Demand Responsive Public Transport for Australia: 1. The trade-offs.[1]

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Abstract:

Demand responsive public transport (DRPT) has been promoted as one means of increasing public transport usage, reducing traffic congestion and generating consequential social and environmental benefits. The past 20 years has witnessed many implementations of DRPT, in different locations, in a variety of forms, and with varying levels of success and longevity. This paper presents an overview of the travel demand markets for DRPT and examines some of the operational features that can match DRPT to market segments A conceptual model of the performance of DRPT relative to conventional public transport is developed and applied in this regard. Together with its companion paper reviewing specific case studies of DRPT in Australia, the paper provides a basis for the appraisal of DRPT as a viable transport alternative.

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1. INTRODUCTION

Conventional public transport is efficient to the extent that it can group travel needs so that a number of people can be carried in a single vehicle. But people's movements have become far more varied in terms of origins, destinations and trip departure times. If public transport is to continue to play an important role in urban transportation, then the efficiencies of mass movement have to be traded-off against the need to provide services that match the heterogeneity of individuals' travel needs. Demand responsive public transport (DRPT) has been promoted as one means of increasing public transport usage, reducing traffic congestion and generating consequential social and environmental benefits. The past 20 years has witnessed many implementations of DRPT, in different locations, in a variety of forms, and with varying levels of success and longevity. Published accounts of these services have concentrated on describing their formats and outcomes but there has been little discussion of key operational parameters and performance measures and their relevance to contemporary urban Australia.

This paper is one of a pair that together provide a critical review of the concept and operation of DRPT in the Australian context, taking into account DRPT experience, performance characteristics of competing modes, and consumer preferences. The thrust of this paper is to examine the markets for public transport and the characteristics of public transport modes, including DRPT, and then match the services to the markets. In this way the most suitable market niches for DRPT can be suggested. The paper then develops a simple conceptual model of DRPT operations to test the conditions under which DRPT could best serve particular public transport market segments.

The companion paper (Radbone, D'Este and Taylor, 1994) then describes a number of Australian DRPT case studies, and provides a critical review of these studies in terms of the market segments, technology and operational characteristics identified in the present paper. Technological capabilities and needs to service particular market segments are then compared and matched. On the basis of this compound appraisal of DRPT a number of findings are given, in terms of the specifications required of DRPT, what role(s) it can play in the urban transport task, and the circumstances where it might offer viable transport service.

2. THE MARKETS

There is a common myth that public transport is a homogeneous service supplied to one user group - the travelling public at large - and that all that differentiates public transport riders from other travellers are idiosyncratic matters of personal preference and choice. The reality, however, is something else. As described by Starrs and Perrin (1989), there is a considerable range of public transport users and a spectrum of public transport services that do or could service the demands of those users. The suburban bus service used mid-morning by an elderly person is quite a different service supplied in a different market to a morning peak hour rail journey downtown by an office worker. The school bus trip made by that worker's teenage offspring to high school is yet another service to another market.

The most comprehensive picture that we have of Australian personal travel characteristics was provided by Wigan (1987). This report provides a systematic examination and analysis of the household interview surveys of personal travel conducted in Australia over the period 1970-81. Wigan noted a general similarity in patterns of public transport usage across eleven Australian cities, from Sydney and Melbourne to Launceston and Ballarat. The effects of car ownership on public transport usage seemed to be matters of choice rather than necessity, for the trip making characteristics of the smaller cities are still within the range of those in the larger metropolitan areas. This might provide the basis for the pervading mythology regarding public transport usage? The interesting circumstances, however, lie in the significant differences observed between different socio-demographic groups within the population of urban Australia. Wigan approached these differences by considering mode usage in terms of two derived parameters for personal travel: participation rate and activity rate.

On the basis of participation rate, which is defined as the percentage of a specified group of people who engage in at least one activity of a specified type in a given time period (such as undertaking a trip by public transport within a particular 24 hour period), a number of significant market segments emerge:

- young people (those between 12 and 25 years of age) are the most likely to use public transport. This holds for both sub-groups within this age category (those under the driving licence age and those above it);

- participation in public transport depends on the particular transport mode considered, with males making more use of rail and females making more use of buses;

- car ownership is a significant factor, although it should not be considered in isolation from other household variables, of which 'stage in family life cycle' was seen to be a major determinant of expressed travel demands. Carless males are the most likely group to use public transport, followed by carless females, with a steady decline with increasing vehicle ownership - females from multiple car-owning households being the least likely to use public transport (with the interesting exception of the use of private school buses, which this latter group was the most likely to use - but perhaps it is not too difficult to conjecture why this reverse trend might be so when other household characteristics are considered?);

- interestingly enough, rising household income (which may be thought to correlate with vehicle ownership) does not necessarily indicate a decline in public transport participation, indeed Wigan found some evidence of increasing participation by higher income households. The male/female balance is maintained, with male dominance of train usage and female dominance of bus and tram. Wigan suggests that this puts in doubt the convenient conventional proposition that household vehicle ownership levels provide a proxy for household income.

On the basis of activity rate (or trip generation as it is more commonly known in transport planning), the general picture is that the rates are relatively stable over age and sex, although males still show higher values in train usage. Thus not only do more males use trains that females, they also appear to travel on them more when they do. Adults from

carless households tended to make about two public transport trips per day, with a slight decline in this average for individuals from households with higher car ownership levels (to about 1.8 trips per person per day). This decline presumably reflects the ability of car owning households to take public transport for only part of a larger daily travel pattern.

The above conclusions, drawn from Wigan (1987), reflect socio-demographic differences across urban Australia as a whole. Regional differences tend to reflect the relative usage of different modes in different cities, largely as a consequence of the availability and coverage of different modes in different places, rather than the collective usage of public modes. For instance, one can contrast the usage of rail services in Melbourne and Adelaide but only when considering the respective levels of coverage provided by that mode in the two metropolitan areas. Wigan's work paints the big picture about the role and usage of urban public transport in Australia.

Wigan's analysis further suggests that taxis should be seen as a niche market in public transport. But contrary to intuition, the travel demand data reveal that taxis as used by the *residents* of an urban area are more likely to be used by lower income groups than others, and that females are nearly twice as likely to use taxis as males. The household data reveal little about the travel behaviour of *visitors* to a city - perhaps that is where many people including transport planners normally see the use of taxis - because the household interview survey rarely seeks information about visitors.

The sparse evidence on personal travel made available since 1981 (e.g. Itorralba and Balce (1992)) indicates that little has changed from the general picture revealed by Wigan in ARRB Special Report 38. Bell (1989) indicated that public transport remained the principal mode of travel to the central city, and that the young constituted a major group of transit users. Participation by the elderly tended to be less than for other age groups, and perhaps was directed towards certain types of trip making, restricted to a local area about the traveller's residence.

Market segments for public transport

The normal justifications for the provision of urban public transport are: (1) the provision of basic levels of mobility for the inhabitants of an urban area, especially for those who do not have access to a private vehicle, and (2) for environmental protection, through reduced congestion and emissions levels than those that would apply in the absence of public transport services. The above review of the characteristics of public transport users lends some qualified support to these suppositions. Three significantly different user groups emerge:

- a 'high-profile' commuter group, comprising central city workers who tend to make long distance trips at peak hour to and from centres of high employment concentration. This group tends to travel by rail where possible. It may be characterised by males with high income status;

- teenagers and young adults (under 25 years), making journeys to work and to educational institutions during peak periods, with a tendency to use buses, and

- elderly people, making bus journeys within a local area and generally off-peak, for social and shopping purposes.

In addition, public transport is used by a more diffuse group of adults, comprising the unemployed and home carers, whose travel patterns are less well-defined (if understood at all) and who tend to travel within a local area (again centred on the residence). The usage of taxis by this group, as noted by Wigan (1987), is of particular interest.

The first question then is what forms of public transport are available to serve the needs of these different market segments?

3. THE SERVICES

It has been argued above that the market for urban passenger travel is not homogeneous. Indeed, there are many markets each of which has its own requirements in terms of origin, destination, timing and quality of service. However if conventional public transport service options are plotted against the relative flexibility of their routes and timetables, as shown in Figure 1, it is clear that the range of markets is not being matched by a range of service types. Conventional modes of public transport cater for the extremes of route and timetable flexibility and leave a significant gap in the service market.

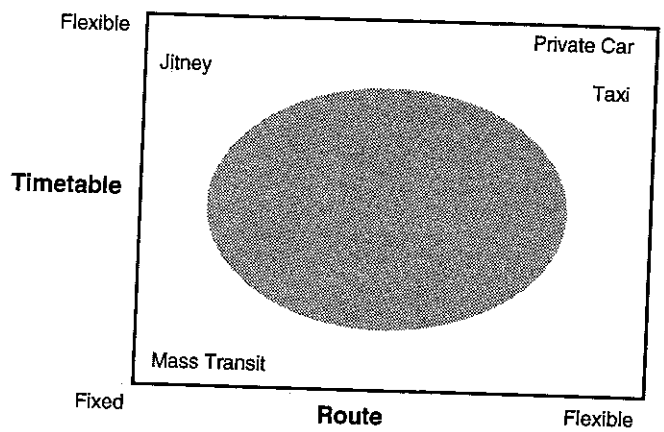

Figure 1 Public transport services

It follows that if public transport is to provide an attractive alternative to the private car and cater for the range of sub-markets that exist in the community then it is no longer sufficient to view public transport in conventional terms of buses, trams and trains providing a fixed-route and/or fixed-schedule service. Public transport must be varied, flexible and responsive to the needs of different market niches.

This Section reviews the concept of public transport and examines the characteristics of the service options that are available to cater for the demands of the travel market. The first step is to develop a definition of public transport that includes the full spectrum of

service options Public transport is a service, not a technology, and can be defined as follows

> *... public transport is a passenger transport service that is provided by a 'third party' and is available for use by all members of the community*

This definition emphasises access for all and the involvement of a 'third party' such as a bus company or taxi driver, and it extends the concept to include taxis and other complementary and unconventional modes, including jitneys and other hail-and-ride services. However it excludes private motor vehicles and the like where there is no 'third party' involvement, and modes with restricted access, such as carpools, school buses, company organised van pools and some forms of subscription services.

The spectrum of services can be represented on a single scale which measures the extent to which they are supply-driven or demand-driven. At one end of the spectrum is mass transit in which individuals organise their travel around the service provided (supply driven), while at the other end is personal transport in which the service is tailored to the needs of the individual (demand driven). The way that the various public transport modes fit into this spectrum is illustrated in Figure 2.

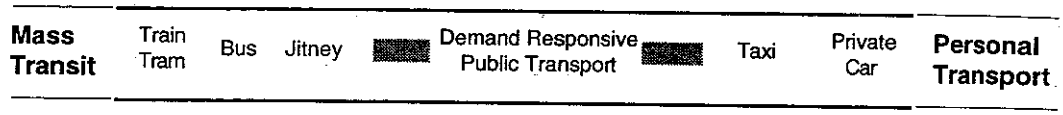

Figure 2 Spectrum of public transport services

In the middle of the spectrum is a region in which there are trade-offs between responding to the needs of individual travellers, and to the operational need to provide an efficient and effective service for the community. This is the realm of *demand responsive public transport*. DRPT can be defined as follows

> *... demand responsive public transport is a public transport service in which the individual traveller can influence the route and/or timing of services*

Within the definition of public transport in general, and DRPT in particular, there is still a wide variety of service types. These types can be classified according to a number of key characteristics (or dimensions) of the service.

Service dimensions

The key characteristics that delineate the various service types are the route, the schedule, the method of collecting passengers and the quality factors.

Route - the route types can be classified according to the flexibility and density of linkages between origins and destinations. This leads to a three dimensional classification of route structures, as illustrated in the following diagram.

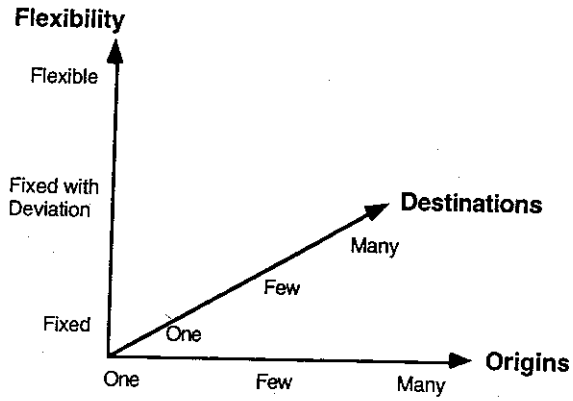

Figure 3 Dimensions of route types

A service may having a route and stopping points that are absolutely fixed or there may be the flexibility to divert over one or more predetermined route deviations or there may be no set route. In all cases, the density of linkages will define a range of service types that can vary from a service which connects a single origin to a single destination (referred to as one-to-one connectivity), to services that connect all origins in a region to one (many-to-one), several (many-to-few) or all (many-to-many) destinations and *vice versa*.

Schedule - concerns the timing of services and the scope to respond to passenger requirements

- Fixed timetable
- Flexible with booking
- Flexible in real time

Method of Collection - concerns the way that demand for the service is expressed and/or the manner in which passengers are collected. The options are

- Stop or station
- Hailing
- Permanent booking
- Telephone call
- Always available

Quality Factors - the modes also vary in the quality of service that they provide. The key elements of the quality of service are

- Certainty of finding a seat
- Comfort
- Privacy and security
- Frequency
- Reliability

The requirement to provide a cost-effective service means that the various types of public transport service tend to use vehicles of a particular size and operating characteristics. It follows that vehicle size can be included as a subsidiary dimension.

Different combinations of these characteristics correspond to different types of public transport services. The operational characteristics of the major modes are summarised in

the Table 1. The characteristics of the service provided by the private motor vehicle has also been included for comparison.

Table 1 Operational characteristics of public transport modes

	Fixed Route Rail	Fixed Route Bus	Jitney	Demand Responsive Public Transport	Taxi	Private Car
Route						
- Fixed	X	X	X			
- Fixed with deviation				X		
- Many to one				X		
- Many to many (local)				X		
- Unconstrained					X	X
Schedule						
- Fixed	X	X				
- Flexible with booking				X		
- Flexible in real time			X	X	X	X
Mode of Collection						
- Station or stop	X	X		X		
- Hailing		X	X	X		
- Permanent booking				X		
- Telephone				X	X	
- Always available						X
Quality						
- Assured seat	No	No	No	Usually	Yes	Yes
- Frequency	Variable	Variable	High	Variable	High	High
- Reliability	Variable	Variable	Moderate	Moderate	High	High
- Comfort	Variable	Variable	Variable	Moderate	High	High
- Privacy & security	Low	Low	Moderate	Moderate	High	High
Vehicle Size						
- Large	X	X				
- Medium		X	X	X		
- Small			X	X	X	X

The relationships between the services provided by the various types of public transport can also be expressed graphically. Figure 4 shows the modes and service characteristics according to the space and time dimensions. The vertical axis shows the frequency of service availability on a relative scale ranging from low to high where a high frequency

indicates that the service is available on demand and a low frequency indicates long intervals between successive services. The horizontal axis shows route coverage or equivalently the accessibility of services. The scale ranges from minimal coverage indicating a sparse network of services, to full coverage indicating that all locations are serviced and hence access to services is easy. Within each identifiable type of public transport service, there is a range of services. Accordingly, each service type is represented by a region on the graph, indicating the variations in the service characteristics within a mode.

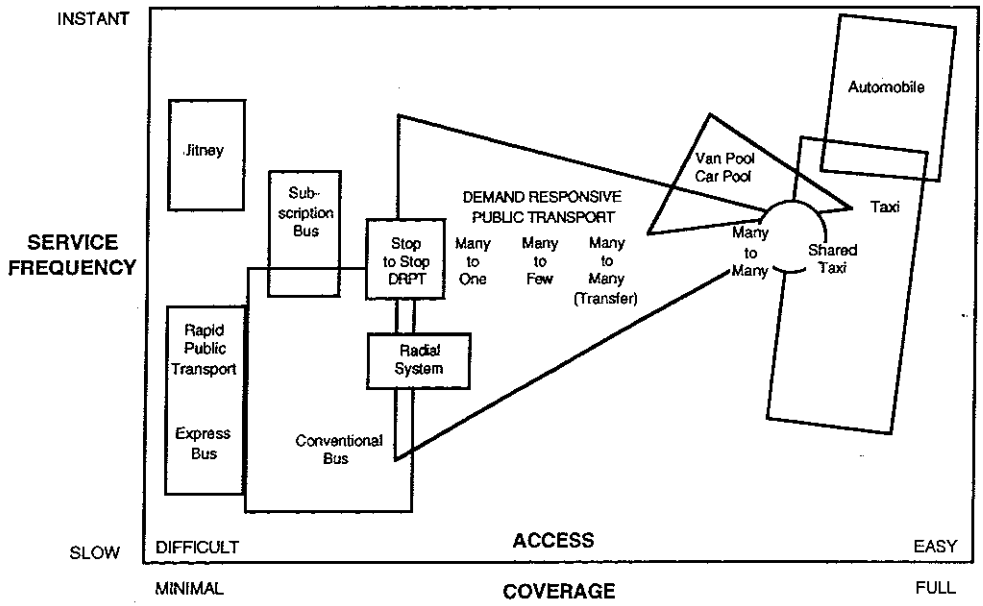

Figure 4 Conceptual framework for public transport services

Types of demand responsive services

The main focus of this paper is on demand responsive services and as demonstrated above, DRPT covers a wide range of combinations of service characteristics. To simplify the following discussion, demand responsive services can be grouped along several dimensions into three broad categories, graduated according to their flexibility and responsiveness;

- corridor services
- zonal (many-to-one and many-to-few) services
- area-wide (many-to-many) services, without transfers

Corridor Services - operate on a fixed route but have some flexibility in space and in time through minor route deviations and/or the ability for the passenger to reduce waiting time by calling the next bus, such as by phone or through the use of a 'smart' bus stop

(i.e. a bus stop equipped with a two-way communication system that can provide information to intending passengers and accept information from them).

Zonal Services - operate over a restricted region of the urban area, but within that region, offer flexible and responsive services with many-to-many or many-to-few coverage and semi-fixed timetables perhaps with advance booking. A common feature is scheduled transfers at a focal point, for instance, as a feeder to a line-haul bus or train service

Area-wide Services - operate with total flexibility over a large area, with a service quality similar to that delivered by taxis.

A complete public transport system for an urban area may consist of one or a combination of demand responsive and conventional service types. The appropriate type of service will be determined by matching the needs of market segments to the service characteristics of the public transport options.

4. MATCHING SERVICES TO MARKETS

Given the earlier identification of four specific market segments for public transport services, it now remains to decide which type of service would best meet the demands of each segment. This may be attempted at two levels, the first being the conceptual level at which broad service features may be compared with the primary trip characteristics associated with each segment. The second level involves the consideration of certain parameters describing the performance of particular services, and then the possible comparisons between services in catering for given market segments.

Service features and trip characteristics

The four main market segments served by public transport were identified as commuters, young people, elderly people and the unemployed and home carers without access to a private vehicle. A broad classification of the service features sought by these public transport users may be attempted in terms of the following travel characteristics pertaining to the users:

- trip frequency, the repetitive nature of the journey to be undertaken;
- trip end location, the geographic locations of the origin and destination points of the journey;
- trip timing, the times of day at which the journey is undertaken;
- trip length, the distance covered in a typical journey, and
- travel time variability, the importance placed on a reliable prediction of travel time for the journey by the traveller.

Table 2 provides a broad overview of these characteristics as they apply in stereotype to each of the market segments.

Table 2 Travel characteristics of the public transport market segments

Market Segment	Trip Frequency	Trip End Location	Trip Timing	Travel Time Reliability	Trip Length
Commuter	twice daily	activity centre, especially CBD	peak period	important	long
Young person	twice daily	local and regional activity centres	peak period	important	variable (medium to long?)
Elderly person	variable	local centres and suburban	off peak		short
Unemployed and home carers	variable	local and regional centres	off peak		variable (short to medium?)

On the basis of this cross-tabulation it is possible to assert that the demands of the public transport market segments can be met by the following service types, using the information provided in Table 1 and Figure 4 :

- commuters - fixed route services for line haul, with DRPT providing a possible alternative for feeder services to connect with the line haul;
- young people - a mixture of fixed route and local services are needed, depending on trip end location. DRPT may be used for local trips or for feeder services to connect to line haul. The intensity of the trip generation at the activity centre, both in terms of numbers of trips and the timing of those trips, might place some limits on the ability of DRPT to provide for this market sector;
- elderly people - local services are required, with the ability to provide door-to-door service an advantage. DRPT would be well suited to this task, and
- unemployed and home carers - both fixed route and local services are required, depending on trip end location. DRPT would be suitable for local travel, especially in view of the off peak nature of many of the journeys and the possible desire for 'door to door' service for (say) shopping trips or indeed for journeys undertaken with or by small children.

Thus DRPT can be seen to have a potentially important role in providing transport services within a local area, either to local activity centres or to transport nodes providing access to metropolitan fixed route services, possibly for each of the market segments.

Limitations on the suitability or attractiveness of DRPT for particular segments may be found where the temporal intensity of the travel demand is high. The predictability and reliability of travel times by DRPT in such circumstances may be suspect. On the other hand, DRPT would seem well suited to off peak travel where travel demand trip end locations are diffused across an area

Basic questions relating to the implementation of DRPT services, especially new services as alternatives to existing ones, concern the expectations of potential users concerning service availability in time and space, and the abilities of various transport technologies to meet those expectations. Some indication of technological capabilities is provided by Figure 4, in terms of access and coverage and service frequency and availability in time. If access to a private vehicle may be assumed to give immediate availability and full coverage of a region, then the use of a taxi service provides full coverage and a short time lag in service availability. What would be the expectations for DRPT, and at what fare levels would DRPT be seen as a viable alternative? The mode of operation of a multi-passenger/pick-up/put-down service (as DRPT must be) is that some deviations from the most direct routes for individual passengers are inevitable. Deviations may thus lead to some increases in individual travel times. The ability to provide door to door service may be important, but is it essential for service operation? Are there circumstances where partial deviation from a prescribed route (say pick-up at a pre-designated point, such as the 'nearest corner') might offer better efficiencies for passengers and service providers alike? Some indications of the possible modes of operation of DRPT and their relative effects may be seen by examining a set of basic service parameters and their interactions with components of the trips.

Parameters and relative performance

All trips may be seen as comprising a set of connected components. In general these components may be thought of as: access to the transport mode (e.g. walking to the garage, parking bay, bus stop or railway station)), waiting for the mode to become available (e.g. for the arrival of the bus or train, starting and warming up the engine or pumping up tyres and adjusting the bicycle helmet), in-vehicle (riding) time, and another access time after leaving the mode and proceeding to the actual destination. There is also the possibility of transfer between modes in mid-journey (and another waiting component associated with that transfer. This breakdown of an overall trip into its component phases has been of particular concern for journeys by public transport, because of the relative importance of the access and waiting components inherent in those journeys. There has been extensive research relating the influence of the separate components (access, waiting and in-vehicle time) to service frequency, route spacing and stop location for fixed route public transport services, see for instance Webster and Bly (1979). One of the outcomes of this research was that different weights can be attached to the activity times associated with each of the components in assessing the responses of travellers. Waiting and access times were found to be weighted far more heavily than in-vehicle time. Webster and Bly suggested that waiting and access times could be weighted at a factor of two compared to in-vehicle time, from their studies of urban bus operations in the UK. More recent research by the State Transport Authority of SA has suggested that even higher weightings, of perhaps a factor of six, might now be appropriate.

A simple conceptual model can be constructed to compare possible DRPT performance with fixed route service. Suppose that a public transport trip has four components (walking, waiting, riding, walking) and that a DRPT service can be represented as a fixed-route service with diversions, such that a 0 per cent diversion is equivalent to a fixed-route transit service, and 100 per cent diversion gives a door-to-door service. Further, assuming that walking distance decreases linearly with the rate of diversion, and that trip time and service headway increase linearly with diversion rate then the total perceived trip duration can be written as

$$\begin{aligned}\text{Trip Duration} = {} & 2\,\alpha\,(\text{Walking Distance})*(1-\text{Diversion})/(\text{Walking Speed}) \\ & + \beta\,(\text{DRPT Headway})*(1+\text{Diversion})/2 \\ & + \gamma\,(\text{Trip Time})*(1+\text{Diversion})\end{aligned}$$

where α , β , γ are perceptual weights assigned by the traveller to the trip components. This simple model permits examination of the effects of route diversion and service frequency and availability, as well as the relative importance placed on the different trip components. The following graphs show the results of comparing the performance of a typical fixed-route service (0 per cent diversion, 250 metre walk to and from bus stop, 50m/min walking speed, 30 minute headway, 30 minute transit time) and a range of DRPT services with different diversion rates and fleet sizes. Headway at 0 per cent diversion can be used as a surrogate for the DRPT fleet size; a large fleet delivers short headways while a small fleet gives headways comparable with the fixed-route service. Each graph shows the relative performance of DRPT (in terms of the ratio of weighted trip duration of fixed-route to DRPT service) for a different type of public transport user - 'normal' (Figure 5), commuter (Figure 6) and mobility handicapped (Figure 7).

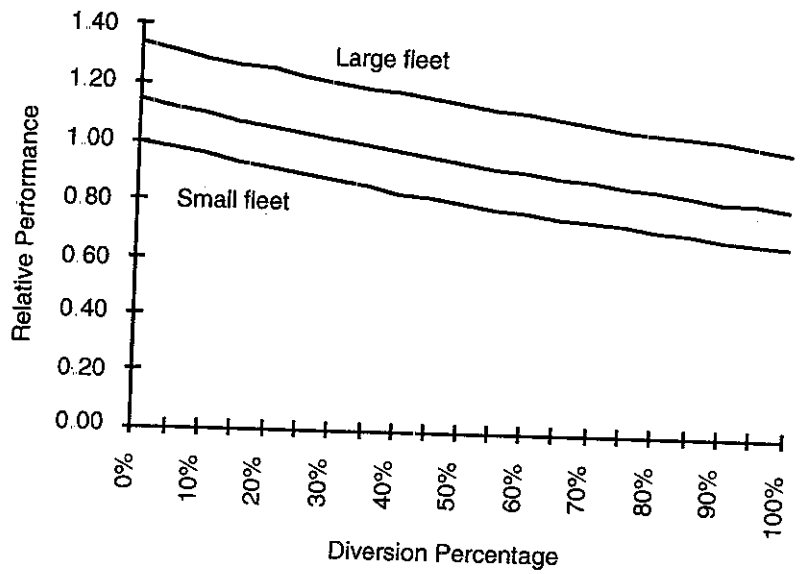

Figure 5 DRPT performance (Normal : $\alpha = \beta = 2$, $\gamma = 1$)

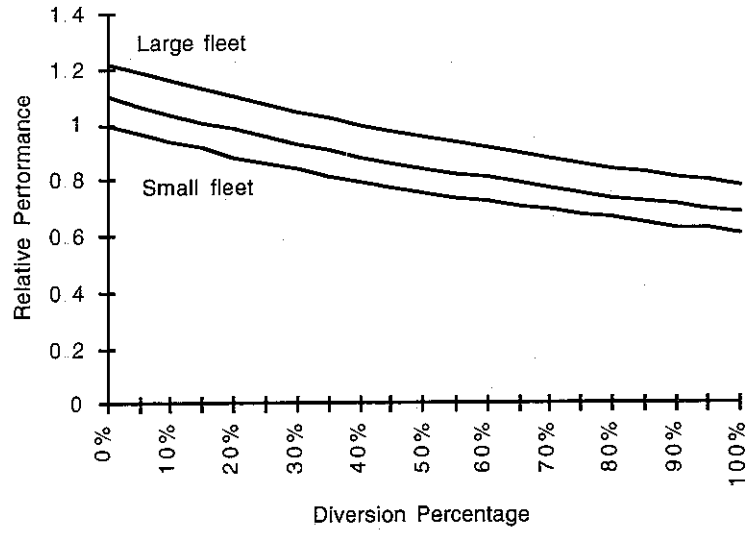

Figure 6 DRPT performance (Commuter : $\alpha = \beta = \gamma = 1$)

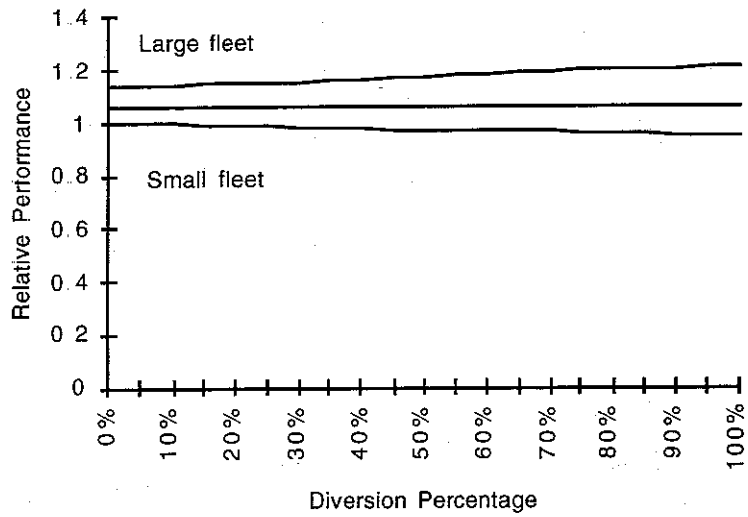

Figure 7 DRPT performance (Mobility Handicapped : $\alpha = 4$, $\beta = \gamma = 1$)

This simple analysis is quite revealing. It indicates that the relative importance placed on different trip components will play an important role in determining the relative merits of DRPT for given travel tasks. The greater the importance placed on (say) walking time (as might be the case for the elderly), the larger the degree of diversion that seems appropriate for DRPT (see Figure 7). Yet at 'normal' levels of weighting associated with this component, DRPT operations may best be suited to partial route diversion only (see Figure 5). For commuters (see Figure 6) diversions must be short if DRPT is to compete on the basis of total travel time from origin to destination.

More detailed analysis is required for a better understanding of these interactions and their effects. This would entail considerations of specific patterns and intensities of travel demand in an area, and a more detailed specification of the technological and operational characteristics of the transport modes, including fleet size, service design parameters, and possible travel speeds. Models of fixed route services including these service design characteristics and travel demand patterns are available (e.g. see Ling and Taylor, 1989a,b), and could be adapted to consider DRPT operations.

5. CONCLUSIONS

A review of the available information about the usage of public transport reveals the existence of four distinct market segments (commuters, young people, the elderly and carless adults), each of which could make use of DRPT services although in different ways and not necessarily with the same propensity. Commuters might use DRPT as local access to line haul services, although the level of 'route diversion' tolerated by this segment might be limited, and would contrast with the possible expectations of (say) the elderly. This suggests the need, at least in theory, for a careful matching of service characteristics to meet the respective user needs, that might be assisted by the differences in trip departure times associated with each user group.

An examination of the operational characteristics of urban transport modes points to a dichotomy between conventional public and private modes, leaving gaps in the spectrum of services provided. DRPT could help to fill certain of these gaps, and would then provide more effective transport services for off-peak travel in particular.

A vexed question has been the extent to which DRPT operations might aim to provide 'door-to-door' service commensurate with that characterising the private modes. The use of a simple, conceptual model of DRPT services considering the access, waiting and riding components of a trip suggests that full-scale diversion of the type intimated by 'door-to-door' service may only be successful under conditions where access time is highly prized by travellers at the expense of overall journey time and cost. Such services might be sought by some users (e.g. the elderly) but not by all. This offers the real possibility that effective DRPT services based on partial diversions from nominated routes may be devised. Important in the consideration of route diversion is the passenger carrying capacity of the DRPT vehicles and the fleet size used to service a given area. Further research is required to ascertain optimum settings for these parameters, but the indication from the conceptual model is that vehicle capacity may be quite small, perhaps a single digit number of seats?

Given the broad view of DRPT operations and market segments provided in this paper, a critical review of recent experiences with DRPT can then be attempted, with the further aim of determining the service characteristics and technological capabilities required for DRPT to prove successful in catering for specific needs of urban Australian travellers.

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