the impact additional off-street parking will have on the street system.

Transport demand

On an average working day, while 60,000 commuters travel by car to the City centre, over 190,000 or 76% come by public transport. Most of the public transport travelers (140,000) come by train, while 44,000 travel by bus, another 9,000 come by ferry. Metropolitan Sydney has one of the highest car ownership levels in the world. Considering this, it is remarkable that Sydney has such a large proportion of commuters using public transport to travel to the CBD.

Planners have been debating for years the issue of modal split for work travel to the CBD. The argument is made that the City of Sydney has been able to develop at the intensity it has because of its high transit accessibility. The long-term planning objective should be to maintain the high transit usage. To understand work travel better it is necessary to analyse the profile of existing workers, and in particular the forces influencing peoples travel-mode choice.

The issues associated with modal split are illustrated in Figure 1. The CBD workers are divided into two classes, public transport users and car users.



MODAL SPLIT OF CBD WORKFORCE Figure 1.

Car users are categorised into three basic groups. Group A contains those workers who travel as passengers in a car to the City (around 6%). This group has the highest probability of shifting to public transport given they are dependent on another person providing transport.

Group B are those workers who receive no financial assistance towards their transport costs. They meet personally the full cost of parking and car usage. Further analysis reveals that women constitute 64% of this group, although women comprise only 30% of the car drivers coming to the City. The convenience and safety of car travel appears to be influencing the choice of mode for women in this group. However, this group could be sensitive to pricing policy, in particular raising the price of parking could shift some of this group onto public transport.

Group C was at the top end of the car-user spectrum. This group comprises workers who are supplied with a company car, a paid parking space, and have petrol and other costs met by their employer. This group is highly unlikely to shift from car travel to using public transport. These workers are generally business executives who decide the company's office location policy and to whom the car is part of their remuneration package. It should be noted that provision of car parking is not subject to fringe benefit tax.

Of transit users there is a small group, roughly 2% of workers, who are supplied with a company car but choose to use public transport to travel to the City. Some of this group are likely to be executives who leave their car at home for another driver to use during the day. This group has a high probability to shift mode given the availability of a company car.

The next group of public transport users, Group E, totaling about 10%, are those who drive their car to a rail station and leave it parked during the work day. These workers could potentially switch to using their car fully if parking availability and price in the City were acceptable.

The largest group of transit users, accounting for over 50% of CBD workers, originate from households owning zero or one car. In fact, analysis of the car-owning characteristics of all CBD worker shows that generally these workers come from households with much higher proportion of zero and one cars available than the Sydney average, while the CBD transit user is higher still. The decision to use a car to drive to work in the CBD is not a real choice for a large number of workers. In fact, it would appear that the economic decision to purchase a second car is averted by people who work in the CBD.

Given the already high transit usage, it would take a severe situation to significantly affect public transport patronage; however, it only takes a small shift from transit user to car user to create traffic congestion on the arterial roads accessing the City. A 2% shift from public transport could lead to a 5% increase in traffic flow into the City. The public transport system is therefore of paramount importance in moving people to and from the CBD for work.

Road traffic

Vehicular traffic flow in the CBD can be categorised into three basic functions; through traffic (about 45%), traffic going to or coming from the City (about 40%) and that traffic which has both an origin and destination within the City (about 15%). Much of the CBD traffic, especially during peak hours, is not going to the centre itself, but uses the street system as a corridor to get to other destinations. The proportional slip between the three traffic functions varies by time of day and location within the city. Between 9 A.M. and 12 noon the amount of through traffic declines slightly, with the internally generated traffic increasing in proportion.

For the 12 hours between 7 A.M. and 6 P.M. the inbound traffic crossing the CBD boundary grew by 8.4% in the 8 years 1979 to 1987, increasing from 208,000 to 226,000 vehicles. Car numbers grew only by 4.7%, but they still accounted for 72% of all the vehicles. The major growth categories were taxis, increasing by 26%, and commercial vehicles, which grew by more than 30%. The dominant route into the CBD remains the Sydney Harbour Bridge with over 100,000 southbound vehicle movements daily. The Harbour Bridge traffic grew only by 3% over the same eight year period. Significant growth was recorded on the other arterial routes leading into and around the CBD. There has been steady, but not outstanding growth in traffic within the CBD.

Kerbside parking demand and Supply

On-street parking accounts for the greater share (30%-40%) of traffic generation on the City's streets. The off-street parking stations, both public and private only account for 15-25% of the traffic. Kerbside activities are therefore responsible for a large amount of the traffic congestion on our city streets.

Within the CBD core there are over 8,500 kerbside spaces, with over 4,000 of these spaces being no stopping or no standing. The interesting feature that emerges from traffic surveys is that the no stopping/standing or no parking zones accounted for 40% of the traffic generation, loading zones produce 12% of the traffic, while resident and free parking only account for 27% of trips. Cars dominate on-street parking activities accounting for 55% of the traffic, with business activities being the overwhelming purpose for travel.

There is large scale violation of the on-street prohibition zones, this was revealed from parking surveys. While the durations of violation are short, involving average stays less than 10 minutes, they are so numerous that enforcement is very difficult requiring continuous monitoring to ensure apprehension. The large amount of on- street parking increases the level of traffic congestion caused by drivers cruising streets seeking a parking space.

Strategic planning issues

The 1971 City of Sydney Strategic Plan, and its subsequent reviews, has remained the major land use planning and development control framework for the CBD. When the 1971 Strategic Plan came into force, it was the principal planning document for the City, providing not only controls but also objectives; it covered building heights, preservation of historic buildings, protection of the pedestrian environment, traffic control and more.

However, for a variety of reasons these policies have not been consistently applied. Perhaps the best example of this relates to the provision of parking. The City Council has had a long standing policy severely limiting parking, particularly on-site parking, in the CBD. The parking policy has been overturned by both the City Council and State Government instrumentalities on many occasions, for example the Queen Victoria Building, Anthony Horderns Redevelopment, Grosvenor Place and Darling Harbour to name just a few. The preservation of the City's environment balanced against the desire for economic development is a principal aim of the City's planners. Assessing the traffic and environmental impact of new developments is of strategic importance in planning the City's growth.

Existing parking parameters

Off-street parking is available as both public and privately provided spaces. Since 1987 the number of public spaces in the core area has increased by about 5,500. However, there are proposals that a further 5,500 spaces will come on-stream in the near future. While the number of private spaces has increased by 1800 spaces since 1987, the forecasts see a further 1,000 becoming available, for further details on parking forecasts see the Central Sydney Planning Strategy report. To provide information on demand for parking, a comprehensive survey of the public and private spaces, covered over 70% of the available public spaces and formed the basis of behavioral analysis. Generally, the public spaces showed maximum "in- rates" during the morning peak 7 to 9 A.M., building up to 80% of maximum accumulations by 11 A.M. As would be expected, maximum "out-rates" occurred during the evening peak between 3.30 P.M. and 6 P.M. The off-street parking is dominated by "commuter" traffic, this is exemplified by the trip purpose where 47% of drivers were going to or from work, while a further 26% said they were on business.

The parking stations in the City can be divided into several functional groupings. The northern core and western periphery are work oriented; the activity profile is characterised by high 'in' rates during the A.M. peak, high 'out' rates during the evening peak and low 'in' and 'out' rates during off-peak periods. Maximum vehicle accumulations occur by 10 A.M. Of interest are those stations in the south western periphery, clustered around the Entertainment Centre, where the parking stations include a social/recreational specialisation and the activity pattern is characterised by very low 'in' and 'out' rates during the morning and evening peaks. These stations have a flat profile throughout the day; and most noticeably, an increasing 'in' rate after the evening peak period. Maximum accumulation is very low and utilisation during business hours never exceeds some 60% of available spaces.

The growth and forecast increase in car parking supply, contained in The Central Sydney Strategy Plan, has focussed attention on the impact this additional parking will have on traffic flows and public transport use. The subsequent analysis has therefore concentrated on identifying the current workers in the CBD who commute by car and the parameters influencing their modal choice. The majority of these workers require longstay parking, which can be satisfied by:

- onstreet (unrestricted) spaces;
- offstreet private spaces; or
- offstreet public spaces.

For each of the above parking categories, of major interest is the number of spaces available and the price of those spaces.

The number of spaces was obtained from the parking surveys undertaken as part of the Traffic Management Strategy Study in October, 1987. For off-street public car parks, an estimate was made of the number of casual, permanent (reserved and unreserved) and earlybird spaces, as this level of disaggregation was not recorded in the October, 1987 surveys.

The price of parking was obtained from data collected during surveys of the major off-street public car parks. Drivers who commuted to the CBD and parked their vehicles on-street were assumed not to have paid for their parking. Most of the long-stay onstreet spaces are classified as unrestricted.

The price of parking for drivers who parked off-street was based on the monthly price of permanent parking spaces as charged in different parts of the City, and are shown as price contours in figure 2. As some of the drivers could pay casual, early bird or discounted tenant parking rates, these contours are an approximation of the general parking rates.

Average cost of parking

Using data from surveys of CBD workers, collected as part of the Traffic Management Strategy project, it is possible to estimate the total cost of parking as a combination of:

- the price paid to park the vehicle; plus
- the perceived cost of walking from the parked vehicle to the building in which the driver is working.

The perceived cost was computed by assuming a walking speed of 4 km/h at a cost of $10/hr. The distance between the building and the parked vehicle was computed using the cartesian coordinates of both building and vehicle and doubling the distance to reflect the return walk journey. The calculations were aggregated by precinct to give an average cost of parking. These calculations are summarised in Table 1.

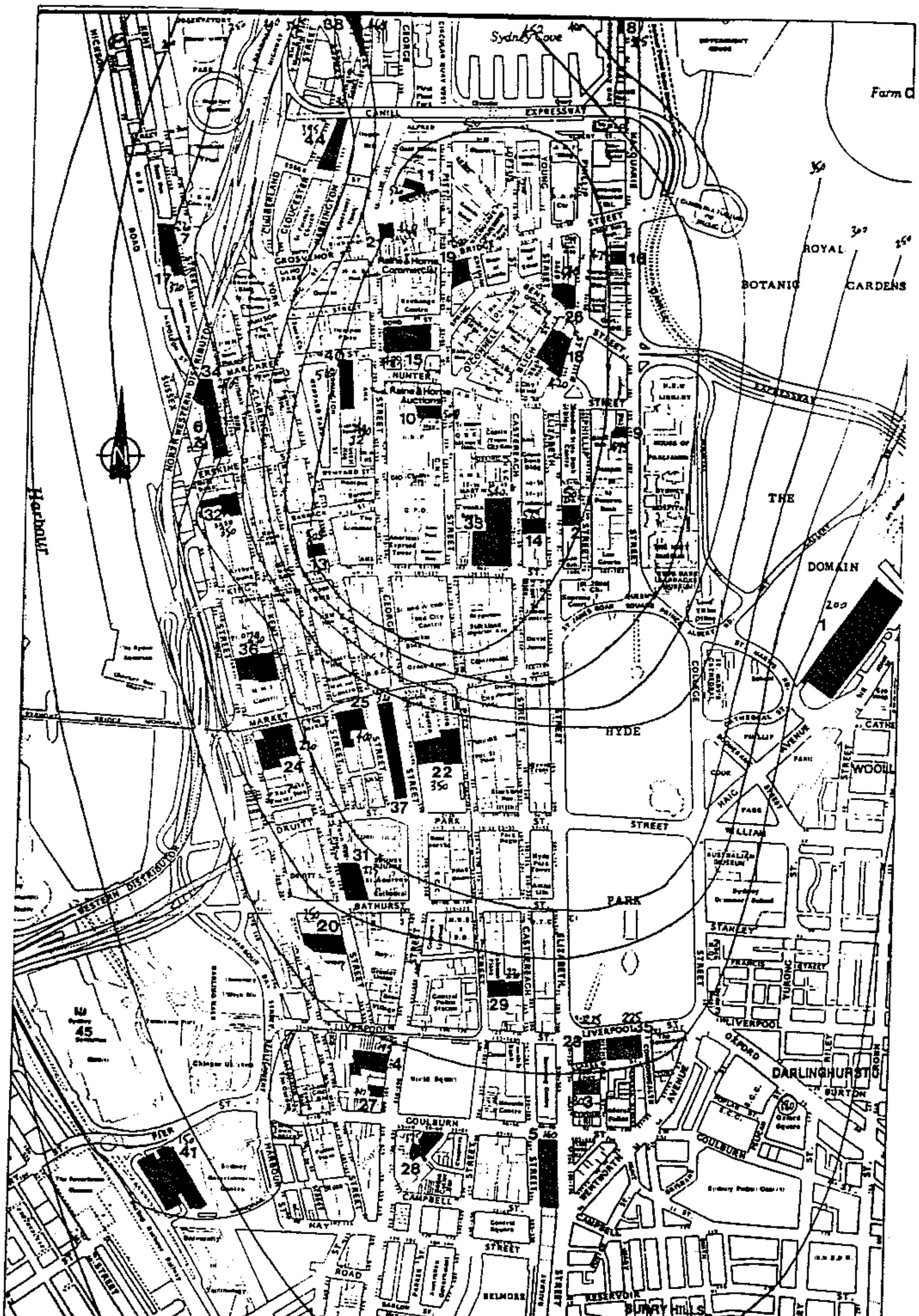


Figure 2: Parking price contours

Table 1: Average Cost of Parking by Precinct ($ per month)

Precinct	Offstreet			Onstreet			Total		
	Av. Park Cost	Av. Perc. Cost	Av. Tot. Cost	Av. Park Cost	Av. Perc. Cost	Av. Tot. Cost	Av. Park Cost	Av. Perc. Cost	Av. Tot. Cost
1	269	14	283	0	12	12	154	14	168
2	394	14	408	0	40	40	280	20	300
3	313	13	326	0	56	56	247	21	268
4	395	20	415	0	52	52	232	35	267
5									
6	261	14	275	0	31	31	215	17	232
7	234	11	244	0	30	30	190	14	204
8	183	6	189				183	6	189
9	188	14	202	0	25	25	150	18	168
Total	327	14	341	0	31	31	288	19	247

Identification of parking demand variables

Following an analysis of the variables recorded in the interview survey of CBD workers, the following dominant factors were drawn out:

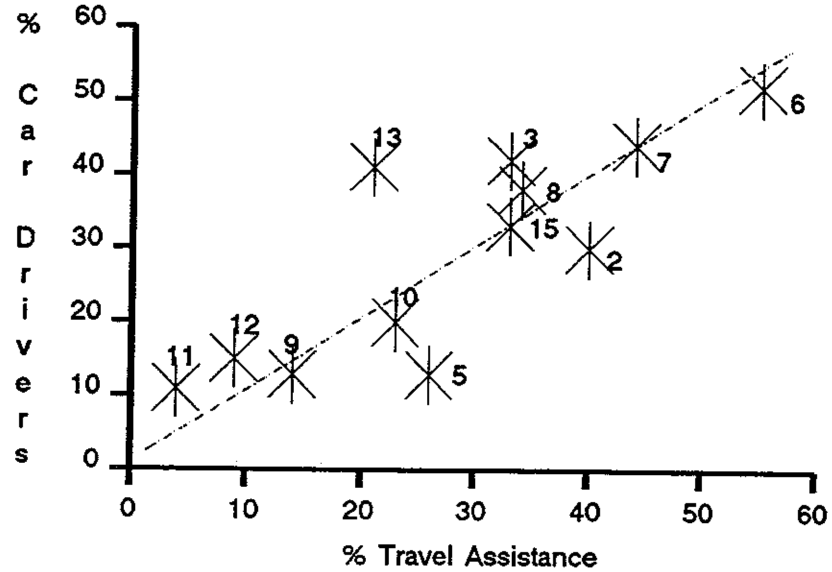
- High income earners comprised 64% of the car drivers, but only 32% of the employees surveyed.

- Of the high income earners the primary determinant of car driving was the industry group in which the person worked. The reason some industry groups had more car drivers than others appeared to relate to the level of travel assistance provided to the employee. The travel assistance could take several forms, including: parking on company premises, paid parking elsewhere, provision of a company car, payment of all car fixed costs, or payment of petrol and other variable costs.

- For the high income earners, the travel assistance varied also according to precinct within the CBD. It is suggested that this variation could be a function of average price of parking or different levels of transit accessibility.

The relationship between car drivers, industry grouping and level of travel assistance in depicted in Figure 3.

Figure 3: Car Driving/Travel Assistance High Income Earners



ASIC – INDUSTRY CLASSIFICATION
2 Mining 3 Manufacturing 5 Construction 6 Wholesale trade 7 Retail trade
8 Transport 9 Communications 10 Finance/Business Services 11 Public Sector
12 Community services 13 Recreation, personal services 15 Other

Development of a forecasting model

The objective was to develop a forecasting technique that could be applied to people who work in the CBD. The model should estimate both the number of vehicles driven to work, and consequently the modal split, and the location of parking within the CBD for these commuters. The model should be capable of responding to changes in the structure of the workforce, the supply of parking and the price of parking within the City.

The model developed consists of two separate parts, a vehicle demand model and a parking distribution model. The linkage between the two parts is shown in figure 4.

Vehicle demand model

The vehicle demand model is based on traffic zones, there being 139 zones in the CBD. The procedure is based on the relationships observed between car drivers and the parameters discussed above. The level of car driving to the CBD can be represented by a logistic function of the type:

Probability(car driver) = $e^u/(1+e^u)$

Where "u" is an indirect utility function defined as

$u = a+b*I+c*TA1+d*TA2+e*TA3+f*P1+g*P2+h*P3+i*P4+j*P5+k*P6+......n*P9$

The independent variables are:

I = income(1,2,3,4,5) - personal income before tax and superannuation
TA1 = travel assistance 1 (0,1) - parking paid by company
TA2 = travel assistance 2 (0,1) - assistance with car costs (petrol,etc.)
TA3 = travel assistance 3 (0,1) - assistance with public transport cost
P1 = precinct 1 (0,1) - buildings in precinct 1
"
P9 = precinct 9 (0,1) - buildings in precinct 9

The parameters that were estimated are a.......to n.

To simplify the industry classification and isolate the effect of price, the fifteen ASIC industry groups, shown in Figure 3, were aggregated into five broad industry categories. These were grouped to obtain a range from low to high levels of travel assistance. Travel data was analysed for each of the five industry groupings and the model calibrated for this data. Parameter estimates were made using a modified version of the TRRL binary logit program which uses a maximum likelihood procedure.

The parameter estimates were compared with the average driving cost described previously. An example of the relationship is shown in figure 5 which graphs the results combined for industry group 3. The combined group 3 consists of ASIC groups 2,8 and 15, these groups exhibit 30-39% levels of car drivers. The figure shows a strong linear relationship.

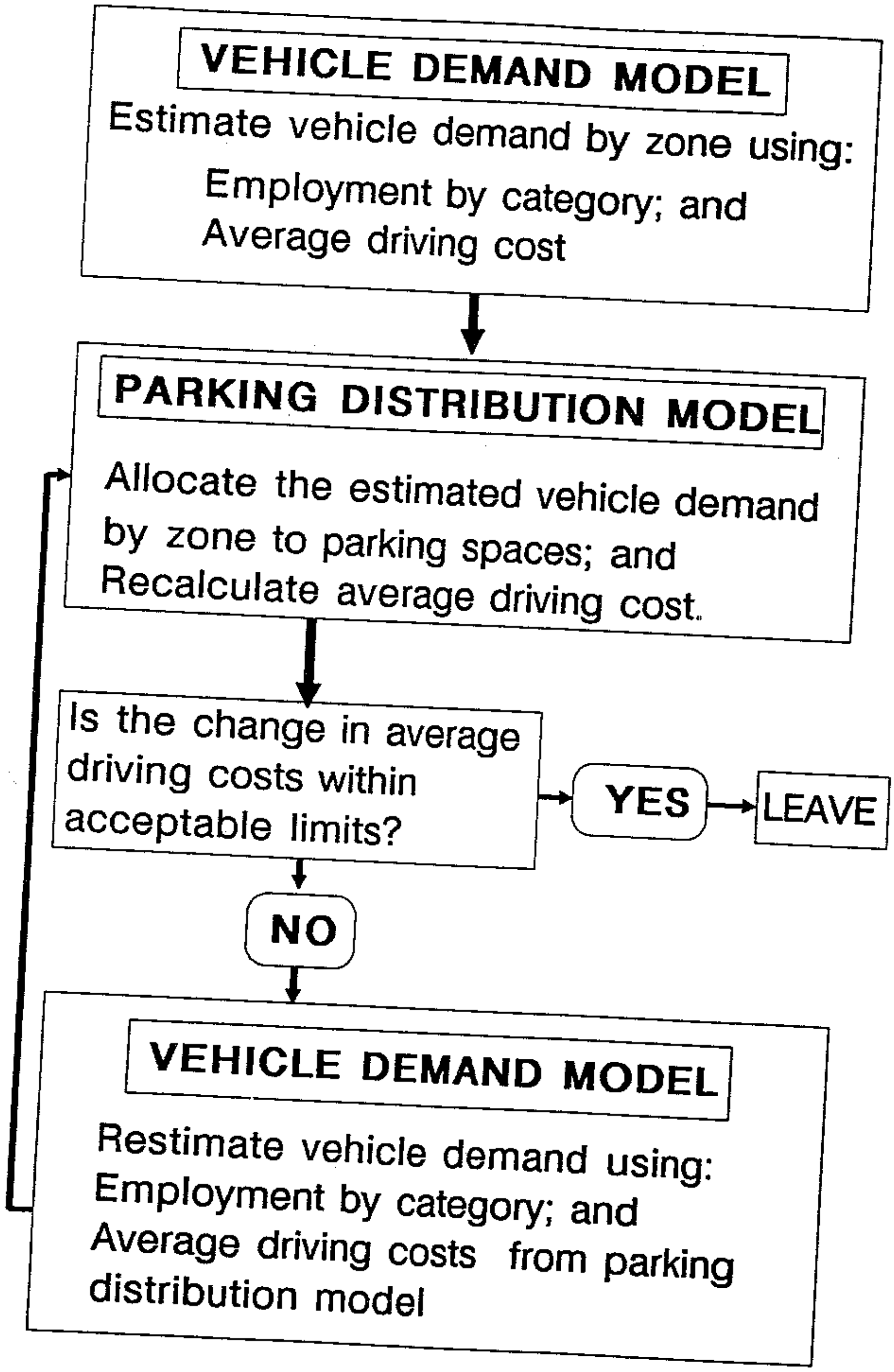


Figure 4: Parking demand model

There was a strong linear pattern for all the variables so the precinct location variables were replaced with a price variable as follows: a'+b'*avdrcost, where a' is the "y" intercept for each of the industry groups, and b' is the slope of the line of best fit for each of the industry groups.

The utility function that gives the best fit based on maximum likelihood estimation is:

u= -0.71+0.279*I+3.629*TA1+1.924*TA2-0.677*TA3-0.01*avdrcost

The constant term a' can be included with the parameter estimate "a".

The functional form highlights the importance of income (I) and travel assistance (TA1 followed by TA2) in determining car driving. Provision of public transport assistance (TA3) has a negative effect on car driving. The results demonstrate the critical element of transforming the locational variable into a price variable.

Parking distribution model

In arriving at variables to be incorporated into the distribution model, the criteria selected was that they are easily measured, can be forecasting and have a policy relationship. The model assumes that vehicle drivers will take three factors into account when deciding where to park their vehicles; the walk distance from the parking space, the price of the parking space and whether a parking space is available. The survey database was analysed for car drivers who had a workplace in precinct 2 to 4, the walk distance and price of parking were compared. Precincts 2 to 4 were chosen because they had a wide range of parking available at differing costs. A plot of the average results is shown in figure 6. A stated preference survey would have provided more reliable data to construct the "trade-off" function. Because of data constraints it was not possible to use stated preference techniques, and for convenience a linear function has been adopted. The "trade-off" function relating cost of parking to walk distance took the following form:

$$v_{ij} = -5d_{ij}-c_j$$

where, d_{ij} = walk distance in metres; and
c_{ij} = cost in cents per day

This function implies that all points on the frontier had equal utility, any point inside the frontier would be of greater utility, any point outside the frontier would be of insufficient utility and the parking destination not chosen. The model uses an all-or-nothing maximum utility computation that is recomputed for varying levels of parking demand. This process effectively results in a multiple path assignment for the total vehicle demand. The final step in the process is to recalculate the average driving costs for each precinct and compare them with the values obtained from the vehicle demand model. If the resulting values were within an allowable estimation the model has converged, otherwise the new values are returned to the model and the vehicle demand recomputed.

Figure 5: Variation in Precinct Parameters
Combined Industry Group 3

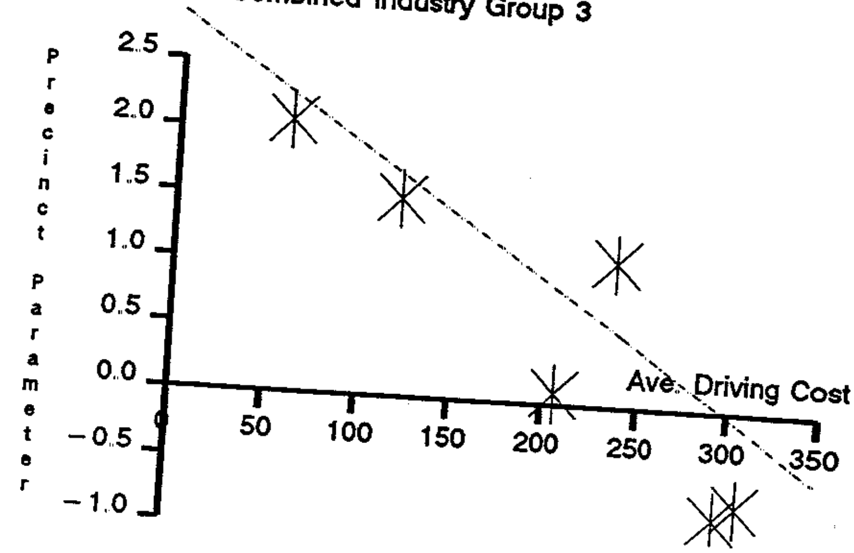
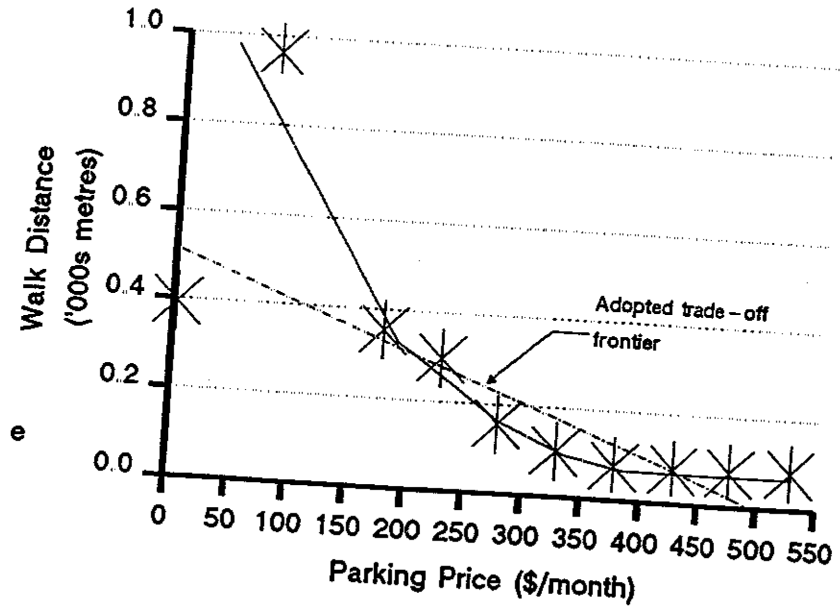


Figure 6: Parking Trade – off Curve



Application of the model to a development

The model has been applied to a hypothetical parking station having 600 commuter spaces, located in the CBD's mid-city precinct. The critical questions that need to be addressed relate to the impact these additional car parking spaces will have on traffic flow, parking prices and public transport usage.

The forecasting model described has been used to estimated the price effect, traffic redistribution and modal split impact. For the purpose of the analysis it has been assumed that 600 spaces will be allocated as permanent parking for commuters. The analysis has been based on existing employment levels and distribution, although the analysis could also be undertaken to reflect employment changes.

The impact of introducing the additional spaces into the CBD will be to alter the existing commuter parking habits, affect the price of parking charged at adjacent stations and potentially influence modal choice for a small group of workers. The model has been used in an attempt to quantify these impacts. To achieve this the model has to be used in an iterative process, where alternative price and demand estimates are evaluated.

For the initial model run a parking price, of $375 per month was assumed (this is higher than the average currently charged in the area). The model showed that no commuters would divert from their existing locations to use the new car park.

The second run involved reducing the monthly price to $325 per month. As can be seen in figure 7, the new Station attracted 390 parkers, these came entirely from other car parks in the area. The model recalculated the average cost of parking by precinct. The resultant precinct changes were negligible, indicating that no additional CBD demand would be generated at that price. We have assumed that the other parking operators do not respond with price reductions to attract back their lost customers.

The third run involved reducing the price to a level that will attract a full 600 parkers. As can be seen from figure 7, this price is about $300 per month. Again the average cost of parking by precinct was recalculated, but this time the reduction was significant and the recomputed costs were used to estimate new vehicle demand. This resulted in an increase of 74 vehicle drivers coming to the City; this would effectively be a modal shift. The assumption that the other parking operators do not reduce their price has been maintained. Because the new Station is operating at capacity the generated trips will be distributed to other City car parks.

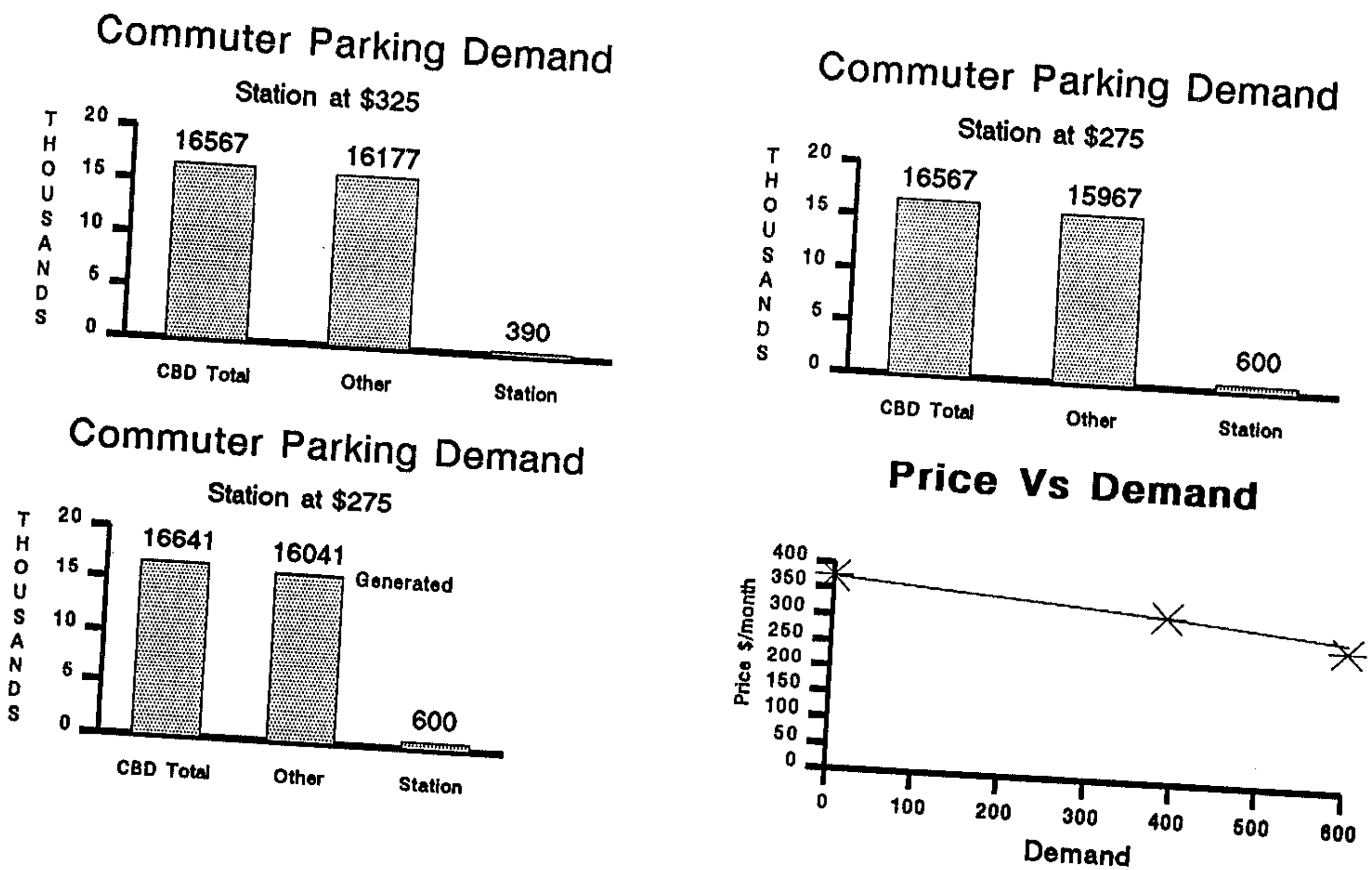

Commuter Parking Demand
Station at $325
THOUSANDS
20
15
10
5
0
16567
16177
390
CBD Total
Other
Station
Commuter Parking Demand
Station at $275
THOUSANDS
20
15
10
5
0
16567
15967
600
CBD Total
Other
Station
Commuter Parking Demand
Station at $275
THOUSANDS
20
15
10
5
0
16641
16041
Generated
600
CBD Total
Other
Station
Price Vs Demand
Price $/month
400
350
300
250
200
150
100
50
0
0
100
200
300
400
500
600
Demand

Figure 7

Conclusions

The objective was to develop a transport demand forecasting technique that could respond to changes in employment levels, workforce structure, parking supply and price of parking. The model described estimates the number of workers who would drive a car to the City on an average weekday. The research has shown a strong relationship between the level of travel assistance and the propensity to use a car, as well as the effect of parking price. It has also highlighted that some industry groups are more prone to provide transport benefit packages than others. The model was applied to a hypothetical City development and the impact on traffic redistribution, parking distribution and parking price were quantified; the parking price would have to be reduced by 20% on current prices to fill the Station. This technique provides an appropriate mechanism for evaluating the impact of new developments and global parking policy in the CBD.

Disclaimer

The work described in this paper forms part of the research programme of the Department of Transport. The opinions expressed are entirely the views of the authors and do not represent those of the Department of Transport or the Government of NSW. The authors would like to acknowledge the assistance of the staff of the Department of Transport in the preparation of the paper.