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LEVEL OF SERVICE EFFECTS ON PUBLIC TRANSPORT PATRONAGE IN THE SHORT-TERM

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ABSTRACT: *A recent research study aimed at measuring the effects of marginal level of service changes on public transport patronage in Melbourne is described. Various analytical techniques for the estimation of level of service elasticities were utilised and an approach using time-series analysis of public transport patronage is described in detail in this paper.*

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LEVEL OF SERVICE EFFECTS ON PUBLIC TRANSPORT

INTRODUCTION

Governments and public transport operators are faced with the problem of achieving a balance between, on one hand, containing the costs of providing services, and on the other providing a level of service acceptable to travellers.

To achieve this balance between the supply and demand for services there is a need to develop techniques for forecasting the effects on operating costs and patronage of relatively small changes in service levels. The forecasting methodologies developed for large scale urban transport planning are not usually appropriate for assessing such marginal changes and more attention is now being given to devising more suitable techniques.

In recent years the Ministry of Transport, Victoria has commissioned several studies oriented towards a greater understanding of the implications or marginal changes in public transport services. This paper describes a component of one of the studies, which was oriented toward measuring the effects of marginal level of service changes on tram, train and bus services in Melbourne

This paper outlines how responses to marginal service changes were measured in a study which had a relatively low budget and was restricted to the use of available data

The paper outlines the several approaches pursued to measure the effects of marginal level of service changes but concentrates on time series analysis as that approach was found to be particularly suited to the budget and data constraints.

The results of the level of service elasticity estimations were less successful than had been anticipated, primarily as a consequence of data limitations and the relative stability of levels of service on Melbourne's public transport over the last few years. However results comparable to those determined elsewhere were obtained and this has prompted the authors to review estimates reported in the literature in light of the Melbourne experience.

THE ANALYTICAL TASK

The study was directed at filling a gap in the techniques available for assessing the consequences of various public transport operating policy changes. Specifically, techniques were required for estimating the patronage changes that might result from changes in service levels, such as frequency, hours of operation, route extensions and reductions, timetabling changes, etc Further, it was desired that as far as possible, such changes should be determined at a route-specific level, rather than on an area-wide basis, in order to be useful for the types of policy that might be considered.

The limited resources available for the study immediately dictated the need to work with existing data sources and readily available analytic techniques. Practically, the requirements outlined above had to be seen as ultimate goals rather than detailed task prescriptions; the quality and availability of data, and the level of analysis that could be undertaken within the relevant constraints, would dictate the extent to which these goals could be met.

The Approaches Possible

In general terms, three types of analytic approaches are possible, the extent to which each could be pursued being dependent on data availability. The first of these is the analysis of cross-sectional information describing travel patterns at a particular point in time. This class of procedures includes both of the familiar approaches to travel demand modelling, aggregate and disaggregate modelling. Responsiveness to changes in service levels is derived from observations of different usage patterns across a wide range of service levels.

A second approach is based on the results of before and after studies, in which responses to known changes in a particular situation are monitored, and used as the basis for estimating future responsiveness

A third is time-series analysis, in which observations of patronage on a particular facility (system, corridor or route) over time are related to the changing influences on patronage over time, which include service level changes (where relevant)

All three approaches were used in the study to some extent. Only aggregate data from the 1976 Census of Population and Housing was available for and amenable to a cross-sectional analysis The results, at a metropolitan-wide level, were used to explore the suitability of this data source for establishing bounds to the results of more detailed analyses. "Before and after" data sources were explored, but the information was not readily amenable to the requirements of the study. The third approach, time series analysis, has much greater potential, given that patronage records for all public transport services existed, albeit at varying levels of quality and detail.

Given the relative abundance of time series data, the availability and ease of application of the techniques for its analysis, past experience with its use in the analysis of the effects of fare changes in Melbourne (Singleton, 1977; Brown and Singleton, 1980), and the lack of other data that could be used as effectively, the study concentrated on this approach. This was not because it is the most appropriate analytic approach for the objectives; rather it was the most potentially useful given the constraints

For these reasons, it is the results of this approach that are reported in this paper.

Time Series Analysis

Time series models of patronage demand relate the levels of patronage over time to a set of influences believed to affect behaviour. The data used may be at any level of aggregation; typically the dependent variable measures total patronage (by system, area or route), while the influences are general ones affecting the entire population rather than individual travellers.

A linear model is most common and has the form:

$$Y_t = \sum_k \beta_k X_{kt} + \varepsilon_t$$

where Y_t = patronage level at period t;

X_{kt} = level of the kth influential variable at period t; the set of variables may also include a time or trend variable denoting unexplained but consistent time-related movements;

β_k = level of influence or effect of the kth variable;

ε_t = a random error term

Model coefficients (β_k) in the general model are readily estimated using multiple regression analysis. Once estimated, these models then yield patronage elasticities with respect to the various influential effects (service, fare etc.) with ease:

$$E = \frac{\partial Y}{\partial X_k} \cdot \frac{\bar{X}_k}{\bar{Y}}$$

where E = the point elasticity of patronage w.r.t. the kth influential variable

∂Y, ∂X_k = partial differentials of patronage and influential variable

$\bar{X}_k$, $\bar{Y}$ = mean of the observations on influential variable and patronage

and the un-normalised partial regression coefficients of the explanatory variables are their partial differentials with respect to the dependent variable.

The models developed may therefore be used in several ways:

(a) to explain the variation in patronage of a particular mode over time

(b) to obtain measures of the sensitivity of patronage to change in various operating policies, e.g. fare or service levels (via direct elasticities)

(c) to predict future patronage levels based on predicted levels of the various influential effects

In the case of the predictive uses, care must be taken to remain within the framework and time-scale for which the model was developed, i.e. to use the models for short-term predictions only. This is particularly true of the use of elasticity estimates, which, being calculated at the mean of the observations, may be irrelevant at the extremities of the demand curve on which they are estimated and certainly will be inapplicable at points on the demand curve beyond the section of curve previously analysed.

REVIEW OF DATA SOURCES

The availability and suitability of the data regarding patronage, level of service parameters and other pertinent factors for Melbourne's public transport service determined, to some extent, the success of the various modelling approaches and constrained the level of detail at which public transport patronage could be modelled.

Ticket sales records by ticket type by week for Melbourne & Metropolitan Tramways Board (M.M.T.B.) services are maintained at a depot level (9 tram and 3 bus depots) and are available for the past several years. With some assumptions, these ticket sales records may be converted to patronage records by ticket type. Overlap of route operations between depots means that patronage records for certain depots should be combined for analytical purposes; the resultant data-sets are at an aggregated level by comparison with the M.M.T.B individual route structure.

VicRail ticket sales records by broad ticket types (singles, returns, weeklies, school terms and periodicals) are available at a monthly level for both the total suburban system and individual stations, although the latter are only available from April 1979. Records are maintained in terms of outward passenger journeys and revenue collected and the equivalent number of passenger journeys are credited to the month of sale for all periodical and school term tickets. Consequently, major patronage "peaks" appear to occur during the year, especially in January/February and no accurate record of rail system patronage by all ticket types is available. Various methods for "smoothing" these periodical ticket sales records were tested, whereby the effect of the tickets was spread over the period of their validity, but unfortunately with little success.

Monthly records of passengers carried on private bus services, revenue and kilometres run are maintained by the Transport Regulation Board (I.R.B.) for some 140 routes or groups of routes operated by approximately 70 private bus operators in Melbourne The patronage record does not differentiate between passenger or ticket type, total passengers only being recorded.

The identification of appropriate measures of level of service (LoS) on public transport facilities is a difficult task. Some possible LoS measures and their likely success in capturing the LoS effect on public transport patronage are discussed below.

DETERMINING LEVEL OF SERVICE VARIABLES

In a research project designed to investigate the sensitivity of public transport patronage to level of service effects, explanatory variables which encapsulate these effects are obviously a prerequisite as an input to the demand function Whilst there is a general agreement that quality of service is at least as important as fare in influencing (potential) public transport passenger's decision-making, there is a lack of consensus as to which aspects of service "quality" should be measured in the demand function, as the term tends to mean different things to different people. Furthermore, there are often real decifiencies in the data available to measure such effects and major complexities involved in the collection of such data.

Level of Service Measures as Perceived by Passengers

When considering public transport travel, the passenger will tend to perceive several components of service quality: walking, waiting and travel time may be quantified but several qualitative factors such as comfort, safety, security etc., will also influence decision-making. The latter are seldom included in demand functions because of this problem of quantification. The former are obviously suited to the "generalised cost" approach, in which quality of service and travel cost (fare) factors are combined in a generalised cost framework Although the level of service measures discussed above are obviously those of most relevance to the travel decision process, being those factors perceived by the traveller himself, it is a fact that data on level of service which is readily available tends to be collected by the public transport operators and therefore reflects those factors perceived to be of importance by the latter. "One-off" studies may be conducted to collect information on level of service relevant to the passengers' perceptions but this approach was not of relevance to this particular project

Level of Service Measures as Perceived by the Suppliers

The supplies of public transport services (the operators, political decision-makers and transport planners) all require fairly precise measures of level of service supplied but as previously stated, these may take a different form to those perceived by the passenger. Commonly used indicators of level of scheduled service are effective running speed, vehicle kilometres run, service frequency, network coverage, hours of operation and route and timetable design. Of these, vehicle kilometres run is probably the best overall measure of the "goodness" of a public transport system and is comprised of data regularly collected by the operators.

The statistic may reflect "scheduled" or "actual" kilometres run and care must be taken in identifying which particular form of LoS measure is captured by the variable.

The vehicle kilometres run variable represents a single quantity summarising the speed, frequency, period of operation, number and length of routes operated. Thus the number of vehicle-kms operated can only be an approximate measure of LoS as seen by the passenger. Within a given total, the operator may allocate vehicle-kms in different ways and so change the balance between the several different aspects of service of importance to travellers. Moreover, it should be recognised that the comments above relate to the quality of scheduled service only; actual service provided, and specifically its reliability, will be of particular relevance. Desirably, separate measures of scheduled and actual LoS should be available in order to fully assess the influence of LoS on public transport patronage. (The number of "lost" vehicle-kms is often recorded as a measure of service unreliability).

Level of Service Measures: Available Data

Vehicle kilometres run are recorded by both the M.M.T.B. and private bus operators and, hence, are available to measure level of service on these systems M.M.T.B. vehicle kilometres is recorded as actual vehicle kilometres run, computed from the total hours out of the depot divided by an assumed running speed. It is therefore influenced by variations in running speed caused by, say, traffic congestion. Furthermore, the computed value (actual vehicle kilometres run) is sensitive to a number of other influences that may cause a difference between scheduled and actual vehicle kilometres run, namely the effects of strikes, short running, vehicle break down etc If the occurrence of strikes is to be included in the model as an influence separate from level of service, the latter should be included as scheduled level of service. This may be achieved by factoring up actual vehicle kilometres in proportion to the time lost due to strikes.

Vehicle kilometres run on private bus services are recorded as scheduled vehicle kilometres (route length by scheduled numbers of trips) which avoids the problem outlined above.

Adequate measures of train level of service proved more difficult to obtain. Only very crude measures of scheduled level of service were available: the number of train sets required to operate the timetable in the peak period and the number of trains scheduled to arrive at Flinders Street station during the day. The difference between scheduled and actual level of service was measured by the total number of train cancellations in the peak period and the number of cancellations over the day

DEVELOPING TIME SERIES MODELS OF PATRONAGE LEVELS

Time series models of patronage levels were developed for M.M.T.B. train and bus services, private bus services, and VicRail suburban services. The objective of this exercise was the derivation of patronage elasticities with respect to level of service and not the derivation of the parameter estimates themselves. It is nevertheless necessary to discuss the development and the resultant models, as these aspects critically affect the values and appreciation of the elasticity estimates obtained

Analyses were undertaken for 3 public transport systems, a number of different fare categories, and a number of routes. This analysis cannot be reported in detail; instead, only a brief summary of the data used and the results obtained for each is given. Full details of the model development programme may be obtained by reference to the report of the research study (Ove Arup Transportation Planning, 1981).

Model Form

Models estimated for the 3 systems had a common form, described below:

$$PAT = CONSTANT + \sum_j a_j\, LoS_j + bFARE + cTIME + \sum_j d_j OTHER_j$$

where PAT = system patronage
LoS = measure or measures of level of service
FARE = average public transport fare
OTHER = variables representing the travel environment, such as the number of strikes, average income, number of workdays and school holidays in each period

The variables included in the models are discussed in greater detail below, being based in general on those variables used in earlier work by the authors (Singleton 1977, Brown & Singleton 1980).

Variables

Level of Service. As discussed above, level of service on private bus and M.M.T.B. services is measured by vehicle kilometres run (adjusted for strikes in the case of the M.M.T.B. measure). Two measures of level of service on VicRail services are available: the number of train sets required to operate the timetable in the peak period and the number of trains scheduled to arrive at Flinders Street station during the day. The difference between scheduled and actual level of service was measured by the total number of cancellations in the month and the number of cancellations during peak periods.

Fare. In all models travel "cost" was represented by the average real fare, obtained by dividing total revenue by total patronage and dividing this by the Melbourne C.P.I. for the relevant period.

Other. The other variables available for inclusion in the models varied between systems. All models included the effect of strikes: for M.M.T.B. and VicRail services the number of strikes on the relevant system was used; because of the rail feeder role performed by many private bus services, it was felt the occurrence of rail strikes would markedly affect private bus patronage. Accordingly, the number of rail strikes was included in the models of private bus patronage.

The numbers of workdays and school holidays were included to capture the influence of commuters and school children on public transport patronage. Time was included in all models to capture the effect of those excluded influences that vary with it. However, its inclusion is complicated by the high correlation it exhibits with other variables used in the models

An attempt was made to capture income effects through the use of average disposable income, deflated by the Melbourne C.P.I. Motor costs - as measured by the motor cost component of the C.P.I. divided by the Melbourne C.P.I. - were initially included but consistently proved not significant.

Previous studies have indicated the significance of weather effects and it was attempted to capture these through the use of a variable measuring the deviation of the period mean temperature below the annual mean.

Patronage. The level at which patronage records are readily available differs between the modes: M.M.T.B. patronage records are kept at a depot (each covering a number of routes) and ticket denomination level; VicRail patronage records are kept at a system wide level for five ticket types; private bus patronage information is kept at a route level.

Models

M.M.T.B. Tram and Bus Services

Models were estimated for five depots and for several ticket denominations at two of the depots: however, not all of the models are reported here. Three models are shown in Table 1; two are models of total depot patronage while one is of an individual ticket denomination. The level of success achieved by all three models is high, with all coefficients entering the equations with the expected sign. Interestingly, fare is not significant in any model.

Level of service is measured by service kilometres run, divided into weekday service kilometres and weekend service kilometres. In all cases the weekday level of service measure is significant and weekend level of service measure is not. Weekday Service elasticities vary between 1.4 and 0.8. The results indicate a highly inelastic response to weekend level of service.

VicRail Suburban Services

Various LoS measures were tested in time-series analysis of total suburban rail system patronage but all failed to achieve statistical significance. In addition, two measures of service unreliability (peak period and all day train cancellations) failed to achieve statistical significance and in the majority of instances entered the model with the "wrong" (positive) sign. Consequently, it has not been possible to estimate LoS elasticities for VicRail suburban operations.

T.R.B. Private Bus Services

Models of patronage for two metropolitan private bus routes - one (route 451) serving a rail station in the western suburbs with little competition from other public transport modes; the other (route 601) serving the south eastern suburbs in competition with both train and tram services - are shown in Table 2. It will be seen that the incidence of train strikes decreases patronage on the former and increases patronage on the latter, a result consistent with their apparent functions. Service elasticities vary widely, with the elasticity on route 601, which competes with other modes, being quite high. This pattern was observed in all the models of private bus patronage estimated.

REVIEW OF REPORTED LoS ELASTICITIES

Table 3 lists a range of service elasticity estimates obtained by Australian researchers. Both time-series and cross-sectional techniques are represented and elasticities calculated with respect to a wide range of LoS parameters. In general, the time-series studies yield significantly higher elasticities with

TABLE 1: SELECTED M.M.T.B. PATRONAGE MODELS

(t statistics in brackets)

Variable	East Preston Tram	Camberwell Depot - All	Camberwell Depot - Adult City Plus Adult 1 Section
Weekday km	5.690 (6.165)	3.143 (5.152)	0.226 (4.548)
Weekend km	-3.844 (1.005)	0.139 (0.074)	0.010 (0.072)
Fare/C.P.I.	-1.454 (1.200)	-1.335 (1.172)	-0.110 (0.982)
Strikes	-7.935 (3.771)	-4.813 (2.980)	-0.373 (2.834)
Workdays	0.098 (0.010)	7.245 (1.153)	0.950 (1.854)
School Holidays	-1.723 (1.785)	-2.520 (3.452)	-0.205 (3.445)
Time	-2.330 (2.672)	1.518 (1.767)	-0.362 (5.572)
Income	-869.139 (1.128)	-771.165 (1.133)	-33.318 (0.561)
Temperature	-9.113 (2.637)	7.385 (2.528)	-0.326 (1.347)
Constant	573.267 (1.233)	682.206 (1.626)	38.764 (1.096)
$\bar{r}^2$	0.726	0.890	0.930

Service Elasticity and 95% confidence intervals*

Weekday km	1.425 ± 0.453	0.913 ± 0.339	0.780 ± 0.332
Weekend km	-0.119 ± 0.232	0.009 ± 0.212	0.008 ± 0.198

*Note: 95% confidence intervals on elasticities derived from 95% confidence bounds of parameter estimates

TABLE 2: SELECTED PRIVATE BUS PATRONAGE MODELS

(t statistics in brackets)

Variable	Route 451	Route 601
km	0.434 (3.520)	2.482 (4.335)
Fare/C.P.I.	-39027579. (2.853)	-6809464.8 (1.158)
Train Strikes	-192.717 (1.192)	510.161 (2.829)
Workdays	2903.057 (4.857)	513.957 (0.469)
School Holidays	-920.580 (11.466)	-733.68272 (8.698)
Time	-472.169 (6.307)	-509.756 (7.047)
Income	963.492 (1.574)	35.429 (0.051)
Temperature	-742.302 (2.112)	-788.587 (2.245)
Constant	17716.916 (0.439)	-14963.239 (0.305)
$\bar{r}^2$	0.866	0.819
Service elasticity and 95% confidence intervals	0.261 ± 0.145	1.235 ± 0.558

respect to vehicle kilometres than do the cross-sectional studies to headways or access time. Whilst elasticity estimates for these three LoS effects would be expected to be of similar magnitude, cross-sectional studies ought to produce higher elasticity values than those obtained from time-series assessments, because of the longer-term nature of the travel choice situation analysed. This apparent reversal of expected relative magnitudes of elasticity estimates is discussed in detail below.

The reader should note that Table 3 is taken from the "Demand for Public Transport", T.R.R.L., 1980; reference to the work of particular researchers may be obtained from that report. The latter is an extensive reference on LoS elasticities derived by the various types of analysis previously discussed and by researchers throughout the world. Additional information may be obtained from "Transit Service Elasticites", Lago et al, Journal of Tranpsort Economics and Policy, 1981.

Constraints Inherent in the Service Elasticity Estimation Processes

Time-Series Analysis

All time-series studies of the type undertaken by the authors and those by others reported above are subject to the problem that changes in LoS may both cause and be caused by changes in demand i.e. supply and demand are not independent and observations of the relationship between patronage and LoS are likely to contain both demand and supply elasticity effects. This is likely to occur because in the situation of declining public transport patronage generally prevalent, operators will tend to reduce services supplied as patronage falls in order to minimise operating costs. Consequently, some portion of the correlation between LoS and patronage is likely to result from this source rather than from the effect whereby a decrease in LoS causes a drop in patronage. To a lesser extent, the same problem may exist in situations of increasing patronage, in that a rise in LoS supplied may be as a result of patronage increase rather than as a factor in producing it. Such interdependence of supply and demand will cause service elasticities to be overestimated.

If it can be shown that supply-side decisions are made independently (in time) of demand-side influences than it may be assumed that the demand function can be identified and the influence of LoS on demand estimated. Naturally it is also assumed that supply "exceeds" demand in peak demand periods in order that the demand function remain unconstrained by supply-side influences; the decision as to what level of supply constitutes a "supply exceeds demand" situation is obviously complex and will depend upon decisions as to vehicle capacities (or level of service) i.e. whether standee passengers are to be accepted as a characteristic of travel within system capacity.

TABLE 3: SERVICE ELASTICITIES IN AUSTRALIA

Elasticity with respect to:	City	Estimate	Notes and references
vehicle-kms	Melbourne	+1.03	tram)Time-series
		+1.18	private bus)study by
		+1.23	MMTB bus)Singleton
vehicle-kms per capita	State capitals	+0.63, +0.67	bus)Time-series study
		+0.92, +1.10	rail)BTE
route-km per capita	Sydney	+1.3	))Time-series study
vehicle-km per route-km (ie frequency)	Melbourne	+1.3	bus + tram)by Shepherd
	Adelaide	+0.5	rail)
	Brisbane	+1.2	rail)
headway	Brisbane	-0.19	hypothetical "before-and after" Duns and Gibbings
wait time	Perth	-0.07	cross-section, Shepherd
	Sydney	-0.10	cross-section, Hensher
access time		-0.15	cross-section, off-peak Bureau of Transport Economics
access time	Perth	-0.13	cross-section, Shepherd
access time	Sydney	-0.10	cross-section, Hensher
in-vehicle time	Sydney	-0.28	cross-section, Hensher
in-vehicle time	Sydney	-0.22	cross-section, Smith
in-vehicle time	Sydney	-0.11	car/bus modal split, Barnard
		-0.16	car/rail modal split, Barnard
in-vehicle time		-0.17	cross-section, off-peak, Bureau of Transport Economics
in-vehicle time	Perth	-0.30	cross-section, Shepherd
door-to-door time	Melbourne	-0.12	cross-section, Shepherd
door-to-door time	Sydney	-0.37	cross-section, Hensher
door-to-door time	Brisbane	-0.25	hypothetical "before-and after" Duns and Gibbings

In the Melbourne situation, it seems safe to assume that current levels of the supply function are based on previous policy and financial decisions, which are in turn based on previous patronage levels of the system. Similarly, it is apparent that in the majority of cases, supply exceeds demand for all but a small proportion of peak periods. Consequently, the estimation of a demand function may generally proceed in the knowledge that supply and demand effects have been separately identified. Given a lack of knowledge of the environments in which the various other Australian (and overseas) studies were undertaken, it is not possible to state whether those reported service elasticity estimates are free of this influence.

A major constraint on the reliability of the service elasticity estimates made by the authors using time-series analysis is the lack of significant level of service change over the period of analysis. Since 1975 the LoS supplied on Melbourne's tram, train and bus services has declined marginally but without any fundamental changes to the hours of operation or service headways. Obviously more reliability could have been placed on elasticity estimates based on significant LoS alterations; the elasticities estimated, although derived from statistically significant parameter estimates, are less convincingly founded in causal terms.

Cross-Sectional Analysis

Cross-sectional studies of both aggregate and disaggregate data may be subject to the same problem of dependence between supply and demand effects as encountered in time-series analysis. Areas of high demand for public transport services will tend to be well supplied with public transport capacity and although information on car-ownership and income will help to control for this cyclical effect, some incorporation of the reverse effect of demand on supply is inevitable in aggregatelevel cross-sectional studies. In disaggregate studies, the problem will persist at the individual traveller level unless the demand function is adequately specified. For instance, public transport demand will decrease as distance to the public transport stop decreases; if "distance to the stop" is not included as an explanatory variable then this effect will tend to be picked up by LoS provision as an aggregate measure. However, it is likely that much of the former influence is due to the matching of supply to demand, whereby routes are more widely spaced in low demand areas and households wishing to avail themselves of public transport services tend to locate close to the public transport route. This interdependence of supply and demand will cause the values of service elasticities to be overestimated.

Cross-sectional data reflects travel patterns established over a long period of time and consequently it is likely that factors other than LoS and journey cost are influential in explaining observed public transport demand levels. Furthermore, it is likely that previous values of the LoS and journey cost variables will have been influential in setting current demand levels. It is possible to remedy this situation by incorporating appropriate variables in the demand function and by collecting data over time such that variation in the explanatory variables in space and also over time may be encapsulated within the model. Nevertheless, it is apparent that various potentially erroneous influences may have affected LoS variable parameter, and consequently elasticity estimates obtained via cross-sectional studies.

CONCLUSIONS

Estimations of LoS elasticities for Melbourne using time-series analysis have yielded similar results to those derived by various other Australian researchers and to those derived worldwide and reported in the two main source documents previously referenced (T.R.R.L., 1980 and Lago et al, 1981). However, the LoS elasticities reported herein have been derived for a period when actual changes to public transport levels of service were relatively small and hence the results must be considered as being less reliable than those measured as a consequence of some defined change in LoS. Given the general lack of information in the literature as to the magnitude and scope of the LoS changes upon which elasticity estimates have been based, it would appear advisable to treat all LoS elasticity estimates based on non-experimental data sources with caution. The need for caution is accentuated by the potential errors inherent in time-series and cross-sectional approaches to elasticity estimation discussed previously.

It is recommended that further estimation of LoS elasticities be based on carefully structured monitoring of "experimental" situations i.e. specific service withdrawals or improvements, service "demonstration" projects etc. In this way, patronage response to identifiable (and "real") level of service changes may be measured.

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