



Parking policy as a IDM measure in CBD areas

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Abstract:

Due to serious community concerns about the adverse environmental impact of urban transport, it is becoming increasingly important to define what might constitute a future "sustainable transport system". To achieve such a system, there is a need to define appropriate policy measures and to set "sustainable targets" for transport and environmental parameters which might then be monitored to identify progress in meeting these targets. One element of these policy measures is parking policy in Central Business Districts (CBDs)

If space is not restricted, the planning objective is to provide sufficient parking places for the full demand associated with a site. However, in central city areas where space is scarce, it is now generally accepted that parking supply should be restricted to a level somewhere below the total demand. However, no information was found in the literature on what might be an "optimal" level of parking supply in such constrained situations.

This study addresses the questions: is it possible to define a "sustainable target" level of parking supply in CBD areas, and if yes, what is that level. Parking provision and policies for selected Australian and overseas cities are compared to the performance of those cities in limiting the use of cars to access the CBD. From this, patterns in policy are found that indicate the degree of commitment by a city to reduce travel demand

A strong relationship exists between the ratio of long-stay parking spaces to full-time employees and the proportion of commuters travelling by car. From this study it appears that this relationship can be used to define a "sustainable target" level of long-stay parking supply for central city areas, once a mode split goal has been set. However, it must be recognised that this is just one element of the CBD parking policy, and further studies are recommended to investigate how a desirable level of short-stay parking supply can be defined.

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Introduction

Communities are increasingly concerned about the adverse environmental impacts of urban transport, such as air pollution, traffic accidents and travel delays due to congestion, mostly associated with a high level of private car use. In an attempt to turn around the continuously worsening trends in the state of the urban environment, it is becoming increasingly important to derive what might constitute a future "sustainable transport system". To achieve such a system, there is a need to define appropriate policy and management measures and to set "sustainable targets" for transport and environmental parameters which might then be monitored to identify progress in meeting these targets

Due to the traditional concentration of administrative, retail, business and entertainment functions in large metropolitan regions, Central Business Districts (CBDs) attract the highest levels of congestion and their associated environmental impacts. CBD areas therefore require special attention in determining appropriate policy options to alleviate congestion and its consequences. One element of these policy options is parking policy.

Parking is an unavoidable component of every vehicle trip. The availability of parking determines the accessibility of a site by private car. If land is not restricted, the usual objective of transport planning is to provide sufficient parking places for the predicted full demand associated with a site. There are well developed methods to estimate the required parking supply to satisfy demand. However, in central city areas where space is usually scarce, it is now generally accepted that not only is it impossible to satisfy the total parking demand but it is neither desirable to do so. A restrictive parking policy has long been recognised and used as a necessary and effective means of Travel Demand Management (TDM) to discourage private car trips into CBD areas.

A substantial amount of literature has dealt with issues related to parking policy in central city areas, and there is a general consensus among professionals as to the necessity of restricting parking availability to a level somewhere below the total demand. However, no information was found on what might be an 'optimal' level of parking supply in such constrained situations. Therefore, in this study we attempt to address the question: is it possible to define a "sustainable target" level of parking supply in CBD areas, and if the answer to this question is "yes", what is that level. The main focus of the study is the Sydney CBD, but the findings may be relevant for other Australian and overseas cities. The study includes a literature review on TDM measures and parking policies, a comparative analysis and evaluation of parking data and policies in selected Australian and overseas cities, a mathematical modelling of some fundamental relationships between parking and modal split parameters, and finally the formulation of conclusions and recommendations. The following sections of the paper provide a summary of the above components of the study based on Cuthbert (1997).

Literature review on parking policy as a TDM measure

Bartley (1995) discusses the results of a survey conducted in Europe on the acceptability of demand management measures by the community. It was found that the community strongly supported any action to improve public transport and moderately supported restricting driving, but was opposed to the implementation of IDM measures such as road pricing, restricting parking supply or increasing the cost of parking.

The implementation of electronic road pricing provides an opportunity to redress some of the more obvious elements of pricing distortion. However many Australian authors highlight the likely political resistance to any electronic road pricing scheme (for example Sanderson and Greenwood, 1991). The community are likely to regard road pricing as "another tax", and treat it accordingly. Cars from all states need to be electronically tagged to ensure an equitable charging system—something that requires national agreement on the need for such a system to be introduced.

Bly and Dasgupta (1995) modelled the impacts of five different travel demand measures on five United Kingdom cities. These measures were based on adjusting public transport fares, fuel costs, parking supply and charges, and a cordon charge. It was found that cordon charges are consistently the most effective in reducing total travel distance, and reducing parking supply has the second highest impact on average. Increasing fuel costs also has a significant effect, while the effect of parking charges varies considerably, and the reduction of public transportation prices has the least reduction in total distance travelled.

Verhoef, Nijkamp and Rietveld (1995) discuss how parking regulation compares to road pricing as a demand management tool. The fundamental advantage that parking policies have over road pricing is that in many city centres restrictive parking policies already exist, reducing the political impacts of implementation. On the other hand parking policy affects only trips having a destination in the area while road pricing affects both local and through trips.

Morrall and Bolger (1996) highlight the role that CBD parking has on transit use in North American Cities. The authors used parking availability data from selected Canadian and United States cities and compared it to the public transport mode split achieved by each city. They found a strong negative exponential relationship between public transport use and parking availability for Canadian cities, and a weaker relationship when United States were included within the sample.

Ulberg (1991) states that 90% of United States employees that drive to work receive employer-subsidised parking. He estimates that this costs employers in the order of \$US45 billion. Willson and Shoup (1990) and Shoup and Willson (1992) examine how user behaviour is altered by parking subsidies by employers. They indicate that one of the major factors hindering car pooling is that the majority of drivers do not pay for parking.

An issue running parallel to this is the use of company-owned cars for commuting trips. Luk and Richardson (1997) discuss the issue of company cars and how they relate to the implementation of TDM measures. About 41% of all company-owned cars are used by executives as part of their remuneration package. Usually the direct cost of running these cars is covered by the employer. In a Victorian survey, 18 per cent of all car trips were made in a company-owned car, of which 9 per cent related to executive travel.

Luk and Richardson (1997) highlight that policies designed to modify user behaviour through price disincentives are unlikely to have a significant impact on the company car user. This is because the driver receives the benefit of the service without personally paying the cost. The company owning the car is likely to have a high tolerance for price claims, considering these to be part of the employee's remuneration. The authors consider that the measure most likely to affect the behaviour of the user would be restrictions on the supply of parking. The role of parking subsidies and company cars cannot be ignored when developing a parking policy. This is particularly important when considering a Central Business District such as Sydney, which has a large executive work force, and hence is likely to have a large proportion of subsidised parking and company car users.

The major negative impacts of a constrained parking policy are similar to that of road pricing. Significant equity issues are raised as lower-income users will have their mode choice restricted to public transport access (or no access at all). However in the case of the Sydney CBD, the impacts of this are relatively minor due to the high accessibility of the CBD by public transport during daylight hours.

Ampt (1993) reports that parking problems in the inner suburbs of Melbourne are attributed to the higher charges and reduced parking availability within the Melbourne CBD. These commuters drive to the inner suburbs (where these charges do not exist) and catch public transport – trams and/or buses – to their final destination. Fringe parking also is likely to represent a problem in the area surrounding Central Sydney, although parking provision has been liberal on the fringe since the implementation of the 1971 Parking Control Code (Urban Systems Corporation, 1971). This is mainly due to the fact that the Darling Harbour Authority has planning control over its area and exercises its parking policy inconsistent with that of Sydney City Council.

A significant concern associated with restricting parking in the CBD is the potential loss of business and reduced development due to reduced accessibility by motor vehicles. Meyer, Asce and McShane (1983) discuss the economic impact of parking policies on CBD development. The traditional goal of parking policies has been to provide sufficient spaces off-street to cater for parking demand. This has been developed on the premise of a primary goal of economic development. However, as a CBD develops, other goals become important. Sydney now considers a goal of the CBD's environmental quality to be an important factor in parking policy. Meyer *et al.* (1983) consider that once a CBD has reached an undefined "threshold value" of activity density, the attractiveness of the centre becomes independent of the availability of commuter parking. This probably is related to

higher activity centres having reasonably convenient "alternative" access modes such as public transport.

McGlynn, Newman and Kenworthy (1991) claim that in many cases the over-provision of parking can have significant detrimental effects, such as increased motor vehicle dependency, energy use, pollution and congestion, and a non-productive use of valuable urban land. Essentially, over-provision leads to a deterioration in the urban environment. However, just what is meant by 'over-provision' is not clearly defined.

Parking policy in the Sydney CBD

The existing parking policies can be traced back to the 1971 City of Sydney Parking Control Code (Urban Systems Corporation, 1971). The 1971 policy was developed with the objective of ensuring that the supply of parking within the CBD did not generate traffic to a level that exceeded road capacity within the CBD. The 1971 code encouraged the development of fringe parking stations, and expected commuters to use public transport to travel between the parking station and the workplace.

The current off-street policy was enacted in 1996 in the Central Sydney Local Environmental Plan (Sydney City Council 1996b) and Development Control Plan (Sydney City Council 1996c), and a new off-street parking policy is under development by Council. The current policies relating to parking have evolved from the initial need to constrain traffic so that road capacity was not exceeded. Traffic constraint is now also viewed from the perspective of minimising the environmental impacts associated with accessing the Central Business District. Policies are designed to discourage commuter trips by car. The council has a target morning peak modal split of 80 % access by public transport, representing a net shift of 5 % towards that mode from the current 75 % (Sydney City Council, 1995). Council also seeks to maintain or improve private car accessibility for short-stay uses such as shopping, deliveries and business-related visits. This is in recognition of the greater inconvenience associated with many short-term uses such as the transporting of goods, and the higher time penalties associated with using public transport in off-peak periods. This greater need is particularly evident when comparing the travel times to the time of stay. Continuing support for short-stay parking also recognises the economic contribution of those visiting and doing business in the city. Their business could in some cases relatively easily be transferred to a suburban location which would result in economic decline of the CBD. The strength of the CBD is vital in supporting a viable public transport system, not only for the CBD but for the whole Sydney region.

As the "owner" of kerbside parking areas, Council can directly control the availability and cost of this parking area. Consequently the use of kerbside parking space has received significant attention. During business hours approximately 4,000 spaces are available for on-street parking (Sydney City Council, 1996a). Using kerb space for parking (for other than loading/unloading) represents a low priority use, and in particular, long-stay commuter

parking receives the lowest priority. This policy decision is reflected in the allocation of kerbside use. Unrestricted parking within the CBD proper does not exist any more.

Sydney City Council owns two parking stations within the CBD, with one now under private management. The majority of off-street parking spaces in the CBD are privately owned. Off-street spaces are provided as car parks open to the public (14,000 spaces) or as tenant car parks (17,000 spaces), providing a total of approximately 31,000 spaces (Sydney City Council, 1996a). These figures do not include parking in the Darling Harbour Authority area. *Accessible City* (Sydney City Council, 1995), using a more restrictive definition of the Central Sydney area, estimates the total CBD parking provision at 25,000 spaces.

Private ownership naturally restricts the Council's power to regulate parking station activities to implement policy. Council's primary policy tool is enacted at the Development Application (DA) stage of a new parking project. Parking requirements are outlined in the Central Sydney Local Environmental Plan (LEP) (Sydney City Council, 1996b) and its associated Development Control Plan (DCP) (Sydney City Council, 1996c).

Council now incorporates the major components of its parking policy within the Local Environmental Plan (Sydney City Council, 1996b). This means that certain parking conditions must be met within the application for consent to be granted and is therefore much stronger than "normal" parking codes and DCPs. Unlike the majority of parking control documents in Australia, the LEP prescribes maximum rather than minimum requirements for new development. This reflects the fact that parking policy is being used as a tool for traffic restraint (ie a supply focus) rather than ensuring that potential parking requirements are catered for on site (a demand focus, for example in the RTA's *Metropolitan Parking Policy*, RTA 1988, or *Guide to Traffic Generating Developments*, RTA 1993).

Public car parks are still controlled by the Development Control Plan (Sydney City Council, 1996c). The policy is designed to encourage short stay users through the use of operational and pricing restrictions. New public car parks are not approved except under very exceptional circumstances such as car parks converting long stay tenant parking to public parking or replacing existing parking with a better or more strategically placed facility. Car parks approved under this DCP are not permitted to accept cars between 5.30 am and 9.30 am weekdays, and a higher hourly price rate is applied to the sixth and subsequent hours in order to discourage long stay parking. This policy has been implemented at Goulburn Street Parking Station, which is owned by Sydney City Council.

The New South Wales State Government applies an annual levy of \$400 per parking space within the Sydney CBD. The objectives of this levy are to provide funding for public transport access infrastructure such as car parks at railway stations and to encourage tenants to convert their long-stay parking spaces to other uses such as short-term spaces. The current charges are extremely small when compared to commercial rates. The charge

represents a cost of approximately \$1.10 per day, when an early-bird user would raise fifteen to twenty dollars for the operator each day. Although the charge is passed on 'up-front' to monthly lessees, it is likely that any possible reduction in parking demand would have been counteracted by the existing under-supply of parking through the implementation of other policies. Also, it is questionable if such a policy would be effective in deterring those receiving parking subsidies or company-owned cars. It is likely that as parking becomes more constrained, the proportion of subsidised parkers increases, and the proportion of paying parkers decreases. Continually targeting a diminishing proportion of parkers will result in very high charges that penalise what may be an occasional long-stay user

If a parking station operator is not complying with the conditions of development consent, Council can take the operator to the Land and Environment Court. This can be a reasonably expensive process with court, legal and evidence collection costs. The collection of evidence can be difficult due to parking stations concealing their non-complying operations. Sydney City Council officers have discovered parking stations operating during the curfew hours even though their advertising indicated that the car park opened after the curfew. In another case, Council learned that a vehicle parked all day (such as in an "Earlybird" scheme) was charged less than half of the advertised rates, even though a condition of approval was to implement the Council's pricing structure.

Comparison of parking policies

In this section we examine how differences in parking policy and implementation has led to differences in travel patterns to Central Business Districts. By analysing how effectively policies impact on transportation performance, conclusions can be drawn as to which policy characteristics successfully reduce car use

Information was collected through questionnaire surveys, literature search and personal interviews (for the Sydney CBD). To assess the effectiveness of a parking policy on travel demand, the written policy needs to be compared with numerical data that measures the degree of implementation and the effectiveness of the measures. It was decided to concentrate on work trips because they provide a good opportunity to reduce travel demand due to the following reasons:

- Commuters represent approximately one quarter of all trips made (US data from Orski, 1991);
- The commuter usually has a consistent origin, destination and departure time throughout the working week. This means that their potential knowledge of alternative public transport services and car pooling opportunities are likely to be higher than that of other groups;

- The long stay of the commuter at their workplace means that any travel time penalties associated with using public transport modes are less significant than for shorter stay users; and
- Commuter work trips primarily occur during peak flow periods, meaning that demand measures will have larger impacts on traffic flow than targeting other groups, and public transport operates at peak frequency, minimising inconvenience

Therefore, the examination of CBD work trips is most likely to provide an indication of how effective a parking policy is in managing travel demand. It is unlikely that travel demand measures will have been implemented that specifically target non-work trips, but it is likely that measures to reduce demand for work trips would also reduce non-work trips as a secondary impact. Consequently the following data were requested:

- parking policy, including objectives and specific initiatives,
- number of long-stay parking spaces and the number of full-time employees (FTEs),
- cost of parking for eight hours,
- morning peak hour mode split.

Of the 23 organisations contacted, a useable response was obtained from nine. Further data was obtained from Calgary GoPlan (1994) and Luz (1996). This provided a total of 29 cities, although the information from some of these was incomplete. The sample provides a good coverage of North American cities and Australian capital cities. Very few responses were received from European cities. Cities in developing countries were deliberately excluded because of their different travel patterns. While this dataset cannot be considered as a representative sample of all CBD areas in developed countries, it was deemed to be appropriate to derive some general trends and relationships between policy objectives and travel characteristics.

A qualitative analysis of the parking policies was carried out by sorting cities into three groups according to peak hour mode split, and comparing the policies between cities to determine what (if any) differences in policy exist between low mode split and high-mode split cities.

Low Car Use Cities (commuters travelling by car less than or equal to 40 %)

The cities in the sample are (in increasing order of car use) London, Sydney, Toronto, Melbourne, Portland and Montreal. These cities have in common a recognition of the need to manage parking supply within the CBD to manage traffic impacts. London, Sydney, Toronto, Portland and Montreal explicitly state the need to reduce long-stay parking provision. Melbourne's policy indicates that a 'balance' between private and public access is to be provided, however, how to define this balance is not clear from the policy. All cities except Melbourne and London mentioned a specific mode split objective, usually expressed as a proportion of commuters catching public transport.

The role of economic development is an objective in most of the policies, but this role appears to be concerted with the concept of maintaining the environmental quality of the centre. Low car use cities regard accessibility for people rather than for cars. A major component of this is pedestrian amenity, and most policies indicate that controlling traffic is a major component of facilitating pedestrian access.

Short-stay parking is regulated in all cities. However it appears that none of the cities in the sample sought to control the *supply* of short-stay parking. This probably is because it is apparent that restricting short-stay parking provision has direct economic impacts. The primary role of parking authorities in relation to short-stay parking is through manipulating the price of on-street spaces, so that nearby on-street parking is available to users close to their intended destination.

Moderate Car Use Cities (commuters travelling by car between 40 % and 60 %)

The cities in the sample are (in increasing order of car use) Ottawa, Vancouver, Brisbane, Winnipeg, Los Angeles and Calgary. Viewed as a whole, cities with moderate car use have similar ideas in their parking policies as low car use cities. Once viewed individually, it can be seen that policies are less comprehensive in their scope. Policies focus on the role of parking as part of a transportation system. All cities mentioned the role of public transport as an alternative to car travel, and sought to encourage transport use. Four of the six cities stated a mode split goal.

Ottawa (the lowest car use in this division) was the only city to discuss the impact of parking policy on pedestrian amenity. The role of short-stay parking is less well defined in many of the policies. Winnipeg, Los Angeles and Calgary did not address the issue of short-stay parking in their responses. This suggests that access to short-stay parking is not a significant issue within these CBDs.

High Car Use Cities (commuters travelling by car greater than 60 %)

The cities in the sample are (in increasing order of car use) Adelaide, Edmonton, Perth, Wellington, Saskatoon, Christchurch and Parramatta. None of the cities had a mode split goal. The role of parking supply as a means of ensuring economic development is dominant for all cities. In some cases this is described in terms of encouraging CBD use, or maximising CBD access. Many cities sought to maximise the availability of parking within environmental and road capacity constraints, although some cities express the desire to control the development of commuter parking. Christchurch considers the objective of economic development to be more important than its parking facilities recovering operating costs.

Interestingly, five of the seven cities mentioned the role of short-stay parking and the need to ensure its availability. This may be related to the desire to maximise economic

development by maximising short-stay user convenience. These cities may experience problems similar to that of Wellington, where commuters were occupying on-street spaces, thus displacing short-stay users to off-street parking stations (Styles, 1997).

It is apparent that the differences in policy between low and moderate car use cities are relatively minor on the basis of content. The major differences appear to be in the degree of commitment to reduce the availability of parking to commuters. The role of economic development of the city is most dominant in high car use cities, while the role of the quality of the city environment is most prominent in low car use cities. A mode split goal is almost universal in the sample of low car use cities, and is not provided for high car use cities. Short-stay parking appears to be an issue in most cities, although it is suggested that in high car use cities the issue is more related to commuters occupying premium parking spaces than an overall supply problem.

Mathematical modelling of relationships

In an attempt to define a desirable level of parking supply, least-squares regression analyses were conducted to find relationships between parking availability and public transport use, parking cost and public transport use, and parking availability and parking cost. Each proposed relationship was tested using a power, exponential and logarithmic transform. However the regression fits derived matched poorly what appeared to be the trend in the data. This probably was a result of the data clustering having a strong influence on the regression at the expense of points at the extremities. Another technique was developed that sought to minimise the error sum of squares (SSE) for a proposed model. This method did not suffer the logarithm compression effects, although the problems relating to the dominance of North American data points still existed. Finding a minimum SSE curve was achieved by altering the coefficients of a proposed model using an iteration process until the SSE was minimised. An advantage of this technique is that the proposed model could have more than one constant and one coefficient. This procedure produced more satisfactory results, although the minimum SSE curves are still only moderately well correlated. Nonetheless, there is a strong indication that the parameters of parking availability, parking cost and car use are inter-related.

Only the relationship between long-stay parking availability and commuter car use is described here because this appears to be the strongest correlation and hence the best candidate for a "sustainable target".

Long-stay parking availability and commuter car use

Figure 1 shows the relationship between long-stay parking supply per full-time employee (FTE) and proportion of private car use during the morning peak hour in Australian CBD areas. A linear regression produces the best fit to the data points. The regression equation indicates that every unit increase in long-stay parking supply induces more than 1.3 unit

increase in car use. However, because of the small number of data points, the general validity of this relationship is questionable, and better results can be expected from an analysis of the full dataset including overseas cities.

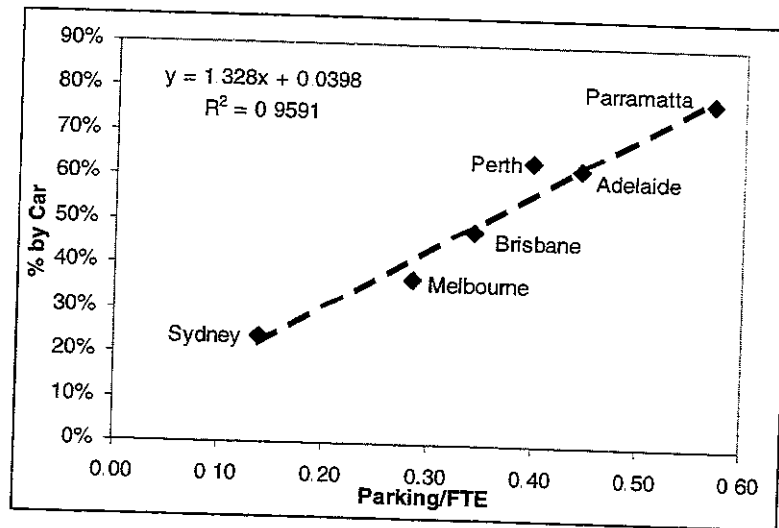


Figure 1 Relationship between long-stay parking supply and proportion of car use in Australian cities

Figure 2 shows the same relationship for all the available data. Some data points were excluded from the curve fitting process, as these were considered 'outliers' that would distort the curve; these data points are denoted by a hollow symbol. The data in Figure 2 suggest that car use initially increases rapidly as parking availability increases. However the rate of increase decreases until a maximum car use is reached at about 80 per cent car mode split. This is supported by the curve fits, although the lack of data points above a parking availability of 0.7 spaces per full-time employee (FTE) results in the curve deviating significantly from the data. The proposed model appears to fit the data reasonably well, and is consistent with the model proposed by Morrall and Bolger (1996).

It appears that once parking availability exceeds approximately 0.5-0.6 spaces per FTE, long-stay parking demand is satisfied, and further increases in parking allocation have little impact on modal split. It is likely that at this level of parking supply those not driving a car do so as a result of lack of choice as public transport captives, or a more attractive alternative mode of transport.

At the other end of scale, mode split is very sensitive to changes in parking availability. If parking availability is below 0.4 spaces per full-time employee, a unit reduction in parking availability results in a greater than unit reduction in the proportion of commuters using a

car. Conversely it highlights the larger than unit impact that allowing additional parking has.

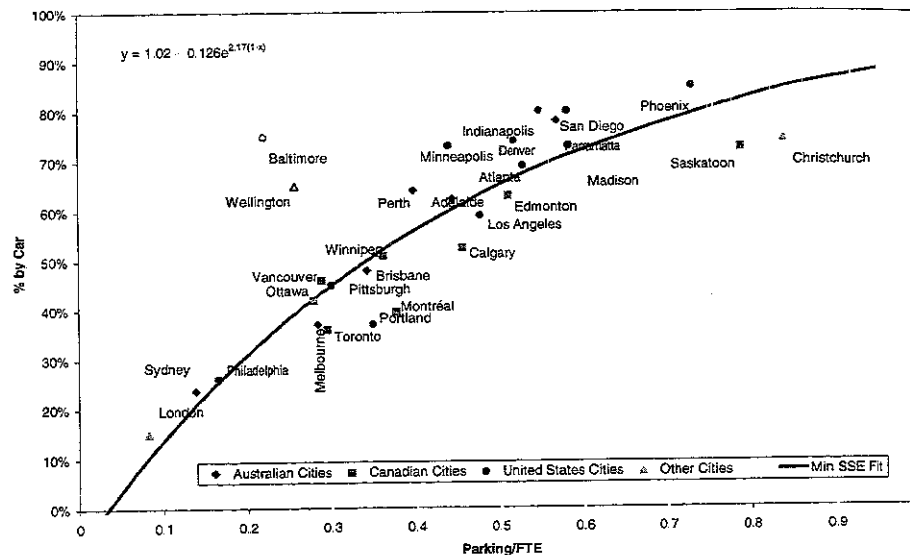


Figure 2 Relationship between long-stay parking supply and proportion of car use in an international sample of cities

Implications for the Sydney CBD

The Sydney CBD has the second-lowest parking availability and car use within the sample. Consequently it is expected that there would be a substantial degree of error in any estimates of impact. Nonetheless, examining how changes in parking availability can affect car use is still a useful exercise to obtain a first order estimate.

Once the World Square development (Sydney City Council, 1997) is complete, approximately 2,500 extra spaces will be added to the CBD parking supply. Using the parking data in *Accessible City*, this represents a ten per cent increase on existing supply, from 0.139 to 0.153 spaces per FTE. Sydney does not plot on the minimum SSE line of Figure 2, which means that directly applying the minimum SSE equation would introduce a large relative error.

To compensate for this, the differential of the minimum SSE equation can be used as a gradient estimate, and then the new point is estimated using a multiple step Euler method (Kreyszig, 1993). This effectively draws a curve parallel to the minimum SSE line. This

technique yields a car use of 0.261, representing an increase of about 4,500 commuters travelling by car as a result of the increase in parking supply.

Sydney City Council has a mode split goal of 80 % of commuters travelling in by public transport. Assuming that this is equivalent to a 20 % car use, this can also be forecast using the same technique as above. Starting from a basis of the World Square parking spaces being available, parking availability needs to be reduced from 0.153 to 0.119 spaces per FTE. This requires approximately a 20 per cent reduction of long-stay parking in the CBD, from 27,500 spaces to 21,500 spaces.

Conclusions

In many cities, the Central Business District (CBD) has a policy restricting parking so that the limited road capacity is not exceeded. Given that a restrictive parking policy already exists, implementing IDM using this technique is most likely to be politically acceptable. Central Business Districts also are characterised by a relatively high quality of access to public transport, providing many opportunities for travellers to use high-occupancy modes of travel.

Significant issues related to managing parking are the economic impacts of restricting the availability of long-stay and short-stay spaces, employers subsidising parking or travel, and equity. Examining the similarities and differences in CBD parking policies yields the following results.

- Generally cities where car use to the CBD tends to be low have a mode split goal
- Cities where car use to the CBD tends to be low or moderate mention the role of public transport as part of their parking policy.
- Cities where car use to the CBD tends to be low or moderate express the need to reduce long-stay parking. High car use cities did not address this issue or the issue was not prominent
- High car use cities tend to have a policy that focuses the role of parking as a means of facilitating the economic development of the CBD

The effectiveness of these parking policies is expressed in the degree of commitment by the city to reduce traffic flows, if that is a commitment at all.

By comparing the availability of long-stay parking to car use, it was found that car use increases in a quasi-logarithmic fashion as parking availability increases. Car use approaches its maximum value of approximately 80 per cent once parking availability exceeds 0.6 long-stay parking spaces per full-time employee. Below 0.4 spaces per full-

time employee, a unit reduction in parking availability results in a greater than unit reduction in car use.

Several deficiencies can be identified in this approach. The most significant deficiencies in the analysis relate to the availability and the quality of data. Data was collected from a wide variety of sources, with authorities in different countries placing a different emphasis on certain aspects of parking management. The poor response from the mail and facsimile survey of parking authorities meant that the majority of data points were obtained from two North American sources (Calgary GoPlan, 1995 and Luz, 1996), which introduced a bias into the sample towards North American cities. The rest of the sample consisted of one European city, two New Zealand cities and six Australian CBDs. The lack of low car use cities significantly affected the curve fitting procedure, and hindered the drawing of implications for the Sydney CBD policy. The inclusion of more European cities would probably redress most of these problems.

Ideally car use data would have been recorded as the proportion of single occupant vehicles accessing the city centre. Most of the North American data provide a mode split that separates car drivers and passengers. However data from other sources did not, and in some cases only a public transport mode split was provided.

For the purposes of this study, parking in fringe areas was excluded. However from the perspective of TDM, the environmental impacts of travelling by car directly to the CBD and parking near the CBD are virtually identical (other than improving amenities in the central area). On the other hand, mode splits based on a cordon count will record fringe parkers as public transport commuters. The magnitude of this activity needs to be quantified when developing policy to ensure that mode split goals actually reflect an improved situation.

Despite the above deficiencies, it appears from this analysis that a "sustainable target" level of long-stay parking supply for central city areas can be defined, once a mode split goal has been set, using the relationship between long-stay parking supply and commuter car use. However, it must be recognised that this is just one element of the CBD parking policy, and further studies are recommended to investigate how a desirable level of short-stay parking supply can be defined.

It is worth mentioning that restricting parking supply to a "sustainable target" level will not be successful without additional measures aimed at maintaining and even improving the accessibility of the area by providing convenient alternative modes of transport. It is noted that *Accessible city* (Sydney City Council 1995) includes these in its integrated strategy.

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