PATRONAGE ESTIMATION FOR STREET PUBLIC TRANSPORT*

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ABSTRACT: *There is a need for public transport operators to have an accurate estimate of patronage levels for any proposed new route. The high costs involved in establishing new routes, requires that the limited funds available to operators for improvements are allocated in a rational way. An accurate estimate of the potential patronage is the first step to ensure this. This paper reviews current methods for patronage estimation. Large public operators have used the results of metropolitan-wide, land-use and transportation models to highlight deficiencies in their networks. Some problems from the operators viewpoint in using this type of forecast are described. The development of alternative methods for patronage estimation is outlined. The adaptation of the four-step modelling approach to transport planning is discussed together with the possible use of both direct demand and disaggregate behavioural models. Details are given of the application of these techniques to a case study. The suitability of the models to more general applications is outlined*

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1. INTRODUCTION

The evaluation of any project involving the introduction of new public transport routes is heavily dependent upon the anticipated patronage level. However, patronage prediction has always been the evaluation component with the greatest degree of uncertainty associated with it.

For most projects the major cost components are those associated with fleet and crew requirements. With the degree of peaking in demand experienced on most routes it is found that these costs are directly linked to peak period patronage. Off peak services are determined by level of service standards and can be provided at a reduced marginal rate. Revenue is obviously tied to all-day patronage.

Not only costs and revenue but also the choice of appropriate mode is sensitive to patronage. Heavy rail, light rail, tram, bus and para-transit services each have an absolute capacity to meet demand and a range of demand levels for which they can operate most efficiently. Some indication of these ranges for operation under typical conditions in Australian cities is given in Fig. 1. The range of observed demand for street public transport in Melbourne is up to 5000 passengers per hour.

Because of the importance of accurate patronage figures and problems associated with current estimation methods some alternate techniques for determining patronage are currently being investigated. Although the study is particularly concerned with the types of services operated by the Melbourne and Metropolitan Tramways Board, the needs of operators of both greater and lesser transit networks have been kept in mind. However, effects of variations in level of service have not been fully investigated because of the uniform nature of the Board's services.

Two different areas of application of patronage estimates are considered. One is for detailed evaluation of one specific project where the emphasis is on accuracy. The second is for strategic level evaluation of a range of potential projects where the emphasis is on minimum cost and maximum ease of application.

This paper outlines some of the progress made in these investigations. It largely reports consideration given to various techniques with less emphasis on empirical evaluation, which is a continuing part of the project. The following sections will review the problems associated with the current methods, describe alternatives and outline their application to a particular case study.

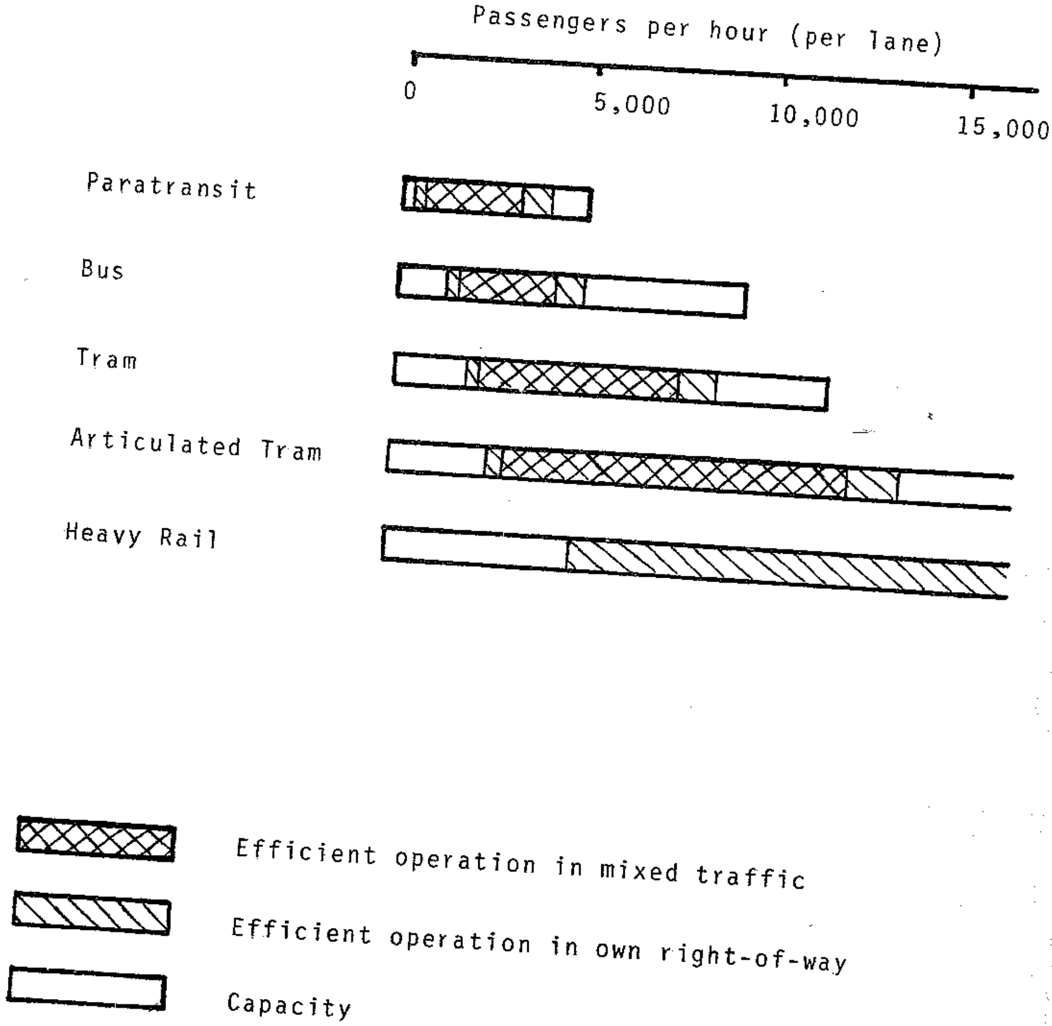

Fig 1 - Capacities of Public Transport Modes

2. CURRENT METHODS FOR PATRONAGE ESTIMATION.

Traditionally the implementation of a new bus service has been a reactive process with the service operated for a trial period and the response monitored. Schedule and routes may then be modified to better serve passenger needs.

One short-coming of this approach is that the trial services require a deployment of capital and labour. Estimates of the period of operation required to determine a maximum patronage figure with a fair degree of reliability vary from 1 month as suggested by Cherwony and Polin (1976) to 4 months by Buttke (1976). These approaches rely on the use of models to relate long term patronage to the observed growth rate at the start of the service. Costs for a trial service would depend on the length and type of route and of course on the revenue collected from the patronage. As an example, to deploy six buses on a trial route for a period of four months would involve approximately $50,000 in labour costs, so significant costs could be incurred. A further problem is that it is only applicable to buses and cannot be used for testing demand for fixed rail systems.

Once a new service has been implemented there are social and political pressures for the service to be retained. Trial services could not be easily provided, reorganised or discontinued at the will of the planner.

Perhaps the greatest problem with the trial service approach is that, due to limitations in supply of capital and labour, it severely restricts the range of potential routes that can be considered. This tends to inhibit the development of a rational network of public transport routes.

In recent years in Melbourne the set of transport planning models first developed for the Melbourne Transportation Study and subsequently refined and updated by the Ministry of Transport have been used by the Melbourne and Metropolitan ramways Board for major route studies. There are, however, several problems associated with their use. They basically stem from the different scale of the models and their required application. Models calibrated on a metropolitan basis cannot be easily applied to a particular route study which may lie within one transport zone. The point at which a centroid connector is fed into the transit newtwork may substantially effect the loading on a particular link being studied. What may only be 5% error in model prediction of mode choice in a travel corridor could easily result in a 50% error in loading on a link for a mode carrying a small share of corridor trips.

The light of the shortcomings of these current techniques there is a warrant for investigating some alternate estimating techniques that avoid both the "scale" problems that arise from using existing metropolitan transport planning model packages and the capital and labour commitment associated with "trial period" methods. Some potential techniques are discussed below.

3. SOME ALTERNATIVE METHODS FOR PATRONAGE ESTIMATION.

3.1 MODELS.

Due to problems associated with "trial period" methods as described above, new patronage estimation techniques would most desirably be based on modelling techniques. These models should be simple enough to be able to be understood and used by personel who are not necessarily skilled in the complexities of advanced modelling techniques and yet be capable of prediction with acceptable degrees of accuracy. The models should also be able to be applied using readily available data, principally Census data, and not require expensive surveys for each application.

The degree of accuracy required for a detailed project evaluation would ideally be within ±10%. As a strategic planning tool an accuracy of ±25% would be acceptable.

3.2 ADAPTION OF TRADITIONAL "FOUR STEP" SUB MODELS.

The first possible approach is to revise and adapt the traditional four-step (trip generation, trip distribution, mode choice and trip assignment) planning model to make it compatible with application to small scale network changes.

One potential simplification which could be made is in the area of mode choice. Previous work in Melbourne by Don (1975) has shown that mode choice is largely dependent on car availability and the gross employment density at the work place end of the trip. The results of a passenger survey, described in a later section of this paper, show that 84% of passengers boarding in a typical section of a tram route were either bound for the CBD and/or had no alternate mode available for their trip. This would suggest that no more than 16% of peak period tram travellers are non-captive to the public transport system and make a choice in their mode of travel.

A model constructed to estimate the number of public transport captives would thus be of some use in estimating public transport usage. However, data on car availability and on worktrip destination is not readily available.

The degree of captivity of most users does suggest that mode characteristics such as relative travel costs and level of service may not be crucial determinants of patronage. If this is assumed then a model that incorporates mode choice into the trip production sub-model without reference to service characteristics may still have some potential as a patronage model.

One of the most common trip production sub-models has been one based on regression analysis. For our application, surveyed loading patterns on existing routes would be regressed against land use and demographic characteristics in the areas adjacent to these routes. Potential independent variables would include numbers of workers, students, housewives and pensioners as well as variables affecting mode choice such as car ownership and proximity to alternate public transport services. The frequency of feeder services and distance from CBD would also be relevant.

As with all regression models there would be problems with correlation between independant variables, existance of non-linear relationships and future forecasting at or beyond the upper range of the variables with which the model was calibrated.

Some of these problems could be minimized if a category analysis trip reproduction sub-model is used in place of the regression model outlined above. In this case the analysis would determine public transport trip rates for different categories of potential travellers. Travellers would be identified in terms of their usual major activity, car availablity, age and sex. Census data would be used to establish category sizes in the areas adjacent to proposed routes to which trip rates would be applied to determine patronage.

As discussed, both these trip production models assume that mode choice is not a crucial determinant of patronage. The models are thus insensitive to changes in level of service. Their suitability for application to Tramways Board services is not substantially impaired due to their uniform level of service, but capacity to deal with services in areas of lower demand density, and usefulness as a policy analysis tool, is substantially reduced.

Some more sophisticated models that can provide sensitivity to level of service and other features warrant investigation. These are discussed below.

3.3 DIRECT DEMAND MODELS.

Recent research in the area of transport modelling has suggested that "direct demand" aggregate models may have application as a patronage estimating tool.

Such models attempt to estimate a demand function directly relating aggregate travel flows to zonal activities and level of service conditions. It is thus a simultaneous rather than a sequential choice process that is being modelled. Level of service thus influences the model not only in the mode choice area but also in trip generation, distribution and assignment phases. A technical discussion will not be entered into but interested readers are referred to Hensher (1976).

As renewed research into direct demand models is very recent there is little indication of their potential for evaluating small scale network changes. Paterson (1976) and Wigan (1976) express doubts about their suitability at this stage though each suggest that useful formulations may be eminent.

In the form of the "DODOTRANS" model a direct demand model was used to assist evaluating a potential outer ring transport corridor in Melbourne. This helped to establish the model's potential as a strategic tool but did not demonstrate its value for small scale project evaluation.

At this stage direct demand models must be viewed as essential research material, and as a strategic planning tool, rather than as a source of a patronage model for immediate use by transport operators.

3.4 DISAGGREGATE OR BEHAVIOURAL CHOICE MODELS

Another recent trend in demand modelling has been toward disaggregate behavioural models where the generator of trips is viewed not as a transport study zone but more realistically as an individual traveller.

Aggregate models indentify zonal variations in traveller behavior but not variance within a zone. Disaggregate models aim to indentify discrete market segments which are homogeneous in regard to socio-economic characteristics and transportation opportunities and for whom travel behavior patterns will be independant of location or of time. This spatial and temporal stability, if established, would allow area wide estimates of travel behavior to be made based on limited data collected at one place at one time. For reference to the technical aspects of these models the reader is referred to McFadden (1976).

The output from such a model would be particularly valuable as a policy tool. It would provide policy makers with a comprehensible view of the relationship between level of service and its effects on travel choices of different community classes. This is not often the case when modelling is abstracted to zonal behavioural responses.

At present disaggregate models appear only to relate to mode choice with rates of trip generation and the distribution of trips as external inputs. For application to the problem of patronage estimation for a public transport service, a local home interview survey of socio-economic and travel characteristics would be required in the potential catchment area for the service. This interview approach was used to evaluate the effects of re-organizing bus services in a transport-deprived area in the western suburbs of Sydney and the project is described in Commonwealth Bureau of Roads(1976). Disaggregate models are also being developed for planning use in Canberra.

Disaggregate models appear to have significant potential for use in estimating public transport patronage. The factor inhibiting their use is the survey work required for each application. If the proposed Ministry of Transport home interview survey is approved then this may alleviate some of the problems.

4. A CASE STUDY

4.1 WEST COBURG TRAM EXTENSION

A typical case requiring a good estimate of likely patronage arose from a study into the potential for extending the West Coburg tram route in Melbourne. The route currently extends 10.3 km north from the CBD and a 2.4 km extension was to be considered. The extension would pass through a primarily medium to low density residential area with some schools and a small pocket of industrial development. A land use map for this area is shown in Fig. 2.

The route is currently serviced by a private bus service operating a 15-minute service in peak periods, a 20-minute service between peaks and an hourly late night service.

As the proposed route would not be dissimilar to most other tram routes in Melbourne there were several trip pattern features already able to be predicted with some accuracy. These include the ratio of peak to counter-peak passenger flows and the ratio of peak to all-day travel. This allowed some simplifications to be made as only trips on city bound trams needed to be modelled and only peak patronage need be derived. Several of the patronage estimating methods discussed in the previous section are currently being tested by their suitability for use for this project.

Initial emphasis has been on the category analysis model because of its conceptual simplicity and the relative ease of model testing.

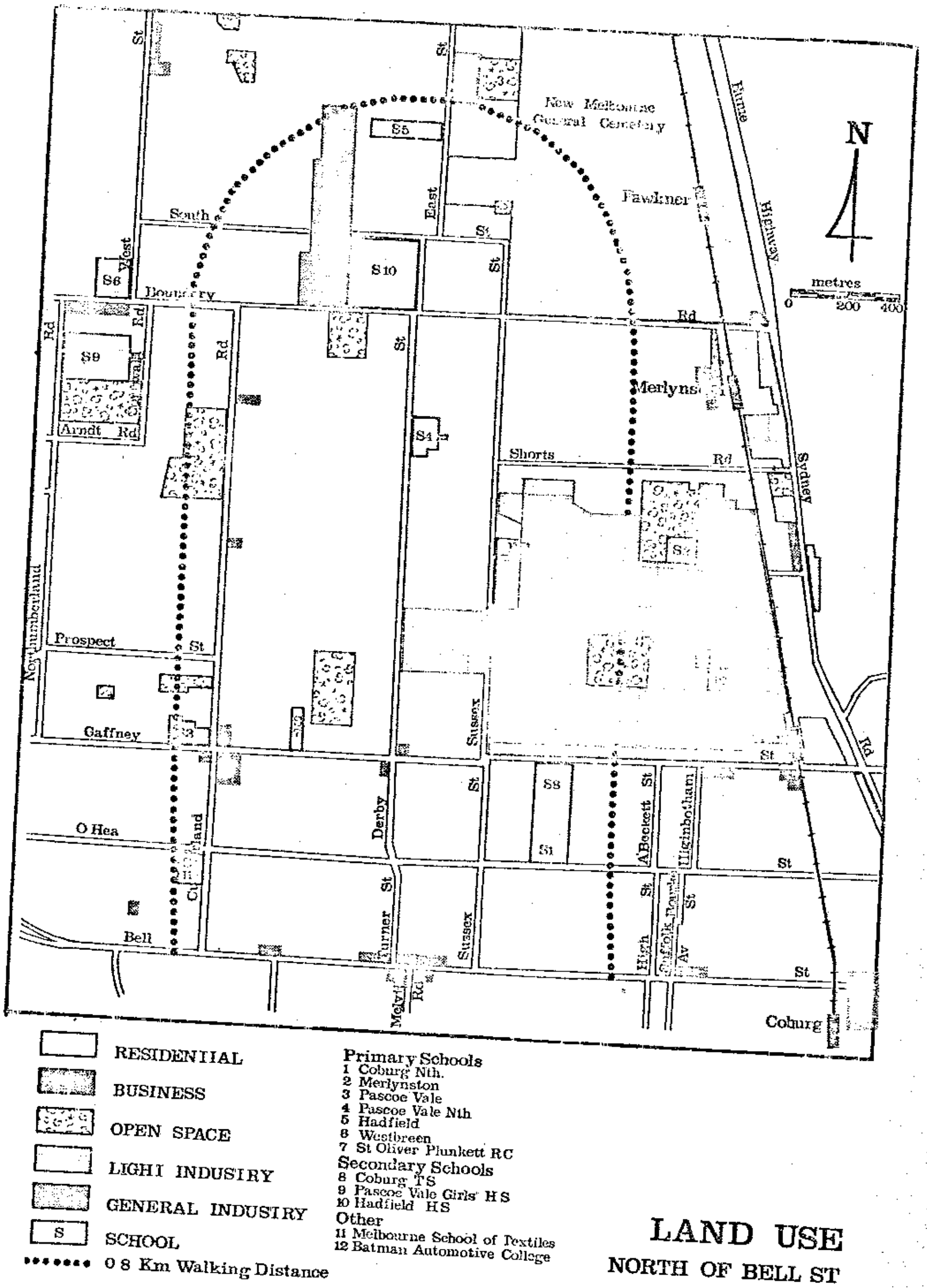

Fig 2 - Area of Proposed West Coburg Tram Extension

The aim was to establish its level of performance as an estimating tool to develop a yardstick by which other more sophisticated models could be measured. A description of each approach and preliminary evaluation results are presented below.

4.2 CATEGORY ANALYSIS MODEL

A category analysis tram trip production model was calibrated by a passenger survey on the northern most section of the existing West Coburg route. This area is demographically very similar to the area of the proposed extension.

On a typical weekday in March 1977 all passengers boarding trams in this section of route between 6.00 a.m. and 9.00 p.m. were surveyed. Due to crowding in peak periods only 85% of passengers were able to be approached and there was an 8% refusal rate leaving 77% of passengers successfully interviewed. Questions included details of the trip and of the household from which the trip maker came.

To determine the catchment area from which these travellers came, and hence to estimate the size of the categories from which they came, an analysis was made of access times to this tram service, and to other services which have been surveyed in the past. The cumulative distribution of walk trip lengths is shown in Fig. 3.

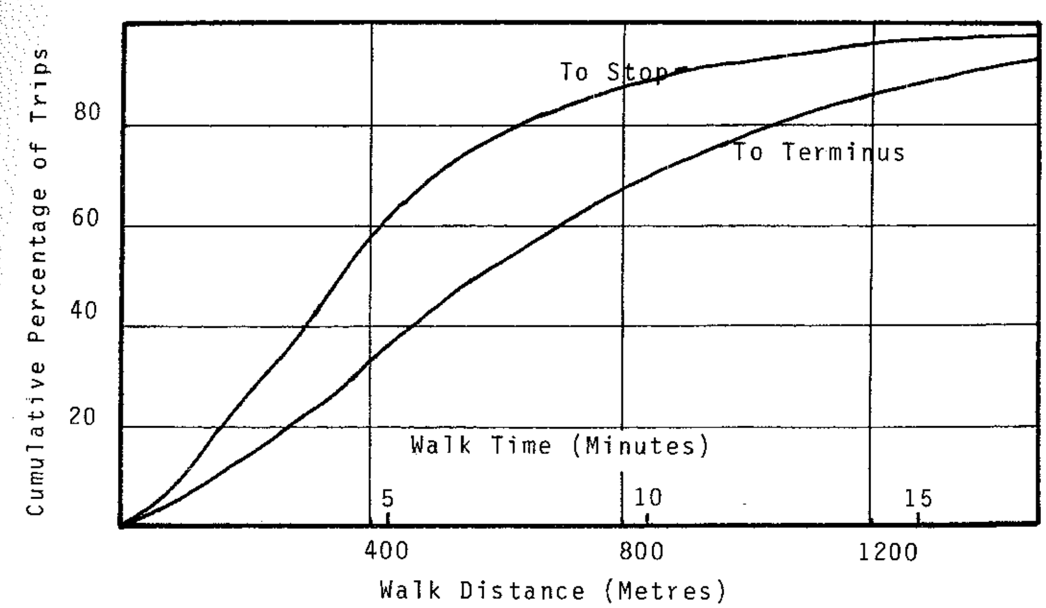

Fig 3 - Length of Walk Trips to Tram Services

A maximum walk distance of 800m to a tram service, or 1200m in the case of a tram terminus, can be seen to include nearly 90% of passengers. Census information was used to find the number of people, by person type, living in the catchment area defined by these limits.

The categories of person-type identified were those defined by usual major activity, car availability, age and sex. Differences in travel patterns for each of the categories will be investigated but it is anticipated that those associated with activity and car availability would be of much greater significance than those due solely to differences in age or sex.

The usual major activity strongly determines the number of trips made daily by all modes; and also influences the likely trip destination. Car availability strongly influences the choice of mode. The activity involving the journey to work was divided into blue and white collar work trips because of the different degree of radial orientation of the work trips. Children of pre-school age and adults involved in house-keeping were grouped together because of their obvious interdependence in travel behavior.

By comparing the number of trips made by each type of person as recorded in the passenger survey with the number of people of that type living in the catchment area, peak period and all-day category trip rates for citybound trips were derived. Trip rates based on "usual major activity" are presented in Table I.

Usual Major Activity	Trip Rate (tram trips per 1000 persons) AM Peak 2 hours	All Day
Blue Collar Worker	23	49
White Collar Worker	115	167
Scholar	55	88
Home Duties and Pre-school Child	2	48
Pensioner	3	21
TOTAL	38	73

TABLE 1

CATEGORY TRIP RATES BY USUAL MAJOR ACTIVITY.

For this route it is clear that white collar workers, frequently working in the CBD, are more likely to use the tram service than any other group. It is their travel that most significantly contributes towards the "peaking" of demand.

When the numbers of people in each of the traveller categories in the catchment area of the proposed extension is determined, and the appropriate trip rates applied, and allowance is made for passenger arrival by bus and car, the best estimate of all-day, two-way patronage was found to be 3,000.

One advantage of this technique is that it incorporates the trips generated by the service itself. This is done by establishing the trip rates in an area already served by a public transport route similar in service standard and direction to the proposed extension and similar in socio-economic status and geographic orientation particularly with respect to distance from CBD. It is a long term estimate for when residential location patterns have adjusted to the accessibility provided by the new service.

The major disadvantage with this approach is that it can only model home generated trips, basically those involving a walk to the service from within the defined catchment area. Passengers arriving by bus or car from beyond this area have to be evaluated separately. Based on patterns of stop access found in other passenger surveys, the numbers of passengers arriving by feeder bus appears to be proportional to the level of service on that feeder route. This is not unexpected as level of service during peak periods reflects the demand for travel. Passenger arrival at stops by car is not a major component of patronage in typical areas where these models may be applied, and typical rates measured on existing routes can be used without introducing major error.

A further disadvantage is that the estimate is not senstive to level of service although, as schedules and pricing will be the same as those in the area in which the model was calibrated, this should not be critical in this case.

4.3 REGRESSION MODEL

The calibration of the model regressing tram trips against land use and demographic features of the area adjacent to the route has been commenced.

The choice of scale at which the model is constructed and calibrated is important. If developed on a stop by stop basis then a more detailed data base is assembled but variance is introduced in terms of inaccurate definition of catchment areas, proximity to end of fare section and the need to sub-divide census collectors' districts to derive the demographic data.

If the model is developed on a section-by-section basis (with a fare section typically being 1.6 km in length) then these potential errors are greatly reduced. However the aggregation of data is wasteful and data collection becomes more time and cost consuming to establish the same number of data points.

As the collection of data on passenger loading patterns is a continuing project within the M.&M.T.B. it was decided to adopt the "section-by-section" calibration approach and to gradually improve the statistical validity of the model as more data becomes available.

It is anticipated that, when sufficient data becomes available, a stepwise regression analysis will be performed that will determine the significant land use and service variables and the degree of accuracy of the optimum model.

The main advantage of the regression model over the category model approach is that it is not restricted to an analysis only of trips generated by households in the catchment area. A single model can incorporate these trips as well as those arriving from outside the direct catchment area and detect any spatial variations in mode usage due to distance from CBD or proximity to alternate public transport services.

The main disadvantages of this method are those associated with calibration and interpretation of the model. A large amount of bus and tram loading data is required for statistically reliable calibration. Since this model is not calibrated for use in any specific area the results are expected to be inferior to the category approach in the West Coburg situation. It has therefore not been given top priority in this project.

Even when operative this model will not be sensitive to changes in level of service.

4.4. DISAGGREGATE BEHAVIOURAL MODEL.

Prior to gaining knowledge of the recent developments in application of behavioural models in Australia, a home interview survey was planned for the area around the proposed West Coburg tram extension. This aimed to establish existing travel patterns and to allow identification of those trips which could be more easily made on the proposed extension than by the existing means. This was to be done by a manual assignment rather than by calibrating a choice model.

A survey of 20% of households in the area of the extension was conducted in a two week period.

From the chosen households completed interviews were obtained in 85% of cases leaving an overall sample rate of 17%. Evaluation proved that this was a sufficient but necessary sample size to adequately establish a matrix of origins and destinations of trips. The appropriate survey area was chosen to be within 800m of the proposed route extending a little further at the terminus. This is the area from which the basic patronage is derived. Trips originating from outside this area, particularly those reaching the service by bus or car, have to be considered separately.

The questionnaire, administered by trained interviewers, gathered information on household structure and travel patterns in a form typical of transportation study interviews. Demographic information from this survey was checked against 1971 Census data for the area and compatability was established with the major variation being an increase in car ownership from 1.17 to 1.30 cars per household in the six year period with the proportion of zero-car households falling from 17% to 11%.

Daily trip rates were 7.3 trips per household or 2.2 trips per person. The 1972 home-interview survey conducted for the MTC showed average trip rates for Melbourne of 7.81 per household and 2.27 per person at that time. Trips currently made with the public transport as the main mode were 20% of the total, a similar figure to the one found in 1972.

The public transport trips were then examined to find which of these could be made more easily on the extended tram route. It was found that 2,100 such trips existed. An examination of trips made by car passengers where the car driver was primarily driving passengers to their destination, for example a mother taking her children to school, found the number of trips which could be conveniently made on the proposed service. Many of these trips are along the proposed new route and would require no vehicle transfers in the future as is the case for use of the present services. No conversion of car drivers to public transport was assumed.

The numbers of passengers accessing the service by bus or car was estimated by the same means as described for the category analysis approach in section 4.2.

When these components were included, the all-day, two-way estimate of patronage was 2,900.

There are several advantages of this type of household survey over the category analysis model to estimate patronage levels. Firstly it provides a full picture of travel patterns.

Peak period and all day information is collected, with detailed information on trip purpose, time of travel, trip destination and present mode of travel. It also facilitates the identification of transport deprived groups with latent travel needs. It is planned that trip rates for various types of potential travellers in the survey area, particularly the aged and those from car-less households, will be compared with those for similar people living adjacent to a tram route.

One major disadvantage of this technique is that trip assignment is made in an ad hoc manner without a sound empirical basis. A further problem is that data collected in this study cannot be used for evaluating other projects in other areas.

Both of these problems could be corrected by using the survey data to calibrate a behavioural choice model. Although surveys would still be required in each area to establish total travel demand levels for all modes, mode choice would be empirically derived and the same choice model used in each case. Although the West Coburg survey was not designed with this purpose in mind, it is felt that the information may be amenable to model calibration.

The degree of compatability between the patronage estimates derived from the category analysis and the home interview survey is encouraging for both methods. A behavioural choice model should have at least comparable predictive powers.

5. GENERAL APPLICATION OF MODELS.

There are two distinct situations in which the above models can be applied. One is the city wide, strategic situation in which a wide range of possible changes to the public transport network are evaluated. In this situation, because of the large number of applications involved, the need is for a model which produces quick results at low cost, the aim being to produce patronage estimates with confidence intervals of the order of ± 25%. This situation has been the area in which traditional land use transportation modelling has been used.

The second situation is the evaluation of one specific public transport change in which a higher level of accuracy of the order of 10% is required to assist detailed costing and evaluation work. As the number of applications of this type is more limited, the restrictions on cost and time are less relevant. Although model testing is still proceeding, preliminary results suggest that the category analysis approach, where the model is calibrated in a very similar area, is well suited to the detailed examination of a network change.

We anticipate that a goal of 10% accuracy can be achieved. If the model is to be individually calibrated for each application then the cost in each case would be about $2,500.

To examine the applicability of the West Coburg model to other areas eight tram and bus routes operated by the Melbourne and Metropolitan Tramways Board were divided into 43 sections and patronage estimates were prepared for each. Comparision of predicted and actual loads showed an aggregate 10% error in prediction with an R2 value of 0.50. The effect of distance from CBD was investigated and it was found that a linear distance decay function was most applicable. Inclusion of this variable reduced the aggregate error to 1½% and improved the correlation to an R2 value of 0.62. The error range for any one prediction was ±50%

Individual model calibrations in several different areas should lead to a more stable model and should significantly improve the overall performance of the model. A suitable strategic model could be developed by these means.

The regression analysis model will be better suited to application in the strategic planning situation. As the model is calibrated on a city wide set of data points there will be errors in the estimates as applied to any particular route since many small scale differences in the locality cannot be incorporated. The cost of building a suitable data base for the Melbourne tram network will be approximately $16,000. As discussed earlier much of this data is required for a patronage monitoring project and is already being collected. Once the large data base has been established, the application of the model will provide an immediate patronage estimate for many network changes at low cost. The level of accuracy of the model will be determined by using standard statistical techniques. Since the model has been designed specifically for public transport it is hoped that confidence intervals will be smaller than for other more comprehensive, city wide demand models.

A behavioral model of mode choice could not be applied to a range of transit network changes without surveys in each area to determine existing travel patterns. Although the transferability of behavioural mode choice equations is anticipated, a survey would still be required in each new area to ascertain total travel demand. As each new survey would typically cost about $10,000, this would still prohibit the use of the model as a general strategic technique for widespread use.

As a project evaluation tool the model would have several advantages as outlined above in the introduction to the models. The main problem still lies in determining the generation and distribution of trips but if this can be successfully determined by survey then this approach would be the most suitable for project evaluation.

6. CONCLUSIONS AND PROPOSED FUTURE RESEARCH.

Although testing of these models is incomplete there are several conclusions that can be drawn regarding the techniques most suited to public transport patronage estimation.

For the production of a rational set of route improvements in which many alternatives need to be evaluated and predictive accuracy is not of critical importance, preliminary studies indicate that the simplistic category and regression analysis approaches have potential. Unless further surveys are carried out and broader based category trip rates are derived, the regression model is the most likely to be applicable. This model is currently being calibrated and tested.

For detailed project evaluation the category analysis is conceptually superior to the regression model. Its application to a small scale route change provides both the analyst and the user with a clear picture of the basis of trip patterns and the direct relationship between dependant and independant variables. For these reasons the category analysis model is preferred in this situation to that derived by regression for home-based trips originating in the proposed catchment area.

For trips originating outside the basic catchment area and reaching the route by bus or car, a separate regression model is recommended. This can be calibrated based on data collected in the current surveys and in similar passenger surveys conducted on other routes in the past.

If home-interview survey techniques can be shown to be capable of deriving an accurate picture of travel patterns, then the use of a behavioural mode choice model may prove superior to both these simple models. This would be especially true in cases where level of service and other policy issues are involved.

When testing of these models has been completed the first stage of the patronage modelling project will have been completed. This will allow estimation of the major component of patronage - travel on city-bound services in an area where the basic generator of trips is the household and the route is radial to the CBD.

The first extension of these models will be to develop an ability for them to predict patronage in areas where the area not only produces trips but also attracts a significant number. Such is the case when the route serves schools, hospitals or other institutions.

A regression based trip attraction model, with likely independant variables being densities of employment, school enrolments and retail activity, will be developed. It is hoped that this will allow adjustment to be made to trip production rates along a route so as to be sensitive to the density of attractions along that route.

The final stage of the project is to investigate models for travel on cross-town routes, rather than the radial routes thus far considered. For the category analysis and regression models it is anticipated that trip rates would be lower than those derived for the radial case, in part due to lower levels of service which are provided on these routes. The behavioural model approach, being sensitive to level of service, may already be applicable to this case. The declining relative importance of the CBD in influencing urban travel patterns increases the need to be able to evaluate non-radial services.

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