URBAN TRANSPORT FUNDING AND PRICING

by

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CONTENTS

APPENDICES

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CHAPTER 1 INTRODUCTION

OBJECTIVES

This thesis is concerned with determining economically efficient price and investment levels for urban transport services in Adelaide, South Australia. The bias is towards services provided by the State government and its instrumentalities: urban arterial roads and urban public transport services (bus & rail).

Both roads and public transport services are subject to severe peaks. The economic models applied are thus based on peak load pricing theory. Differential fares currently exist on public transport services in Adelaide, in part recognition of the capacity costs imposed by peak users of the services. There is no such time variation in charges for the use of roads.

There is little or no attempt at economic justification of levels of funds made available for roads and public transport. The outcomes are in general the result of institutional and financial factors including the level of Commonwealth grants, financial pressures from other State government expenditure areas, and the desire to maintain particular workforce levels. It would be purely coincidental if these factors produced the economically optimum level of funds for urban transport services.

METHODOLOGY

In determining the level of grants to the States for roads the Commonwealth government receives advice from the Bureau of Transport Economics (and formerly the Commonwealth Bureau of Roads)[1]. This advice has been

[1] CBR, Report on Commonwealth Financial Assistance to the States for Roads 1969, CBR (Melbourne 1969)
- , Report on Roads in Australia 1973, CBR (Melbourne 1973)
- , Report on Roads in Australia 1975, CBR (Melbourne 1975)
BTE, An Asssessment of the Australian Road System 1979, AGPS (Canberra 1979)

based on comprehensive benefit cost analysis of proposed road improvements in Australia, although the suggested total levels of spending on roads have never occurred [2]. This seems to indicate the use of an incorrect technique for justification, or incorrect use of the technique [3]. Kolsen pointed out the difficulties of applying the technique where prices were not charged:

> "Properly interpreted, benefit/cost studies simulate the workings of the price mechanism.
>
> Unfortunately, there are very great difficulties here, because the information on what users would be willing to pay is not easily obtained unless users can actually be made to pay it, and because substitutes for actual data are frequently of a nature which subject the supply of road space to criteria very different from those applicable elsewhere in the economy. The use of the appropriate area under the demand curve as a measure of consumer benefit is a popular device. Its unqualified use (now rare, but not unknown) implies that the rest of the economy consists of perfectly discriminating monopolists" [4].

Where prices are not charged, investment decisions tend to be made separately from pricing decisions. There are no prices as such charged for road use on most Australian roads, although there are many and varied charges on road use [5]. The effect of this lack of prices (or prices below cost) should be incorporated into the benefit cost framework. As Blackshaw has noted:

> "...the recommended procedure for calculating user benefits to new traffic is to sum perceived benefits (changes in perceived costs) adjusted for perceived cost/resource cost differences. However, the procedure in respect of "normal" traffic (which would have used the facility with or without the improvement) is simply to take the change in resource costs associated with that traffic, and to ignore the effects of inappropriate

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[2] BTE, ibid, Chapter 6.

[3] J. Stanley & D. Starkie, "Evaluating Investment in Rural Local Roads", <u>7th Australian Transport Research Forum</u> (Hobart 1982)

[4] H.M. Kolsen, <u>The Economics and Control of Road-Rail Competition</u> (Sydney University Press 1968), p.89.

[5] Fuel taxes and tolls are the only charges which can be considered prices for specific use of a road.

> pricing policies so far as that traffic is concerned. Thus if price or perceived cost understates true social cost (as is common for use of inner city roads, for example), "normal" traffic is excessive, yet resource cost savings are applied to that level of traffic, not the lower level of traffic which would use the roads if proper road pricing applied. Thus, the project is being credited with many cost savings (lower time and vehicle operating costs from reduced congestion) which could have been achieved in the first place by proper pricing" [6].

The approach adopted in this thesis is to use an economic model which simultaneously determines the price and investment levels for urban arterial roads. The basis of the model is that the road system should be expanded to the point where marginal cost of the expansion equals the marginal benefit of the expansion. This is basically what a benefit cost analysis attempts for individual road projects, but in general uses average rather than marginal cost as the price of road use. There will be a difference between the two because of the congestion externality associated with road use.

Once the optimum road situation is determined, a similar analysis could then be undertaken for urban public transport services. (The same difficulties in applying the benefit cost technique would occur for public transport improvements as prices are below cost). This analysis is not performed for two reasons: firstly it is unlikely that the optimal road prices can be charged in practice; and secondly the private and public modes are subsititutes so interactions between the two should be taken into account.

The approach taken for urban public transport adopts second-best pricing of public transport services, and calculates consequent funding levels. This methodology can be criticized as it results in higher levels of output for both roads and public transport than the

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[6] P.W. Blackshaw, "The Treatment of Cross-Modal Effects in Transport Evaluations" in BTE, Transport Economics and Operational Analysis No.1, AGPS (Canberra 1975), p.42.

charging of marginal cost [7]. Despite this the methodology is pursued. The two models are linked through road system capacity. Most previous applications of second best public transport pricing take as given the existing road capacity and demand. In this application, the optimal road capacity is used rather than the existing capacity, and the second best pricing will determine a demand that makes best use of that optimal capacity (given that prices below marginal cost are charged for road use).

STRUCTURE

The thesis contains six chapters, with this Introduction being the first. The second describes the existing arrangements for transport funding which apply to the State government in South Australia. All modes and both urban and rural expenditure are included in the description. The accounts of authorities and departments are such that it is difficult to dissect expenditures and revenues for the parts considered in this thesis. An estimate is made indicating that urban arterial roads and urban public transport services account for approximately 50% of State government transport expenditure.

The third chapter is a review of relevant literature. The pricing and investment models are taken from the literature (with some modification) and applied in Adelaide. The application of the models and the pricing and service level results are described in Chapter 4. The input data to the models are described in the four Appendices. The model results are then translated into annual funding levels for roads and public transport services. These funding levels are presented and compared with existing expenditures and revenues in Chapter 5.

Finally, weaknesses in and qualifications to the data and model formulation are discussed in Chapter 6.

[7] R. Pryke, A Policy for Transport? (The Nuffield Foundation 1977)

CHAPTER 2 EXISTING TRANSPORT FUNDING AND PRICING

INTRODUCTION

This section describes the existing arrangements with respect to funding of transport in South Australia. The major items of expenditure are on roads and public transport, and this modal view is adopted as it truly reflects the existing situation with respect to transport funding. In most cases it also applies to evaluation of investment programmes where there is little comparison between alternative road and public transport projects.

The chapter covers all State (public) expenditure for transport although the thesis is only concerned with urban funding; this results from the difficulty of separating urban and non-urban portions of transport budgets. Further it is only concerned with effects on the State budget for transport purposes.

Road construction (capital) and maintenance (recurrent) funds are drawn from "revenue" souces, the major ones being Commonwealth government grants and State motor vehicle charges. There is no attempt to treat the road stock as a capital asset and charge depreciation on an annual basis, the accounting is aimed at matching revenues and expenditures in each year [1]. The accounting for public transport services (operated by the State Transport Authority) on the other hand, is along normal commercial enterprise lines with some capital funds being provided through the State loan account and others from internal sources; and operating funds (deficit) through the revenue account. Public transport operating costs are increased by annual capital charges (interest on loans, depreciation and leverage lease payments) in each year. These differences in accounting make comparisons of relative funding levels difficult.

Further information and historical data on roads and public transport expenditures are found in Appendix A.

[1] Although it can be argued that maintenance expenditure is aimed at maintaining the asset in its original condition, and thus there is no need to allow for an additional depreciation element.

ROAD FUNDING

Commonwealth Grants

For the description of road funding the three road categories used for Commonwealth grants are used: National Highways, arterial roads and local roads. National Highways are funded by the Commonwealth government through grants made to the State for this purpose under S.96 of the Australian Constitution [2]. The State may, and does make available funds for National Highways if it feels the Commonwealth grant is inadequate (in 1981/82 the amount was $300,000)[3]. Arterial roads are funded from Commonwealth grants and State sources, while local roads are funded from Commonwealth and State grants and local government sources. In the latter two cases the Commonwealth makes grants largely on the assumption that State and local governments will also make funds available.

Until 1981 a matching quota was specified by the Commonwealth government for the level of State funds required to be spent on roads as a condition of receiving the grant [4]. Table 2.1 shows the quotas required. The relaxation of the quota was partially related to the then Commonwealth government's federalism policy which was aimed at encouraging the States to accept more responsibility for both revenue raising and expenditure [5].

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[2] S.96 reads "During a period of ten years after the establishment of the Commonwealth and thereafter until the Parliament otherwise provides, the Parliament may grant financial assistance to any State on such terms and conditions as the Parliament thinks fit".

[3] From 1974/75 to 1979/80 the State spent between $2.5m (1974/75) and $12.5m (1976/77) on National Highways. BTE, "Australian Road Financing Statistics 1970-71 to 1979-80", Information Paper 3 (AGPS 1982).

[4] Quotas applied to each category of road included in the Commonwealth grants, although local government was not subject to matching provisions.

[5] Another possible step in this policy is that specific road grants be abolished, and absorbed into the general revenue grant from the Commonwealth government to the States. This method of funding roads was favoured by the previous Liberal government (1979-1982) in South Australia.

TABLE 2.1
State and Commonwealth Road Construction & Maintenance Funds and Matching Quotas, 1968/69 to 1981/82 ($M)(1)

Year	State Funds(2)	Federal Funds(3)	Matching Quota
1968/9	16.333	19.432	n.a.
1969/70	18.411	21.000	13.803
1970/1	18.081	23.800	n.a.
1971/2	20.749	25.850	15.196
1972/3	22.347	28.975	15.842
1973/4	24.694	31.702	16.888
1974/5	27.992	31.268	25.400
1975/6	31.996	40.764	33.500
1976/7	41.234	38.800	n.a.
1977/8	41.667	40.400	37.200
1978/9	44.366	43.207	39.790
1979/80	46.706	46.544	42.760
1980/1	51.363	51.686	48.200
1981/2(4)	56.424	56.302	Discontinued

n.a. Not available

Notes (1) Source Highways Department Annual Reports.

(2) Road user charges net of road safety, police traffic services and M.V. Troubridge expenditure plus other income (rent, land sales, etc.) See note (4) and page 12.

(3) Net of Commonwealth planning and research funds, 1974/5-1980/1.

(4) Method of accounting changed. It has not been possible to reconcile the 1981/82 figures with the previous accounting method, thus other income of $9.954m is omitted from the 1981/82 figure for State funds (see Table A.1, Appendix A).

Commonwealth grants for roads in 1981/82 paid under the Commonwealth Roads Grants Act, 1981 were $56.30m, covering the following road categories:

National Highways	$27.24m
Arterial Roads	16.66
Local Roads	12.40
	$56.30m

State Charges and the Highways Fund

The grants from the Commonwealth are paid into the Highways Fund, the operation of which is specified in the Highways Act, 1926-82, Part III. The other major source of road funds, State charges on vehicle users are also paid into the Highways Fund. There are three main charges: motor vehicle registration fees, driver licence fees and a levy on the sale of petrol and diesel fuel. The first two of these charges are collected by the Motor Registration Division of the Department of Transport under the Motor Vehicles Act, and paid into the Highways Fund. Motor vehicle registration fees are charged according to a complicated power/mass formula for different types of vehicles (commercial vehicle rates in general are higher) but in fact represent a simple linear relationship between the fee and the power/mass ratio [6]. Driver licence fees are a flat charge every three years. Collection costs, which are deducted prior to the revenue being paid to the Highways Fund, were $9.538m or 19% of the gross registration and licence fees collections in 1981/82.

The fuel levy is collected under the Business Franchise (Petroleum Products) Act, 1979 which provides for the licensing of persons who sell petroleum products. It is collected by the State Taxation Office of the Treasury Department at a cost of $57,000 or 0.2% of revenue collected in 1981/82 [7].

The fuel levy was introduced in 1979 as a replacement to the former Road Maintenance charge which was a "tonne-km" tax on heavy vehicles. At the time it was introduced motor vehicle registration fees were varied in an attempt to ensure that users of light vehicles did not pay more, and users of heavy vehicles did not pay less with the replacement charges. The structure

[6] Director-General of Transport, Adelaide Urban Transport Pricing Study: 2nd Stage Report, prepared by R. Travers Morgan Pty. Ltd. (Adelaide 1980), p.38. The structure of charges will be simplified on 1 April 1984 when motor cars will be charged based on the number of cylinders, and heavy vehicles on the basis of unladen mass.

[7] Report of the Auditor General and the Public Accounts prepared by the Hon. the Treasurer for the Financial year ended 30 June 1982, p.106.

of charges did not appear to be completely successful in this aim. The fuel levy is a percentage of the declared pump price of petrol (4.5%) and diesel(7.1%) fuels. A legislative procedure is involved to vary the declared pump price [8]. The rates of the charge at the end of 1981/82 were 1.49 c/litre for petrol and 2.53 c/litre for diesel.

Table 2.2 shows the amounts collected from the various State charges on vehicles and vehicle users over several years. It can be seen that the fuel levy has become an important source of revenue and represented 37%

TABLE 2.2
Composition of Road User Revenues 1968/9 to 1981/2(1)

Year	Registration & Licence Fees(2)		Road Mtce Charge		Fuel Levy		Total ($m)
	($m)	%	($m)	%	($)	%	
1968/9	12.533	83	2.557	17	-		15.090
1969/70	13.250	82	2.839	18	-		16.089
1970/1	14.212	83	2.958	17	-		17.170
1971/2	18.001	85	3.287	15	-		21.288
1972/3	18.829	85	3.401	15	-		22.230
1973/4	19.871	84	3.859	16	-		23.730
1974/5	25.841	86	4.050	14	-		29.891
1975/6	27.574	87	4.242	13	-		31.816
1976/7	40.081	89	4.716	11	-		44.797
1977/8	39.848	89	4.825	11	-		44.673
1978/9	42.352	90	4.812	10	-		47.164
1979/80	35.339	70	1.077	2	14.158	28	50.574
1980/81	35.586	64	.050	0	20.167	36	55.803
1981/82	40.210	63	-	0	23.737	37	63.947

Notes (1) Source Highways Department Annual Reports 1968/9 to 1981/82. All amounts are net of collection costs.
(2) Includes funds for road safety purposes, police traffic services and M.V. Troubridge. See page 12.

[8] Declared pump prices were 33.04 c/l for petrol and 35.65 c/l for diesel in June 1982.

of all collections in 1981/82. There was a significant fall in collections of motor registration fees (16%) in the year the fuel levy was introduced (1979) but in total collections increased by 7%.

There are several other miscellaneous revenue items which can be made available for road construction and maintenance. They include rent for properties acquired in advance of road construction, land sales, plant sales, revenue from the operation of the M.V. Troubridge (see below) and a road maintenance payment from the STA[9]; these amounted to $10.864m in 1981/82[10]. Table 2.3 shows the composition of all receipts for 1981/82.

TABLE 2.3
Sources of Road Funds (Net)

Item		Amount ($m)
Commonwealth grants		56.302
Motor Registration fees $44.435m	)	
Driver licence fees $5.312m	)	40.209
Fuel levy		23.737
Land sales		4.431
Rents		3.224
Plant sales		1.349
M.V. Troubridge revenue		1.810
STA road maintenance		.029
Other		.021
Total		131.112

Source: Report of the Auditor General, op.cit., p.104

Road Construction & Maintenance

Expenditures by the Highways Department are largely on the construction and maintenance of arterial roads. Some of the Commonwealth local road grant is given direct to local governments ($8.487m in 1981/82) and the remainder plus some State funds ($473,000 in 1981/82) is spent on local roads by the Highways

[9] This payment was discontinued on 1 July 1982 by the repeal of S.36a of the Highways Act, as the STA pays the fuel levy. The charge was previously justified on the grounds that no registration fees were paid for STA vehicles.

[10] Report of the Auditor General, op.cit., p.104.

Department. Both the Commonwealth local road grant and the Highways expenditure on local roads are included in the Highways Department's reported expenditure [11]. Road construction and maintenance expenditure in 1981/82 amounted to $97.113m, with 65% spent on construction and 35% spent on maintenance.

The amounts expended on the different road categories is shown in Table 2.4. When National Highways are excluded, the proportion of funds spent on construction falls to 57%.

TABLE 2.4
Road Construction and Maintenance Expenditure
by Road Category, 1981/82

Road Category	Expenditure ($m)		
	Construction	Maintenance	Total
National highways	23.481	4.074	27.555
Developmental	.333	-	.333
Rural Arterial	10.152	15.970	26.122
Rural Local	4.773	6.895	11.668
Urban Arterial	21.204	6.922	28.126
Urban Local	3.023	.286	3.309
Total	62.966	34.147	97.113

Source: Report of the Auditor General, op.cit., p.107.

[11] Highways Department Annual Report 1981/82. In 1983/84 a new procedure for allocating Commonwealth local road grants will apply: 40% will be retained by the Highways Department and 60% will be allocated on a formula basis to local governments. The formula for distribution between metopolitan and rural councils will be on the basis of equal weighting of road length and population. The distribution between metropolitan councils will be on the same basis while for rural councils the formula will include those two items plus an allowance for "road effort" (reflecting the amount spent from the council's own resources in the previous year). D. Starkie, "The Specific Effect of Specific Road Grants in South Australia", Australian Economic Papers (forthcoming).

Other Expenditures

Under the Highways Act there are certain statutory requirements regarding the uses of the funds collected from motor vehicle charges. Revenue from the sale of personalized number plates, and one-sixth of the revenue from driver's licence fees are allocated for road safety purposes (Section 32(l)). A proportion of the gross collections of motor registration fees is payable to the Police Department on account of traffic services provided on roads in S.A. by the police (Section 32(m))[12]. The Highways Department is financially responsible for the operation of the M.V. Troubridge which provides passenger and freight service to Kangaroo Island (Sections 31(2)(i) and 32(n)). Expenditure on the service exceeded revenue by $2.1m in 1981/82, and this amount was a charge on the Highways Fund.

Another major payment from the Highways Fund was $10.843m in the general administration of the Highways Department. Miscellaneous payments amounted to $11.996m in 1981/82 and included such items as planning and research, plant purchases and debt charges. The composition of all expenditure in 1981/82 is given in Table 2.5.

TABLE 2.5
Uses of Road Funds 1981/82(1)

Item	Amount ($m)
Construction and maintenance	97.113
Bicycle track construction	0.152
Building and land maintenance and operation	3.303
Planning and Research	1.854
Plant and stores	1.840
General Administration & other expenses	10.843
M.V. Troubridge operation	3.929
Road Traffic Board activities	1.580
Repayment and debt charges on loan funds	1.911
Road Safety(2)	1.049
Police traffic services	4.355
Total	127.929

Notes (1) Source Report of the Auditor General, op.cit., p.104.
(2) $1.049m represents receipts from personalised number plates and allocation for road safety from drivers' licence fees collections. Actual expenditure was $1.53m from current receipts and accumulated funds. ibid p.105.

[12] 9.8% in 1981/82 and increased to 12.5% in 1982/83.

Concessions

Concessions on motor registration fees and drivers' licence fees are available to certain groups of people and fees are not charged to other groups. The revenue foregone from these concessions and omissions was $10.163m in 1981/82, made up as follows [13]:

Registrations	
- primary producers	$ 2.881m
- crown, statutory, local government and other bodies	2.547
- interstate plates	2.613
- pensioners	1.416
- outer area residents, prospectors	.423
Licences	
- pensioners	.283
	$10.163m

In the case of many other concessions a reimbursement is made by the State government on account of concessions, e.g. for public transport, water and local government rates concessions. This is not done for road funding as it would require a payment from general revenue funds to the Highways Fund, whereas with the other reimbursement payments it simply requires transfers between budget lines within the state revenue budget. The cost of the concessions could however be relevant in any comparison of revenues and costs of road use. This would not be the case for all payments above, in particular it is not possible to collect registration fees from holders of interstate licence plates as this is considered to be a restraint of trade under S.92 of the Australian Constitution [14]; also where residents of outer areas are not users of public roads a concession may be justified on the grounds of non-use.

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[13] Report of the Auditor General, op.cit., p. 179.

[14] S. 92 reads "On the imposition of uniform duties of customs, trade, commerce and intercourse among the States, whether by means of internal carriage or ocean navigation, shall be absolutely free..."

Trends in Costs

The amount spent on road construction and maintenance in real terms has fallen in recent years as can be seen from Figure 2.1. The figure is derived from Tables A.3, A.4 and A.5 in Appendix A. The real figures have been inflated to the June 1982 level using the Highways Department road construction cost index. This index rose 19% faster than the CPI from 1968/69 to 1981/82 (see Table B.1, Appendix B).

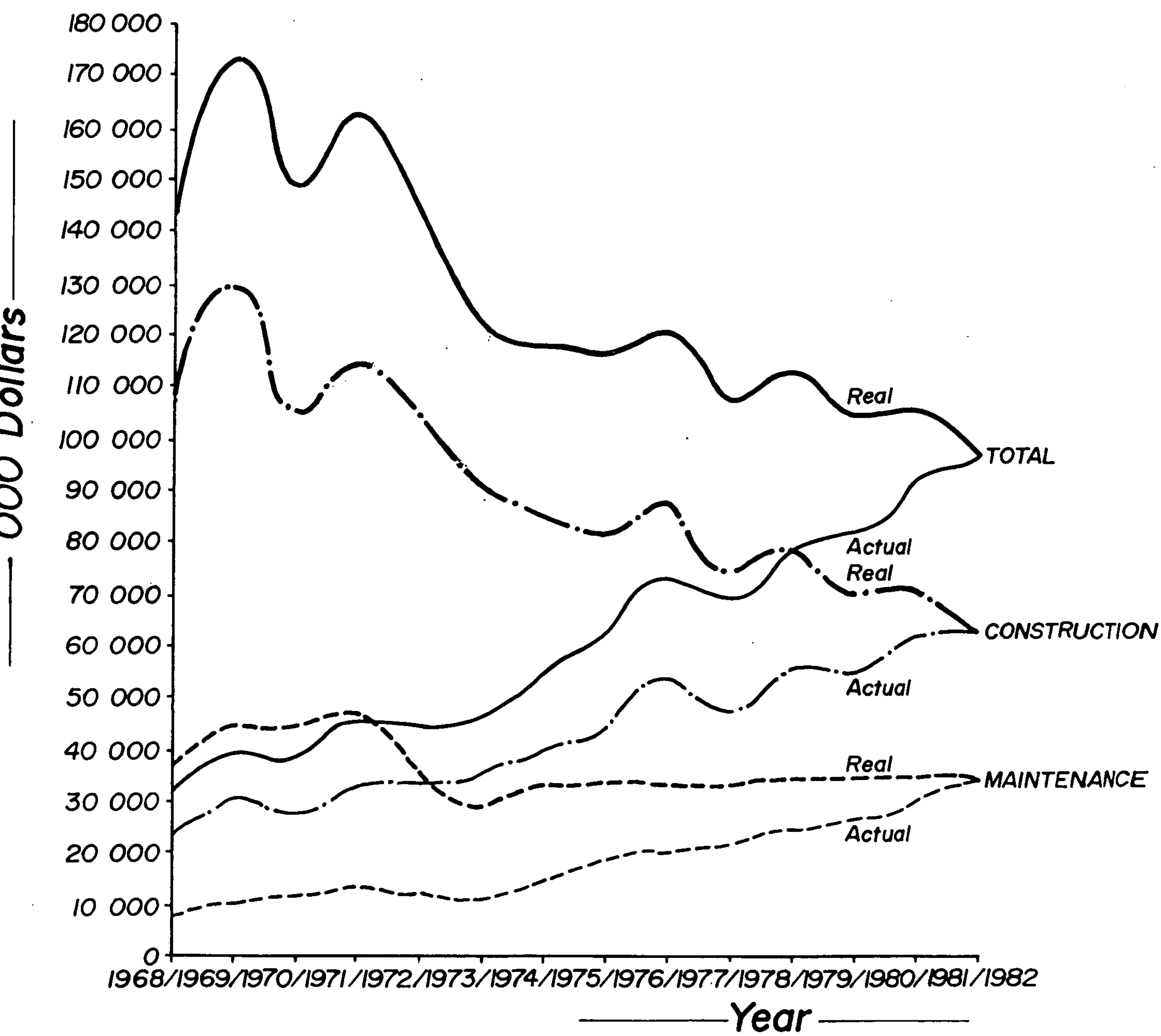

Fig. 2.1 Actual & Real Road Expenditure 1968/69 to 1981/82

PUBLIC TRANSPORT FUNDING

Public transport services in Adelaide are provided by the State Transport Authority (STA) which was established in 1974 by combining two public bodies (one for bus and tram, and one for rail services). Soon after establishment, the STA, on the direction of the government, acquired most private companies operating metropolitan bus services, thus giving the STA a virtual monopoly of regular route public tranpsort services in the metropolitan area. The STA operates one tram route, four main suburban rail routes (with six branch lines) and over 100 bus routes.

Recurrent Funding

Road funding is almost solely from current charges on motor vehicles and vehicle users, and from Commonwealth Government grants administered through a statutory fund. In contrast to this, funding of public transport service is through user charges, and the State Government's revenue and loan accounts. The STA prepares financial statements as a trading enterprise, and any deficit on current operations (including annual capital charges) is funded through the State revenue account. Payments for items of a capital nature have generally been through the State loan account. The different methods of funding public transport make comparisons with road funding levels difficult.

The profit and loss statement for the STA for 1981/82 is given in Table 2.6: costs exceeded revenue by $62.286m, giving an overall cost recovery of 38%. Non-current payments (depreciation, leases and interest) amounted to $12.940m, whilst interest on funds invested amounted to $5.873m. These two items are a result of the method of funding the STA. A grant is made from the revenue account which covers the deficit (or part thereof) on all costs, including non-current items. This means that an amount greater than cash requirements is received by the STA, this amount is then invested and interest earned on the investment. In some years the grant has been more than the deficit, in others less, depending on decisions of the government, presumably taking into account its overall financial position. The accumulated cash reserves of the STA may then be used for capital items.

TABLE 2.6
STA Profit and Loss Statement 1981/82 (1)

Item	Amount ($m)			
Revenue				
Traffic	28.011			
Sundry	3.830			
Interest	5.873			
Total		37.714		37.714
Expenditure				
Traffic	36.654			
Maintenance	24.525			
General Expenses	16.081			
Fuel, Oil & Power	7.629			
Total Operating Expenditure		84.889		
Operating Loss			47.175	
Capital Charges				
Depreciation	5.418			
Lease payments	2.171			
Interest on Loans	7.522			
Total Capital Charges		15.111		
Total Expenditure				100.00
Total Loss				62.286
Comprising:				
- Contribution from Revenue Account				55.350
- Decrease in cash reserves held by STA				6.936

(1) Source STA Annual Report 1982

The first lease payments for the purchase of buses were made in 1981/82. This form of financing is likely to increase in the future so that the potential for the accumulation of cash reserves will decrease along with interest earned on investments; the effect on the STA accounts will be to increase the deficit, although all that has happened is a change in the method of financing rollingstock purchases.

Trends in Costs of Operation

The cost of operating public transport services in Adelaide has increased sharply in recent years. Figure 2.2 shows costs, revenues and deficit from 1970/71 to 1982/83. Figure 2.3 shows the same items inflated by the CPI to 1982 dollars. These figures are derived from Tables A.7 and A.10 respectively in Appendix A. For the years prior to the integration of the STA accounts (1968/69 to 1977/78) the amounts for bus and tram, and rail were simply added together, although the basis of the accounts was different.

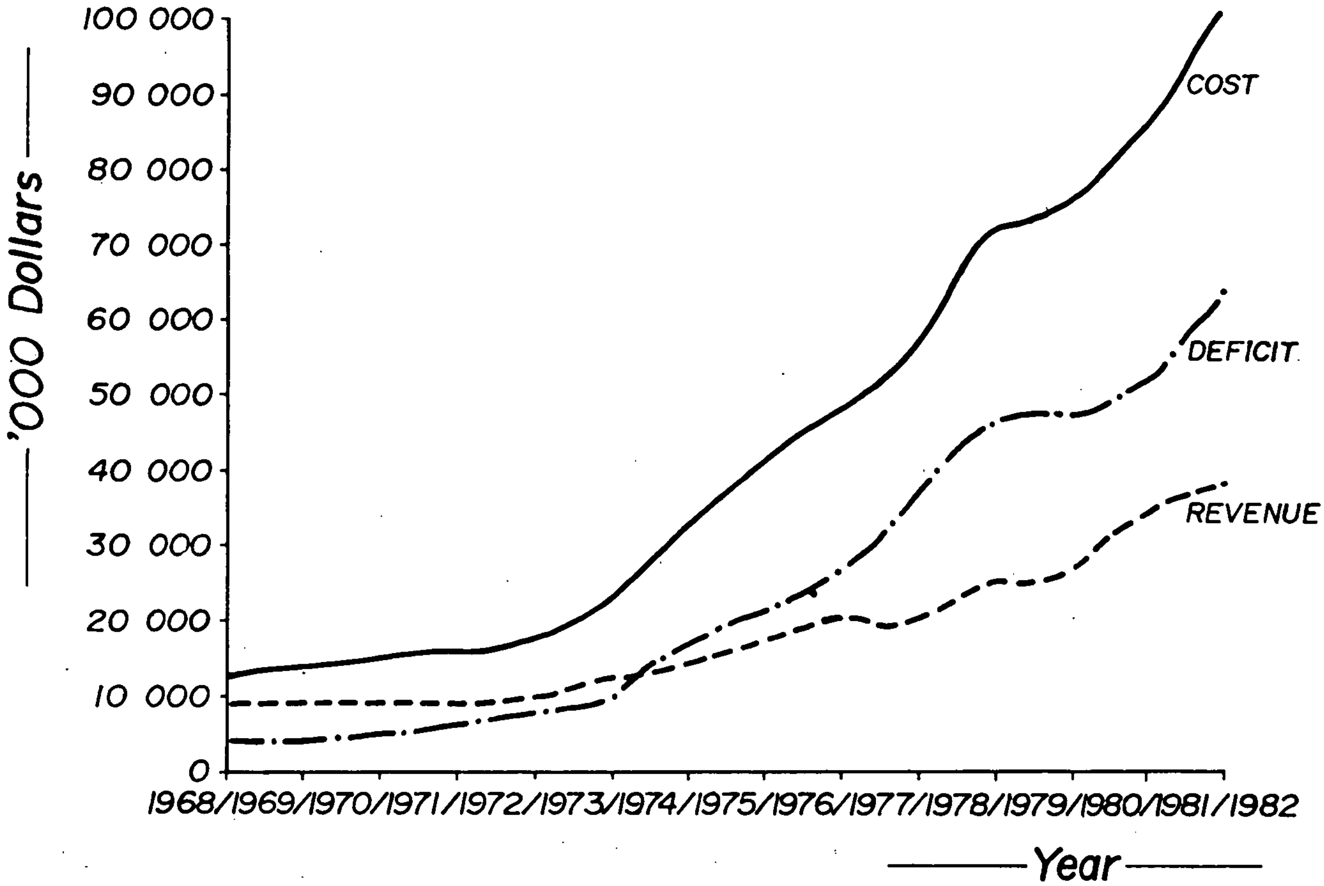

Fig. 2.2 Public Transport Costs & Revenues 1968/69 to 1981/82

Costs have risen at a much faster rate than the CPI, while revenue has remained relatively constant over the same period. The large increase in costs in the mid-1970s was associated with the acquisition of the privately operated bus services in Adelaide by the STA [15]. The acquisition resulted in the STA bus fleet almost doubling in size. The increase in public transport costs constrasts with expenditure on roads which has fallen in real terms (see Figure 2.1).

[15] P.G. Kain, Urban Transport Crisis - A Study of Adelaide Bus Operations in Transition 1967-81, Honours Economics Thesis (unpublished) (Flinders University of S.A. 1981)

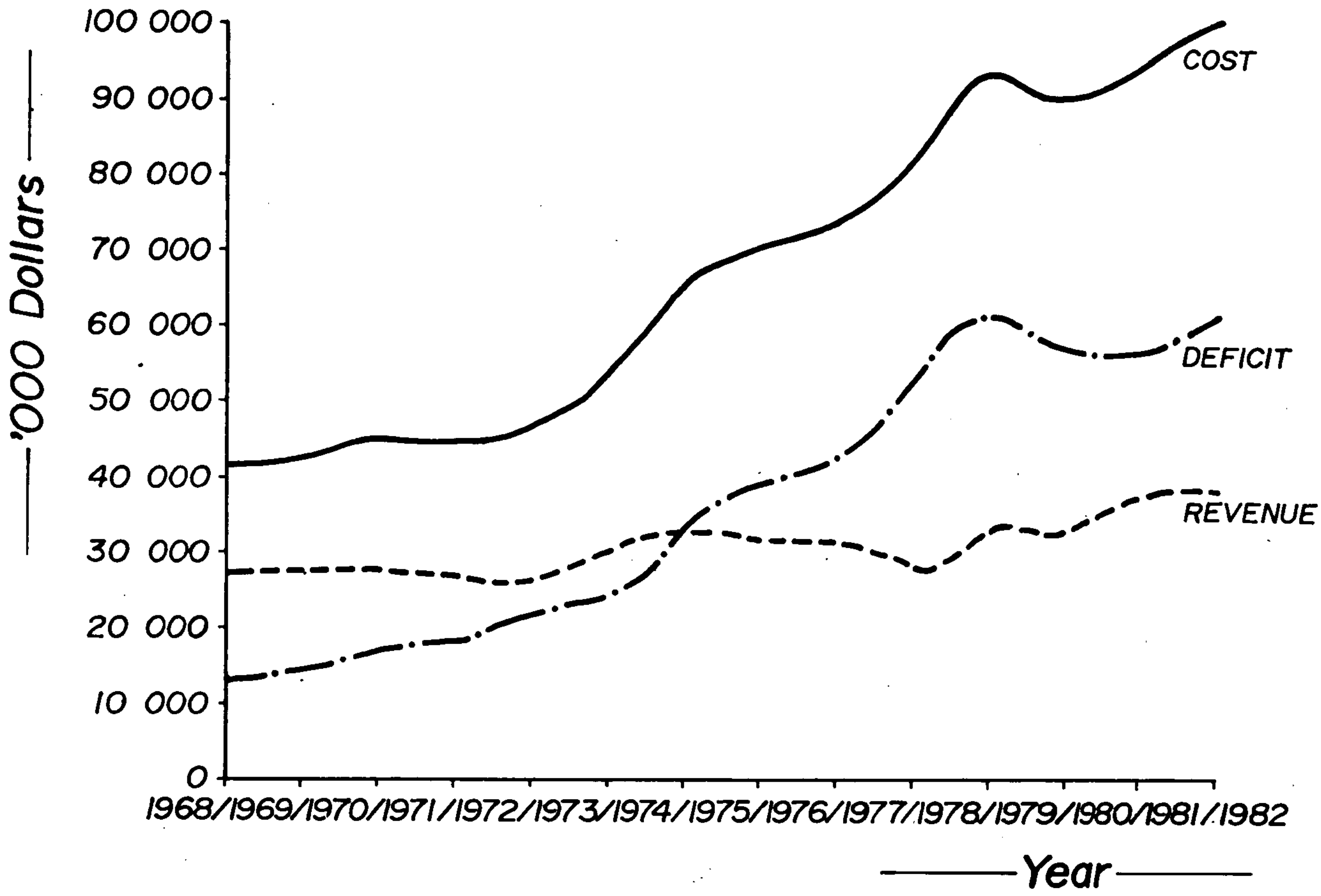

Fig. 2.3 Public Transport Costs & Revenues 1968/69 to 1981/82 (1982 Dollars)

<u>Capital Funds</u>

In 1981/82 the STA held $75.539m in loans from the S.A. loan account and $5.166m in loans from other institutions. New loans taken out in that year however amounted to less than $1m. The capital expenditure of $11.Ø34m was mainly funded from decreases in accumulated cash reserves. Table 2.7 shows the changes in loans, grants, assets and cash reserves for the last four years.

TABLE 2.7
Loans, Grants, Fixed Assets and Cash Reserves of STA
1978/9 to 1981/82 ($m)(1).

Year	Loans		Commonwealth	Fixed	Cash
	State	Other	Grants(2)	Assets(3)	Reserves
1978/9	6.431	0.968	4.089	19.327	34.854
1979/80	16.357	1.156	4.000	21.455	41.995
1980/1	-	1.087	4.500	2.807	38.542
1981/2	-	0.958	-	11.034	29.511

Notes (1) STA Annual Reports. 1978/9 is the first year that integrated accounts are available.
(2) Grants under the States Grants (Urban Public Transport) Act, 1978 were discontinued in 1981/82.
(3) This is the increase in fixed assets, without adjustment for depreciation.

Concessions

Included in the Traffic Revenue of the STA are reimbursements on account of the carriage of passengers at concession fares. In 1981/82 these amounted to $5.755m, and are a payment by the State government in addition to the deficit for the operation of public transport in Adelaide. The reimbursement payments comprise:

Pensioners, blind and incapacitated	$2.860m
Students	2.030
Unemployed	.865
	$5.755m

OTHER TRANSPORT FUNDING

The other major source of expenditure on transport by the S.A. government relates to the operation of the Department of Transport and the Department of Marine and Harbours. The main functions of the Department of Transport are the provision of policy and administrative support to the Minister of Transport, planning & research, collection of motor vehicle fees, road safety, operation of the Government Motor Garage, and licensing of privately operated bus passenger services. The Department of Marine and Harbours constructs and operates the State-owned ports in S.A., and has responsibility for the safe operation of recreational boating and some aspects of the fishing industry.

Department of Transport

The Department of Transport is a net cost to the State revenue budget as the bulk of the revenue it collects is paid into the Highways Fund (after deduction of collection costs). Table 2.8 shows the recurrent revenues and costs for the Department of Transport in 1981/82; there was a net cost to the State revenue budget of $2.454m. Other expenditures are made through the Department of Transport budget and in 1981/82 these were:

- $877,000 from the loan account for planning and research projects [16];
- $3,414,000 from the revenue account for concessionary travel by various groups on various services [17];
- $256,000 from the revenue account for subsidies for the operation of country town bus services [17]; and
- $99,000 from the revenue account for grants for the establishment of community bus services [17].

Department of Marine and Harbours

The Department of Marine and Harbours (DMH) operates six major ports in S.A. and several smaller ports, jetties, etc. The accounts for the DMH are prepared partially along commercial lines. Interest is charged on loan funds used for capital purposes, however there is no charge for the depreciation of capital assets operated by the DMH. In 1981/82 revenue of the Department exceeded operating costs by $8.157m however when capital charges (no depreciation) were included a deficit on operations of $3.649m resulted. This amount is the net cost to the state revenue budget. Loans for capital projects amounted to $5.916m, increasing the total loans to the DMH to $108.261m as at 30th June, 1982. Table 2.9 shows the main revenues and costs for the operation of ports where some state responsibility occurs.

[16] Report of the Auditor General, op.cit., p.177.
[17] ibid, p.181.

TABLE 2.8

Department of Transport Revenue Funds, 1981/82(5) ($'000)

(i) Departmental Operations

Revenue

Motor vehicle fees	49,747		
less Highways Fund	40,209		
		9,538	
Commissions(1)		832	
Road Safety & Motor Transport			
- Highways Fund(2)	1,049		
- Commonwealth grant	19		
- Other(3)	214		
		1,282	
Government Motor Garage		217	
Other		12	
			11,881

Expenditure

Motor Vehicles	8,094		
Road Safety	1,603		
Government Motor Garage	1,380		
Administration	442		
Planning & Research	669		
Departmental overhead(4)	2,147		
			14,335
Net cost to State revenue budget			2,454

(ii) Other Recurrent Expenditures

Transport Concessions(6)

Pensioners	3,078		
Australian National	156		
Incapacitated	145		
Blind	35		
			3,414
Country Town Bus Services			256
Community Bus grants			99
			3,769

Notes

(1) MRD collects fees on behalf of other Deptartments, for which it receives payment.

(2) Actual payment to Road Safety Fund. Expenditure was $1.530m including drawings from previous years collections.

(3) Mainly Licence fees for passenger bus licensing, vehicle inspection fees.

(4) Includes building maintenance, superannuation. Also covers Division of Recreation & Sport which was a Division of Department of Transport from 1979 to 1983.

(5) Source Report of the Auditor General, op.cit., p.176-7.

(6) Other payments for transport concessions are paid through the Department of Community Welfare budget for the unemployed and the Education Department budget for students, giving a total of $6.664m in 1981/82.

TABLE 2.9

Department of Marine & Harbours Revenue Funds, 1981/82(1) ($'000)

Revenue		
Wharfage & Tonnage	14,793	
Pilot Fees	4,207	
Bulk Handling Charges	4,759	
Fishing Industry	187	
Conservancy Dues	1,149	
Total		25,095
Expenditure		
Management	6,367	
Operating & Maintenance	10,047	
Fishing Industry	524	
Total		16,938
Operating Profit		8,157
Debt charges(2)		11,806
Net cost to state revenue budget		3,649

Notes (1) Report of the Auditor General, op.cit., p.124
(2) Includes interest, Sinking Fund Contributions and Superannuation.

USER CHARGES

Many user charges have been discussed above, however other fees do exist which have not been considered as they are not used for transport funding. Some of the charges may be regarded as general taxes, but all are included here for completeness.

State charges on road users are:

- motor vehicle registration fees which vary from $8 p.a. to $3929 p.a. depending on the power mass of the vehicle and whether it is used for commercial or non-commercial purposes. Total collections were $44.435m in 1981/82

- driver licence fees of $24 each 3 years. Total collections were $5.312m in 1981/82

- stamp duty on new registrations and transfer of registrations. Total collections were $21.760m in 1981/82, this amount being credited to the State revenue account [18]

- compulsory third party (CTP) insurance which is solely offered by the State Government Insurance Commission (SGIC). The amount of the charge varies with the class of vehicle (based on accident analysis), and $90.717m in premiums was collected in 1981/82 [19]

- stamp duty on CTP insurance which amounted to $2.013m in 1981/82, is paid into the Hospitals Fund as a contribution to the difference in hospital charges and costs on account of road accident patients [18]

- State fuel levy of 1.49 c/litre on petrol and 2.53 c/litre on diesel. Collections amounted to $23.737m in 1981/82 of which approximately 77% is attributable to petrol. The Commonwealth government also imposes charges on fuel through excise duty and the import-parity levy. The exise in 1981/82 was 6.155/litre (including 1 cent/litre for the ABRD programme) for both petrol and diesel. The collections amounted to $970m throughout Australia in 1981/82.

The only charges on STA public transport users are fares which vary between zero and 90c per journey depending on the class of user, the length of journey, and the time of journey. Revenue from fares (including reimbursements for concession riders) amounted to $28.011m in 1981/82.

Various charges on users of port facilities are made (see Table 2.9). Collections amounted to $25.095m in 1981/82.

Table 2.10 summarises the amounts collected from transport users as state charges in 1981/82.

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[18] ibid, p. 177.

[19] Reserves in excess of $300m are held by SGIC for outstanding claims.

TABLE 2.10
State Collections from Users of Transport Services, 1981/82

Road Users	Amount ($m)
Vehicle registration	44.435
Stamp duty on registration	21.760
C.I.T. Insurance	90.717
Stamp duty on C.I.T.	2.013
Driver licence fees	5.312
Fuel levy	23.737
Total Road Users	187.974
Public Transport Users	28.011
Port Users	25.095
Total - All Transport Users	241.080

SUMMARY

Figure 2.3 summarises the major flows of funds for transport purposes in S.A. in 1981/82 which involve the State government. The major source is the State revenue account, followed by Commonwealth grants for roads and motor vehicle fees. Despite the differences in accounting, the public transport system still appears to require a larger proportion of state revenue funds (as a consequence of low user fees) than either roads or ports. Public transport fares represent only a relatively small proportion of the cost of operating public transport services (33% of operating costs and 28% of total costs), in contrast to ports and roads.

The major use of funds is for the operation of public transport. It should however be noted that this amount includes annual capital charges, both depreciation and interest, or lease payments. No depreciation is included in the DMH accounts, while no capital charges on the road stock are included in the Highways Department accounts.

The description of transport costs and revenues presented is restricted to effects on the State budget for transport purposes. A complete picture of transport expenditures would include other direct costs to the government and externalities associated with transport. Direct costs could include costs to the public hospital system as a result of road accidents and which are not recovered from hospital users [20]; and police traffic services (the payment from the Highways Fund does not cover the cost of these services [21]). Externalities could include accidents (the loss to society through lost production) and various forms of pollution generated by transport activities.

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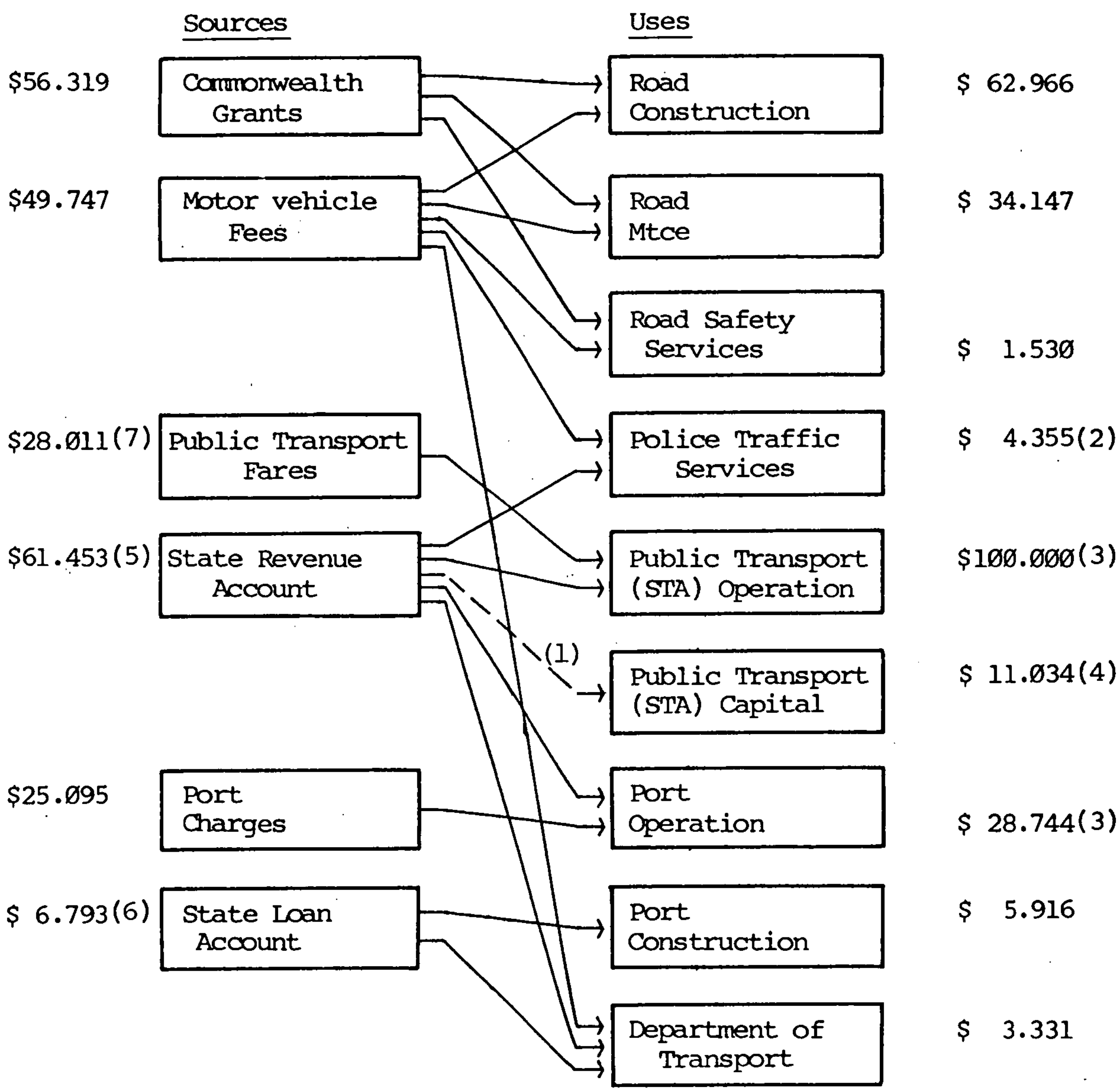
[20] Director-General of Transport, Adelaide Urban Transport Pricing Study: Interim Report, prepared by R. Travers Morgan Pty. Ltd. (Adelaide 1980), para B.15.

[21] ibid, para B.17.

FIGURE 2.3
Major Sources and Uses of Funds for Transport
South Australian Government 1981/82



Notes
(1) This is an indirect flow as a consequence of the method of funding the STA deficit. See page 15.
(2) Only the share of cost paid through the Highways Fund.
(3) Includes annual capital charges (depreciation, interest and lease payments.
(4) Capital expenditure from internal sources, see page 19.
(5) $55.350m for STA deficit, $3.649m for DMH deficit and $2.454m for DoT. Excludes Police services - see Note (2).
(6) $0.877m for DoT and $5.916m for DMH.
(7) Includes $5.755m for transport concessions from State revenue account.

CHAPTER 3 INVESTMENT AND PRICING THEORY

INTRODUCTION

As stated in the introductory chapter the aim of this thesis is to determine optimal investment levels for urban transport services provided by the government of South Australia. The concentration is on the provision of arterial roads and public transport services in Adelaide. These represent approximately 50% of the total State expenditure on transport services throughout South Australia.

The urban optimization procedure is based on existing published work on optimal congestion tolls for urban freeways in the United States, and on optimal subsidy levels for public transport in the United Kingdom. This chapter describes that work and other work relevant to the problem under study. The theory described determines optimal price levels, from which will flow optimal investment levels. The road approach is "first-best" but it is arguable whether the optimal tolls can be collected in practice because of institutional and political constraints. The option of second-best pricing of the competing public transport modes is therefore considered in order to achieve the optimal flow level on the (optimal) road capacity.

The relevance of other second-best approaches, i.e. optimizing prices, given a budget constraint, are discussed although not entirely relevant to the aim of the thesis which is to determine the appropriate funding level for transport services.

OPTIMAL ROAD TOLLS

Keeler and Small [1] have developed a model for optimal charges for urban freeways in the Bay Area of San Francisco. The model is formulated to maximize the net benefits (benefits minus costs) of the freeways. Benefits are measured in terms of demand (vehicle miles of travel), and costs in terms of road construction (including land acquisition) and maintenance costs, and private road user costs, i.e. travel time. Travel time provides the marginal social cost component of the model, i.e. an extra vehicle imposes extra cost on all other vehicles currently using the road so that the marginal cost is above the average cost of road use. This marginal social cost increases rapidly at higher traffic volumes. The effect is presented diagramatically in Figure 3.1.

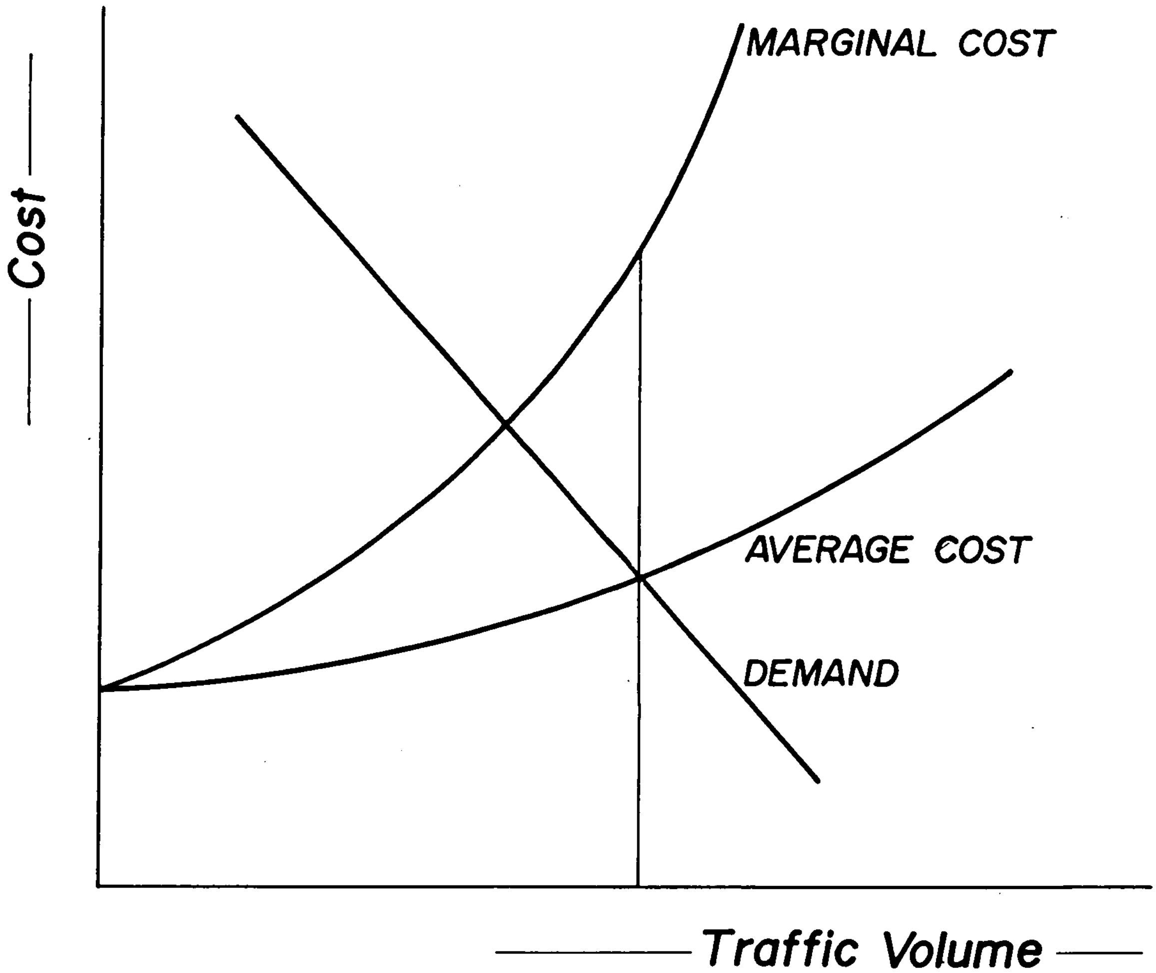


Fig. 3.1 Average & Marginal Cost of Road Use

[1] T.E. Keeler & K.A. Small, "Optimal Peak-Load Pricing, Investment, and Service Levels on Urban Expressways", Journal of Political Economy 85, 1 (1977), pp. 1-25.

Two basic assumptions of the model are that road plant is divisible and that demand in each period is independent. With respect to the former assumption Keeler and Small contend that this:

> "....... is not an unreasonable assumption for large urban highways, for the wider the roads in the system, the less relevant indivisibilities become to the analysis" [2]

In their estimation however a lane is used as the extra unit of capacity; this simplification tends to weaken the assumption of divisibility of plant. The alternative of estimating the model with small increases in capacity, such as improved channelization at intersections and/or the implementation of parking bans at heavy traffic flow times (Clearways) [3], would introduce complexities into the road cost estimation and may make the model inoperable. Estimating the model with the implicit assumption that an extra lane is the only means to increase output (capacity) appears to be a weakness [4].

Keeler and Small treat their second assumption, i.e. independent demands, by undertaking sensitivity testing of the results. These tests are carried out by making assumptions about the likely spreading to other time periods that would occur if optimal tolls were introduced. The model is based on peak load pricing theory [5].

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[2] ibid, p.2.

[3] In this case the extra capacity is gained through improved management of plant, not an increase in plant as such.

[4] D.N.M. Starkie, "Road Indivisibilities", Journal of Transport Economics & Policy (September 1982). Here it is argued that indivisibilities are small, particularly for rural Australian roads, as capacity may be increased by many measures other than extra lanes, e.g. width of the lane, its curve and/or gradient.

[5] O.E. Williamson, "Peak-Loading Pricing and Optimal Capacity under Indivisibility Constraints", AER 56 (1966), pp. 810-827.

Specifically, the Keeler & Small model maximises the net benefits (NB) of all trips over the life of the road:

$$NB = \sum_{t=1}^{T} \left[\int_{o}^{Q_t} P_t \, (Q_t) dQ_t - Q_t C_t (Q_t w) \right] - p(w)$$

where T is the life of the road.
t is the time period.
Q_t is the flow of vehicle trips over a given route per unit time.
P_t is the total user cost of a trip (including travel time).
C_t is the average variable cost (user and publicly supplied inputs) that vary with vehicle miles of travel.
w is the size or width of the road.
p(w) is the cost of road provision which varies with width of the road.

The road cost function, p(w), comprises 3 elements: annual rental for the investment in the road, both construction rental and land acquisition rental, and road maintenance costs. Formally the function is:

$$p(w) = \frac{r}{1-e^{-rL}} K(w) + M(w) + rA(w)$$

where r is the interest rate.
L is the effective life of the road.
K(w) is the construction cost as a function of width.
M(w) is the maintenance cost that varies with width.
A(w) is the land acquisition cost as a function of width.

In their estimation of road costs Keeler and Small use the number of lanes which comprise a road, as a proxy for width or road size.

The two relevant conditions for maximizing net benefits occur when NB is differentiated, firstly with respect to each Q_t:

$$P_t = C_t + Q_t \frac{d\, C_t}{d\, Qt} \qquad (t=1,\ldots..T)$$

i.e. the price should be set equal to average variable cost plus the congestion toll which equals the marginal social costs of road use; and

and secondly with respect to w:

$$-\sum_{t=1}^{T} Q_t \frac{dC_t}{dw} - p'(w) = 0 \qquad (1)$$

This states that the number of lanes should be expanded to the point where the marginal cost of an extra lane is equal to the marginal value of user cost savings brought about by that investment.

To use the model, the function p(w), and a speed flow curve for the urban freeway system are estimated. The speed flow curve takes the form:

$$V/C = a + bS - cS2$$

where V is the volume of traffic per hour
C is the capacity (based on engineering standards)
V/C is the volume capacity ratio
a, b & c are estimated parameters
S is the speed in miles per hour

The time taken for each trip, which determines the congestion toll portion of the cost of a trip is simply 1/S. To convert time to a monetary value, a value of time and data on vehicle occupancy are required. Based on accepted engineering standards Keeler & Small use a lane capacity (C) of 2000 vehicles per hour.

Keeler and Small optimize the prices in each period and the overall investment level in a two step process:

(i) An optimal investment policy is determined such that for any given traffic level, total costs are minimized according to (1) above. The actual output is an optimal volume capacity ratio as a function of lane capacity costs (construction, land acquisition and maintenance), and time values (from the speed flow relationship).

(ii) Given the optimal volume capacity ratios, the optimal long run price for each period is determined. Of interest is the congestion toll component of the price.

The significant innovation of the Keeler and Small work is that the analysis time frame is long run. Much previous analysis of road congestion tolls has been short run, i.e. there is no adjustment to capacity possible, and level of service can only be improved by decreasing volumes (as a result of the congestion tolls). This is not the case with the Keeler and Small model where prices and capacity are both operated on to improve the level of service (volume capacity ratio).

The results of the application of the model to the Bay Area suggest that in the mid-1970s when their research was undertaken the optimal price levels were well in excess of existing user charges. For example in the peak periods on downtown freeways, tolls between 14.5 and 31 cents/vehicle mile are estimated compared to the user charges at the time of 1.15 cents/ vehicle mile. On the other hand at the lowest demand times, a toll of 0.2 cents/vehicle mile is the optimal level.

The practical problems of collecting tolls on urban freeways are given only scant attention by Keeler and Small [6]. The problems would be greatly magnified on urban arterial roads (because of the greater difficulties of controlling entry and exit) unless perhaps they are collected by means of a tax on fuel. This method raises issues to be addressed when formulating the policy to be adopted in setting road user charges. In particular, are there greater or smaller efficiency losses by charging the high demand (peak) toll at all times relative to charging the low demand (off peak) toll at all times; and is there a further second-best option that is feasible, e.g. subsidizing public transport to achieve a switch from road use to public transport use during periods of high demand thus enabling the optimal road volume capacities to be achieved even though the optimal (peak) toll cannot be charged.

Varying Tolls with Demand

Walters [7] refers to the problem of the level of congestion tolls with respect to urban (congested) and rural (uncongested) roads where they are collected by means of tax on fuel. He is mainly concerned with

[6] Keeler & Small, op.cit., p.23.

[7] A.A. Walters, "The Theory and Measurement of Private and Social Cost of Highway Congestion", Econometrica 29, 4 (October 1961), pp. 676-699.

the problem of urban residents making trips to the country to buy fuel and thus avoid the toll:

> "I should have thought that it would be possible to hold this differential in the large urban areas such as New York, Philadelphia, Chicago, and Los Angeles. For the vast majority of the population in these areas, the distance from any rural area, where the elasticity is very low, is usually great enough to prevent gasoline "poaching". For the smaller urban areas surrounded by rural highways with low elasticities the tax differential would probably have to be lower. On the other hand, the motorist who undertakes a long cross-country journey will, of course, be able to buy gasoline at the low rate of tax. This is desirable since most of his mileage will be on (uncongested) tollways or on freeways between urban areas." [8]

The urban/rural question is not central to this thesis, however the implications for rural road use of optimal tolls set for congested metropolitan road conditions and charged by means of State-wide fuel tax are mentioned in Chapter 5.

Sherman [9] explicitly treats the question of price levels at different times of the day for two competing modes, car and bus, where it is not possible to vary the charge by time of day (or level of demand) for the car mode. Sherman's model also includes allowance for the congestion effect of one mode on another, called congestion interdependence. For example an extra car trip will cause increased congestion on the road system thus affecting both car and bus modes.

Sherman concludes:

> "...the choice of policies, between rush-hour or off-peak first-best optimality, will depend on the amount of travel and the seriousness of misallocations in the separate periods. The choice is not an easy or direct one, and a mixture of the two solutions might even be better than either one alone, especially if the amount of travel is nearly the same at the peak as it is at all off-peak times combined". [10]

This issue is not addressed in this thesis but it is possible that the models used could be expanded to do so.

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[8] ibid, p.28.
[9] R. Sherman, "Congestion Interdependence and Urban Transit Fares", Econometrica 39, 3 (May 1971), pp. 565-576.
[10] ibid, p. 575.

OPTIMAL PUBLIC TRANSPORT FARES

Sherman provides a methodology for determining optimal public transport fares in a second-best environment; another approach is that of Glaister and Lewis [11] which is described below. Jackson [12] has an approach similar to Sherman but does not include congestion interdependence. His diagramatic presentation of the problem is good; it is adopted here to enable explanation of the second-best nature of the problem.

Figure 3.2 shows the demand and cost curves for road use, H_1 is the resulting volume of traffic (intersection of demand and average cost curves), while H^* is the optimal volume (intersection of demand and marginal cost curves). The social loss is the triangle ABC, and a congestion toll of amount AD would reduce the volume of traffic to the optimal level, H^* and eliminate the social loss. If it is not possible to charge the toll, AD, then a second-best solution is to lower the price on a competing mode so that the volume of car traffic is reduced. This is the short run solution as there is no opportunity to vary capacity. Figure 3.3 shows the demand and cost curves for competing public transport services. There are T_1 public transport trips at a fare equal to average cost of AC_1. The second-best policy reduces the fare to AC_2 by the provision of a subsidy to the public transport operator and this subsidy results in a social loss of ACD in Figure 3.3 and an increase in public transport passengers to T_2. The social loss (ACD) is the cost of the subsidy (ABCD) minus the fare revenue from the increased passengers (ABC).

The second-best policy has increased the social loss: originally the loss on the road system was ABC in Figure 3.2, and now we have created a

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[11] S. Glaister & D. Lewis, "An Integrated Fares Policy for Transport in London", Journal of Public Economics 9 (1978), pp. 341-355.

[12] R. Jackson, "Optimal Subsidies for Public Transit", Journal of Transport Economics and Policy 9, 1 (January 1975), pp. 3-15.

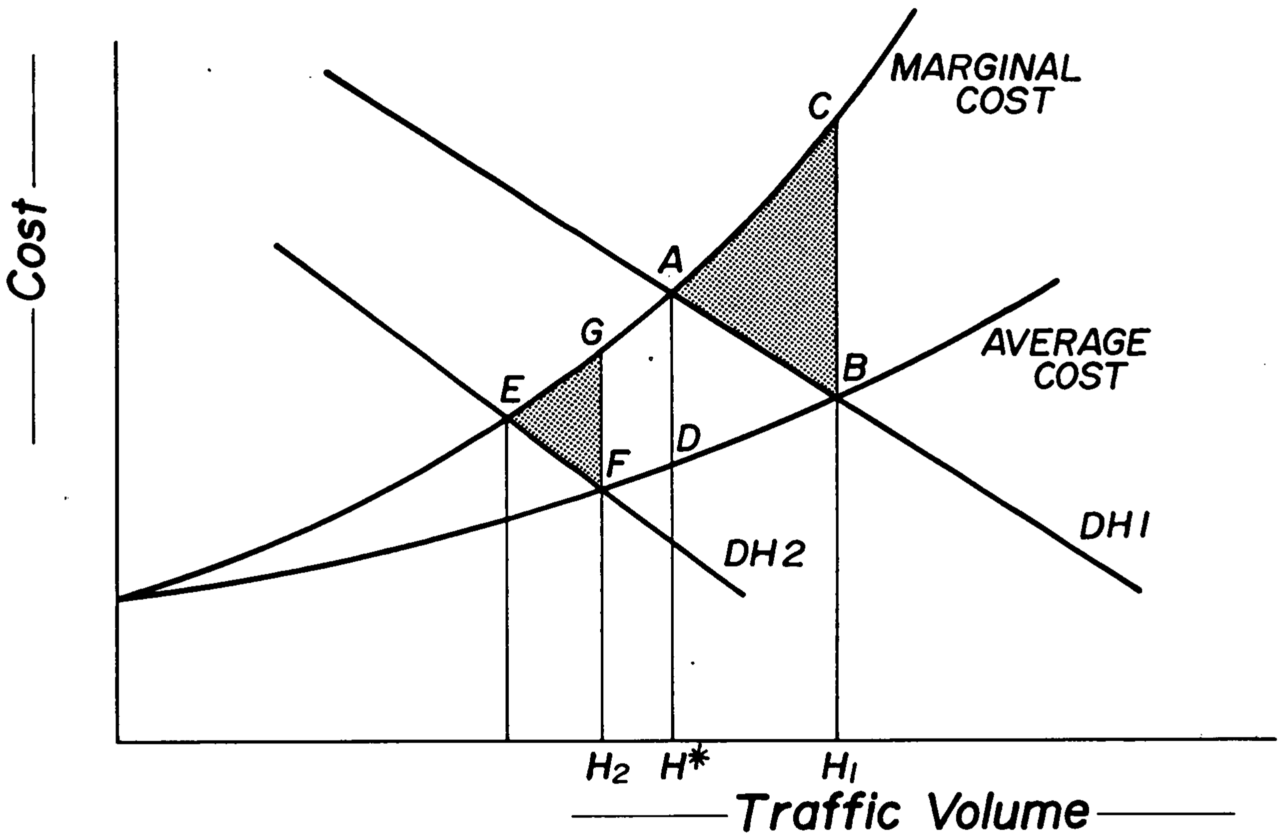

Fig. 3.2 Demand for and Cost of Road Use

loss ACD in Figure 3.3. However as a result of the increased public transport usage there will be a decrease in the demand for road travel, shown as DH2 in Figure 3.2. This lower demand causes a smaller social loss (EFG) on the road system. The net gain (or loss) in welfare as a result of the second-best policies depends on the relative sizes of the three social loss triangles. The net gain is calculated as:

(i) the social loss on the road system prior to the second best policy (ABC in Figure 3.2) minus

(ii) the social loss on the public transport system as a result of the second-best policy (ACD in Figure 3.3) minus

(iii) the social loss on the road system as a result of the second-best policy (EFG in Figure 3.2).

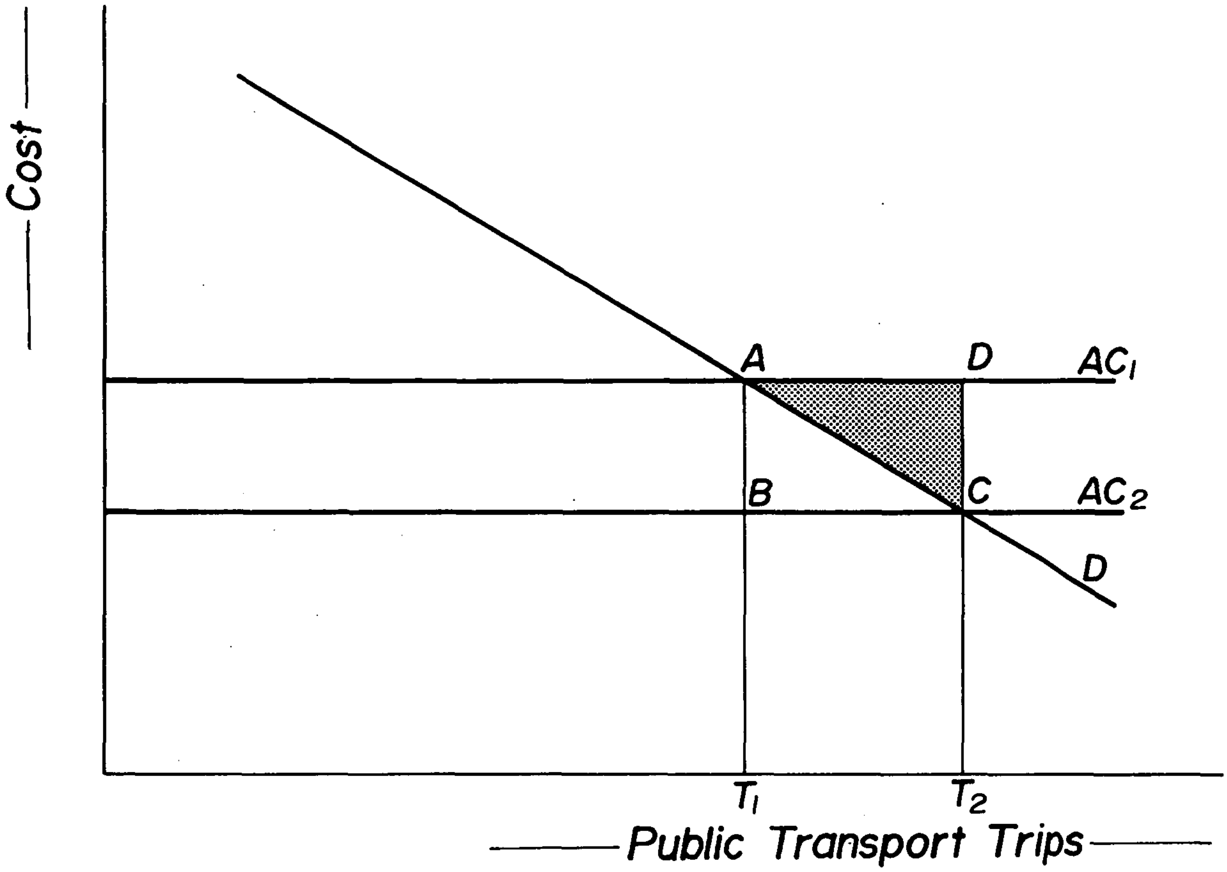

Fig. 3.3 .Demand for and Cost of Public Transport Use

The subsidy to public transport should be designed so that the net welfare gain is maximized. Jackson goes on to make an estimate of the gain based on the demand and cost characteristics of the road and public transport systems. The resulting equations are complicated and are not reproduced here as it is not intended to use the Jackson methodology mainly because it requires estimates of several cost elasticities (as does Sherman) which are not available. The Jackson approach is implicitly only concerned with the peak period, i.e. an assumption is made that there will be no time switching of trips as a result of the subsidization of public transport. Using available U.S. data on cost and demand elasticities Jackson provides a tentative conclusion on the efficacy of subsidies to public transport to reduce road congestion:

> "Such subsidies may improve allocative efficiency, though no significant improvement is apparent unless marginal social cost per car passenger mile is at least 80 per cent above private cost in the highway sector" [13].

Jackson also notes that the cross elasticity of demand for road travel with respect to the price of public transport travel should be greater than 0.2 [14].

The approach used by Glaister and Lewis for determining a second-best policy for public transport is the one adopted in this thesis. The model developed by Glaister and Lewis is intended to determine the optimal level of subsidy, given that it is not possible to charge the marginal social cost of road use. Their aim is the same as that of Jackson, but the methodology is quite different. The model is formulated in terms of expenditure functions (G) for both the current and optimal position, and the public transport subsidies (aggregated across all individuals); the expression is maximized and optimal prices and subsidy levels determined. The model allows for 3 modes (car, bus, rail) and 2 time periods (peak, off-peak) giving six types of transport as follows:

1. peak car
2. off-peak car
3. peak bus
4. off-peak bus
5. peak rail
6. off-peak rail.

---

[13] ibid, p. 13.

[14] ibid, p. 10.

Formally the model determines optimal prices (p_3, p_4, p_5, p_6) by maximizing:

$$\Big\{ (G\ (a_3,a_4,a_5,a_6,X^1(a_3\ldots,a_6),X^3(a_3\ldots,a_6),p,u)$$

$$-G\ (p_3,p_4,p_5,p_6,X^1(p_3\ldots,p_6),X^3(p_3\ldots,p_6),p,u)$$

$$-[C^3(X^1,X^3) - p_3X^3] - [C^4(X^4) - p_4X^4]$$

$$-[C^5(X^5) - p_5X^5] - [C^6(X^6) - p_6X^6] \Big\}$$

where G is the expenditure function
p_3,p_4,p_5,p_6, are the variable public transport prices
p is the vector of all other (fixed) prices including p_1 and p_2
u is a vector of constant utility levels
$a_3\ldots,a_6$ are a set of base prices for modes 3...,6
$C3\ldots,C6$ are the costs of operating modes 3...,6

The difference between the expenditure function evaluated at the base (a) prices and the optimal (p) prices is the compensating variation, i.e. the change in expenditure required to maintain a constant level of utility as prices increase from $p_3,..p_6$ to $a_3,..a_6$. The volumes of peak car travel (X1) and peak bus travel (X3) are included in the top two lines of the expenditure function because of the congestion effects of these two modes, i.e. in Sherman's terminology the model allows for congestion interdependence .

When the expenditure function is differentiated with respect to $p_3,..p_6$, and converted to elasticity form, a linear system of equations is obtained:

$$\begin{bmatrix} e_3^3 & e_3^4 & e_3^5 & e_3^6 \\ e_4^3 & e_4^4 & e_4^5 & e_4^6 \\ e_5^3 & e_5^4 & e_5^5 & e_5^6 \\ e_6^3 & e_6^4 & e_6^5 & e_6^6 \end{bmatrix} \begin{bmatrix} (p_3-S_3)X^3 \\ (p^4-C_4^4)X^4 \\ (p_5-C_5^5)X^5 \\ (p_6-C_6^6)X^6 \end{bmatrix} \frac{1}{S_1X_1} = \begin{bmatrix} e_3^1 \\ e_4^1 \\ e_5^1 \\ e_6^1 \end{bmatrix}$$

where e are income compensated elasticities, and e_4^3 is the elasticity of demand for mode 3 with respect to the price of mode 4.

S_1 and S_3 are the marginal social costs of peak car and bus traffic respectively where:
$S_1 = \frac{dG}{dX1} + \frac{dC3}{dX1}$ and $S_3 = \frac{dG}{dX3} + \frac{dC3}{dX3}$

Glaister & Lewis interpret the system of equations as follows:

> "...both peak and off-peak prices will be below respective marginal social costs by an amount proportional to marginal social costs of car use, both because of the possibilities of attracting peak car users directly (through e_3^1 and e_4^1) and reallocating demand between periods (through e_3^4 and e_4^3) so as to allow further adjustment to car traffic"[15].

Glaister and Lewis proceed to use the model to estimate optimal fare and subsidy levels for London's public transport. The use of income compensated elasticities makes little difference to the results as the share of expenditure spent on the public transport modes is low (0.0027 to 0.0076)[16].

The marginal social cost of a peak bus was assumed to be 0.05 pence per passenger mile. It was more difficult to obtain data on the marginal social costs of peak car travel so two cases were tested, both arbitrary. Use of a speed flow relationship for London could have provided the means of estimating the marginal social cost of car travel.

The Glaister and Lewis model is formulated in terms of price, while service quality is another, often more important, determinant of demand for transport services[17]. The marginal costs of the public transport modes used are private, i.e. costs to the operator, while the marginal social cost of car travel is used. When considering public transport pricing Turvey & Mohring claim:

> "The right approach is to escape the notion that only costs which are relevant to optimization are those of the bus operator. The time-costs of the passengers must also be included too, and fares must be equated with marginal social costs"[18].

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[15] Glaister & Lewis, op.cit., p.346.

[16] ibid, Table 2, p.349.

[17] S. Glaister, Fundamentals of Transport Economics, Basil Blackwell (Oxford 1981).

[18] R. Turvey & H. Mohring, "Optimal Bus Fares", Journal of Transport Economics and Policy (September 1975), pp. 280-286.

A positive externality is associated with the use of scheduled public transport services, often termed the frequency benefit, which leads to decreasing marginal social costs [19]. More services mean decreased waiting times to existing passengers, or decreasing social costs as output increases. This omission appears to be a weakness in the formulation of the model. It is however not clear how the omission would effect the Glaister and Lewis model. As Waters [20] notes regarding scheduled public transport services:

> "There are several other sources of delay and inconvenience costs borne by users which also involve externalities, some of them are negative such as congestion delays and crowding. The latter tend to be important on heavily travelled routes, i.e. those where the increasing returns just discussed are not so important. There are also possible increasing returns to producers, i.e. the traditional sources of decreasing costs. Thus, several factors are involved in determining optimal prices for scheduled transport services and it is not necessarily the case that the increasing returns will dominate. Optimal pricing could result in either a financial deficit or surplus".

For their preferred application in London, the Glaister and Lewis model produced all prices below cost (as expected), peak bus fares just over twice those of the off-peak, peak rail fares thirteen times those of the off-peak, and subsidy and car traffic levels approximately in accord with what existed at the time in London. The results are interesting in light of Jackson's conclusion that the cross elasticity of demand for car travel with respect to bus price should be greater than 0.2 for subsidies to be effective. Glaister and Lewis use cross elasticities of 0.025 (bus) and 0.056 (rail) [21] and suggest significant subsidies. This may indicate that their model formulation is sensitive to the elasticity values used, or alternatively could result from a high differential between social and private car costs in London. As noted above Jackson suggests the differential must be at least 80% for second-best pricing of public transport to be a viable option.

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[19] J.O. Jansson, "Marginal Cost Pricing of Scheduled Transport Services", Journal of Transport Economics and Policy (September 1979), pp. 268-294.

[20] W.G. Waters II, "Recent Developments in the Economics of Transport Regulation". Canadian Transport Commission, Research Seminar Series, 8 (Spring 1982), p. 19.

[21] Glaister & Lewis, op.cit, Table 3, p.349.

OTHER SECOND-BEST APPROACHES

Train [22] has used the Boiteux [23] solution to the second-best pricing of BART (rail) and A.C. Transit (bus) in San Francisco. The solution of problems of this general type, however require the imposition of a budget constraint, for example a breakeven position if marginal costs are less than average costs. For the Train case the budget constraint used is that BART cover its operating costs and that A.C. Transit cover its total costs. The prices are then optimized within the total budget constraint for the two modes.

The use of this approach for determining the price of and investment in urban arterials in Adelaide does not appear appropriate for two reasons. Firstly, as mentioned previously the thesis is aimed at determining appropriate funding levels whereas funding is a constraint in the Boiteux method. Secondly, it is more difficult to apply the method to the publicly funded road system where congestion occurs. An analysis comparable to this has recently been applied by Taplin & Waters [24] to the carriage of interstate freight in Australia. The two modes considered are road and rail, and the budget constraint the existing "public revenue surplus", over marginal costs. For road freight the budget constraint applies to the road system rather than the freight services, and optimal prices are enforced by charges on the use of roads.

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[22] K. Train, "Optimal Transit Prices under Increasing Returns to Scale and a Loss Constraint", Journal of Transport Economics and Policy 11, 2 (May 1977), pp. 185–194.

[23] M. Boiteux, "On the Management of Public Monopolies Subject to Budgetary Constraints", Journal of Economic Theory 3 (1971).

[24] J.H.E. Taplin & W.G. Waters, "Ramsey Pricing under a Comprehensive Budget Constraint : The Case of Competing Road and Rail" (draft, 1982).

CHAPTER 4 APPLICATION OF THE PRICING MODELS

INTRODUCTION

This chapter describes the models developed for Adelaide to determine optimal urban road and urban public transport prices. Implications for funding urban transport are considered in Chapter 5.

The procedure adopted was to use the Keeler and Small model, with some modifications (the road model), to determine optimal road prices, levels of service and system capacity. The road system capacity was then transferred to the Glaister & Lewis second-best pricing model,adapted for Adelaide, (the public transport model) to determine public transport prices and services, given that the optimal road prices are not charged. Both models were programmed to run on the South Australian Department of Transport's computer. A complete description is contained in the manuals produced by the Department's consultants employed to write the programs[1].

The data required for the models is extensive; some was readily available and some had to be collected from other cities or "guesstimated". Descriptions of the data collection and estimation processes are contained in Appendices B, C and D. The text of this chapter simply reports the data and comments on its reliability.

The chapter is organised in the following manner:

- the modifications to the road model are described;
- the input data to the road model are presented and discussed;
- the results of the road model application are presented;
- the input data for the public transport model are presented and discussed;
- the results of the public transport model application are presented; and
- implications for road and public transport levels of service are discussed.

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[1] Director-General of Transport, Road Pricing, Investment and Service Levels - An Economic Model, Prepared by R. Travers Morgan Pty. Ltd. (Adelaide 1983).
Director-General of Transport , A Public Transport Pricing Model Application Manual, Prepared by R. Travers Morgan Pty. Ltd. (Adelaide 1981).

MODIFICATIONS TO THE ROAD MODEL

The major modification to the Keeler & Small model was the incorporation of varying demand by the inclusion of own price elasticites for each time period. Arc elasticities are used implying a convex demand function with a constant elasticity value. The model allows for up to five time periods. The demand curve for each time period is of the form:

$$X/X' = (P/P')^e \tag{1}$$

where
- P = current user cost of a trip
- X = current hourly traffic flow
- P' = new user cost
- X' = demand at price P'
- e = elasticity of demand.

The road model was written to allow for switching of trips between time periods resulting from a price increase in one of the time periods. This facility was not used in the applications due to lack of reliable data on time switching elasticities.

The mathematical formulation of the net benefit equation differs in the Adelaide model to allow for varying demands, so there will be changes in both prices and demands. Figure 4.1 illustrates the position for one time period. The base position is given by the curves MC_1 and AC_1 resulting in a demand of V_1. Following the capacity optimization process, i.e. expand capacity until the marginal cost of capacity added equals the marginal benefit to road users, new cost curves MC_2 and AC_2, and a new demand V_2 result. The resource cost to existing users is reduced by the difference between AC_1 and AC_2 at the existing volume V_1, i.e. ABCD, and there is an increase in the pre-toll surplus to new road users, i.e. BCEF. From these two must be deducted the toll revenue DEFG, giving a net benefit to road users of ABFG.

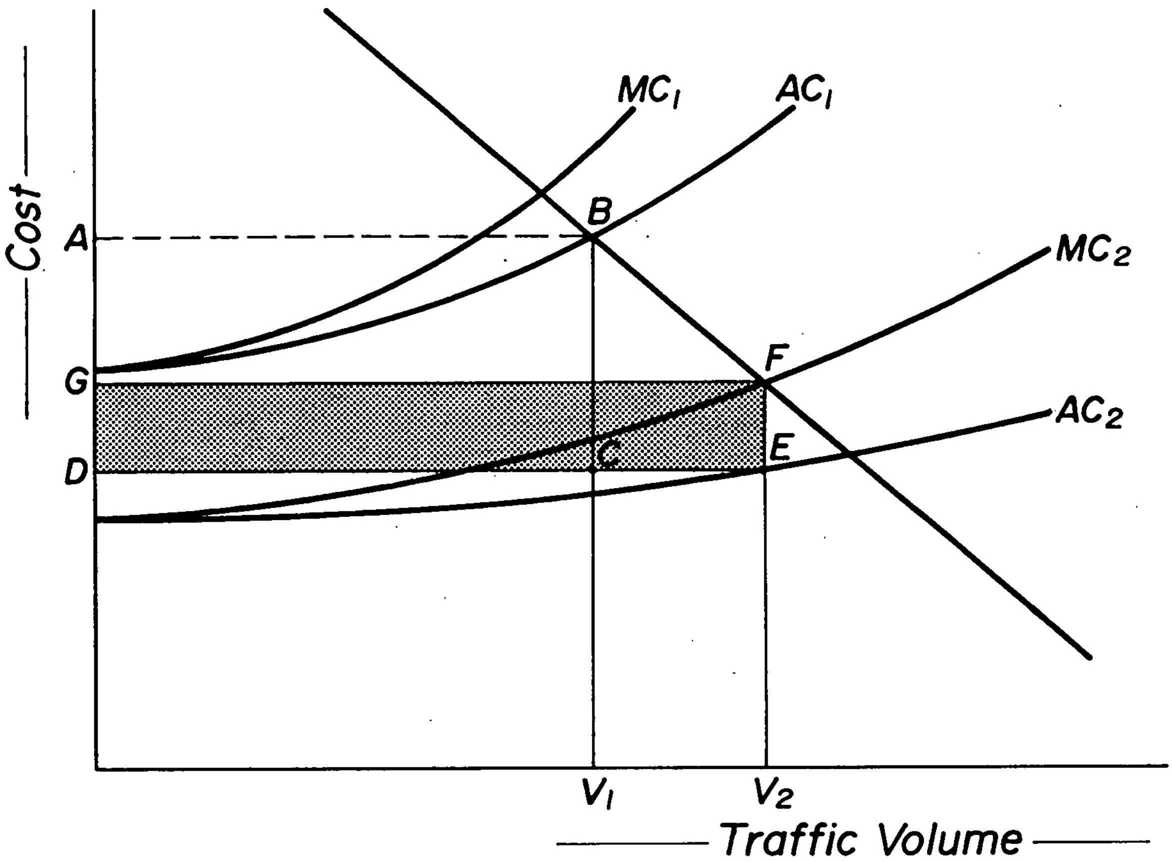

Fig. 4.1 *Benefits to Road Users as a Result of Road System Expansion*

The mathematical formulation of the model is now described. The benefit equation for one time period is:

$$\text{Benefit} = \int_{P'}^{P} X \, dp \qquad (2)$$

where P = current user (average) cost of a trip
P' = marginal cost of a trip
p = dummy variable representing cost for the purpose of integrating between P and P'

Equation (2) measures the change in area under the demand curve (= consumer surplus) as a result of a change in price from P to P' (the area ABFG in Figure 4.1). By substituting for X from equation (1), equation (2) can be expanded:

$$\text{Benefit} = \int_{P'}^{P} X/Pe \; pe \, dp$$

$$= \frac{X}{(1+e)Pe} \quad P(1+e) - P'(1+e) \qquad (3)$$

The benefit equation (3) occurs for each time period, these being summed to give the total benefit of any change in capacity.

Following Keeler and Small the user cost equations are derived from a speed flow relationship and a value of time. The form of the speed flow relationship is different to that adopted by Keeler and Small as conditions on urban arterial roads, not freeways, are being represented. The speed flow relationship which is described in detail in Appendix C is as follows:

$$S = Sf \frac{(1-X/cw)}{(1-mX/cw)} \quad \text{for } X/cw < Ucrit \qquad (4)$$

where S is the speed of traffic
Sf is the free flow speed
X is the hourly volume of traffic
c is the hourly lane capacity
w is the number of lanes
m is a level of service parameter
Ucrit = 0.85 + 0.10m is the critical degree of saturation above which over saturated conditions prevail.

The average cost to road users is:-

$$C = \frac{V}{S} \qquad (5)$$

where V is the value of time
S is the speed of traffic

Using equation (4), equation (5) is expanded to:

$$C = \frac{V\ (1-mX/cw)}{Sf\ (1-X/cw)} \qquad (6)$$

The marginal cost is obtained by differentiating equation (6):

$$MC = C + X \frac{dC}{dX}$$

$$= \frac{V(1-mX/cw)}{Sf(1-X/cw)} + \frac{V(1-m)X/cw}{Sf(1-X/cw)2} \qquad (7)$$

By definition the toll is the difference between marginal and average cost, giving:

$$T = \frac{V(1-m)X/cw}{Sf(1-X/cw)2} \qquad (8)$$

The road capacity costs are input in the same form as Keeler and Small as an annual rental cost per unit of capacity, Aw where w is the number of lanes and A is the annual rental in $/lane km, i.e. the assumption of constant costs with respect to capacity is adopted (see Appendix B for derivation). The cost to society of building extra road capacity is the increase in the annual rental cost, A(w'-w).

In this formulation the toll is included as a cost to road users (equation (7)) and thus must be included as a benefit to the toll collecting authority. The net benefit of extra road capacity is thus:

$$NB = \underset{\text{(equation (3))}}{\text{Benefit}} + \underset{\text{(equation (8)x X)}}{\text{Toll Revenue}} - A(w'-w)$$

The program iterates through successive values of w to determine the value of w for which NB is a maximum. The optimum demand, marginal cost, average cost and toll are determined from the intersection of the demand and marginal cost curves at that value of w.

Following Keeler & Small only time costs are allowed to vary in the road model, for determination of optimum prices. Other costs will vary with changes in road use (fuel, accidents, policing) and these could be included in the cost functions if appropriate data were available.

<u>INPUT DATA FOR THE ROAD MODEL</u>

This section describes briefly the input data. Full details and references are contained in Appendices B & C with the appropriate appendix in brackets for each data item.

<u>Annual Rental Cost of Roads</u>

<u>Construction costs</u> (Appendix B) were estimated using regression analysis of 27 Highways Department urban arterial road projects concerned with

construction, re-construction and widening. All projects were commenced in 1968/69 or later and completed by 1981/82. Costs were updated to June 1982 levels using the Highways Department road construction cost index.

Two estimations were carried out, the first with width (in metres) as the independent variable. The result of the first estimation was (t-statistics in brackets):

$$\ln \text{cost/km} = \ln a + b \ln \text{width}$$
$$= -2.9855 + 0.9500 \ln \text{width}$$
$$(-5.0737) \quad (4.3793) \qquad R^2=0.4442$$

At the 5% significance level the null hypothesis that b=1 is accepted, thus indicating constant returns to width in road construction. Constant returns are an assumption of the cost functions in the road model. A one metre addition to the width of a road will result in approximately $50,500 expenditure per km.

The second estimation was in terms of lanes (rather than width) as a cost per lane km is required for the annual rental cost. Only traffic lanes were included in the lanes variable, the provision of parking lanes being indicated by a dummy variable. The result of this estimation was (t-statistics in brackets):

$$\ln \text{cost/km} = \ln a + b \ln \text{lanes} + c \text{ parking dummy}$$
$$-1.5983 + 0.7825 \ln \text{lanes} + 0.4271 \text{ parking dummy}$$
$$(-5.3473) \quad (3.5957) \qquad (2.2554) \qquad R^2=0.4314$$

Based on this equation, the marginal cost of an extra traffic lane is $207,000 per lane km, when parking is not provided. Marginal costs under other assumptions are given in Table B.4.

<u>Land acquisition costs</u> (Appendix B) for a typical road widening project are estimated by the Survey and Property Branch of the Highways Department to be $100,000 per lane km.

Maintenance costs (Appendix B) were $3,120 per lane km in 1981/82. In recent years total expenditure on maintenance has increased in real terms, so to the extent that they continue to increase $3,120 will be an under-estimate.

Construction, land acquisition and maintenance costs are then combined to give an annual rental value. The formula requires an interest rate and life of road for the annualized value to be calculated. This interest rate should represent the social time preference rate or a real interest rate. Rates of 5% and 7% will be used. A variety of values have been used in previous work for the physical road life ranging from 10 to 50 years; the Highways Department has agreed that 30 years is appropriate (Appendix C).

At 5% interest rate the annual rental value per lane km is $21,443 and at 7% is $26,632. These values are used for any increases in capacity but a lower value is used for decreases in capacity. If road capacity is reduced the re-construction and maintenance costs would be saved in the long run. However, for decreases in capacity, the uses to which the land occupied by a lane could be put (parking, landscaping, use by abutting land owners) are likely to have a lower value than land required for road expansion. A value of zero is used although this is likely to overestimate the optimal road capacity.

Speed Flow Relationship (Appendix C)

A speed flow relationship based on urban arterials in Adelaide was not available for use in the thesis. The form of the relationship used is different to that used by Keeler and Small as the model is being applied to different types of roads (see Figure 4.2 and the mathematial formulation on page 46). The urban arterials differ from freeways in speed flow characteristics as the maximum flow is restrained by intersections, at a level well below that achieved on freeways. As a result of this difference a different form of speed flow curve is required.

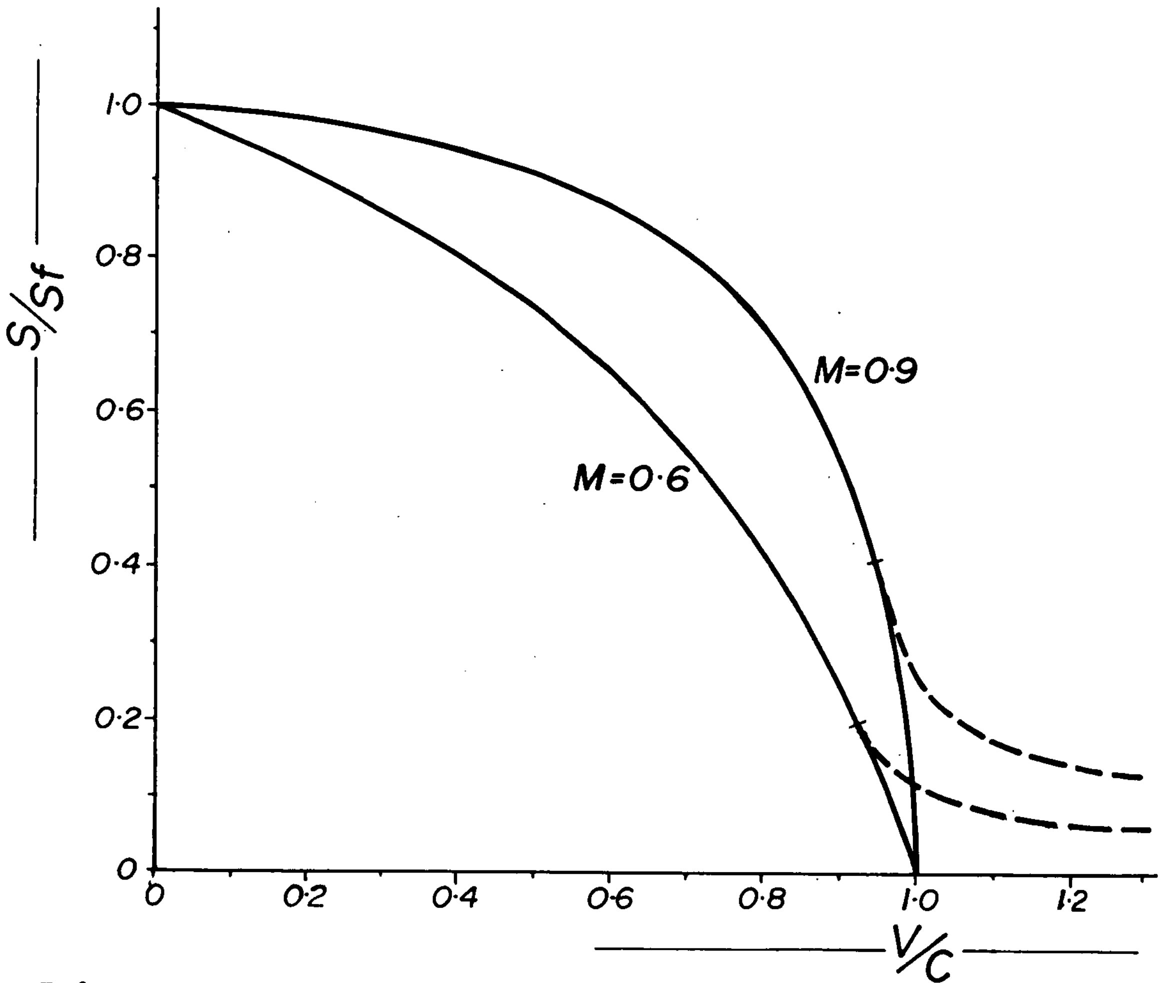

Fig. 4·2 Speed Flow Curve used in Adelaide

The shape of the speed flow relationship used is determined by a level of service parameter, m, which should be determined from calibration of existing conditions. This has not been possible and a value of m=0.85 has been used based on evidence from other cities and advice from traffic engineers; this value is at the high end of the range of experience. As the models (both the road model and the public transport model) used are sensitive to the form of the speed flow relationship, this item of data is one of the weaker links in the application of the models.

Other parameters required for input to the speed flow relationship are free flow speed (46 kmh) and capacity (1100 pcus/lane hour). The former is derived from traffic assignments to the Adelaide road network. The capacity figure is based on various sources and should be fairly reliable.

Value of Time (Appendix C)

There is no agreement in the literature on appropriate values of times, or on the appropriate method of measurement. Despite this, fairly consistent values in the order of 25% - 33% of the average hourly wage rate are constantly used. An estimate from a mode choice model for work trips in Adelaide was 28% of the average hourly wage rate. The value required for the model is a weighted average value of time per vehicle. To calculate the value of time per vehicle from a value of time per person an average occupancy figure is used. The average value is weighted by the proportion of different vehicle types in the traffic stream. The value is $3.23/hour.

Fuel Consumption (Appendix C)

The fuel consumption rate is used to translate the optimal toll from cents/km to cents/litre, on the assumption that any toll will be collected by a fuel tax. The rate used is 12.5 litres/100km (22mpg).

Number of Lanes (Appendix C)

The dimensions of urban arterial roads in Adelaide (in term of traffic lanes) by responsibility and area are given in Table 4.1. The current analysis is restricted to the 649 km or 2196 lane km in the inner area as the arterials in the outer area have the characteristics of rural roads based on this data the average number of lanes on urban arterial roads in Adelaide is 3.38.

TABLE 4.1
Urban Arterial Roads in Adelaide by Responsibility and Area.

Maintained by	Area		
	Inner	Outer	Total
Highways Department			
- length	511	221	732
- lane km	1750	468	2218
Local Governments			
- length	138	53	191
- lane km	446	106	552
Total			
- length	649	274	923
- lane km	2196	574	2770

Traffic Flows by Time Period (Appendix C)

Five time periods are used with traffic flow per lane hour being derived from peaking ratios and the average peak hour flow. Annual flows are derived in the model by using the annual number of hours for each time period and the average number of lanes. The data are:

Peaking Ratio	Traffic Flow (per hour)	Number of Hours (p.a.)
1.0	2129	520
0.70	1490	416
0.58	1234	2080
0.55	1173	884
0.20	426	4836

The traffic flow data are averages for urban arterials in Adelaide; there are some roads which carry more traffic, and others less. The road model is being applied to the urban arterial network and therefore the use of average traffic flows is proper. If applied at the individual road level, the traffic flow for the particular road would be appropriate.

The traffic flow data includes cars, light commercial vehicles and trucks (both rigid and articulated). Light commercials are counted as one passenger car unit (pcu) and trucks as two pcus. Keeler and Small excluded truck traffic and reduced the annualized road cost by 23% [2].

Elasticities (Appendix C)

The demand elasticity data is another area of weakness in the input data. No estimates are available for Adelaide. Although demand models for urban travel have been estimated recently they have been undertaken in such a way as to make it impossible to determine elasticity values for car travel. Using data from Perth and from overseas, the following own price

[2] The proportion of road construction cost estimated to be attributed to trucks by the U.S. Bureau of Public Roads. Keeler & Small, op. cit., page 8.

elasticity values which are at the high end of the range of evidence available will be used:

-0.38 for peak travel
-1.2 for non peak travel.

RESULTS OF THE ROAD MODEL

The model was applied using the data described above at interest rates of 5% and 7%. Some sensitivity testing of other parameters was undertaken and this is described below. At both interest rates, the existing road capacity in Adelaide is close to the optimum level (within minus 8%). Improvements in the use of capacity could be achieved by the imposition of relatively small congestion tolls (in addition to existing road charges) during the heavier traffic flow times.

The existing cost situation is shown in Figure 4.3. It can be seen that at the peak hour flow of 630 per lane the difference between average and marginal cost is 3.3 cents, the toll required to achieve the optimal position. At other time periods when traffic flow is lower, the average/ marginal cost difference is much smaller, and thus smaller tolls are required. Even at the lowest traffic flow period in Adelaide there is some friction in the flow causing a difference between marginal and average costs of 0.1 cents/vehicle km.

The price and traffic flow results at the 5% interest rate are given in Table 4.2. The capacity of the road system would then need to be 1.2% less than exists now. Given the quality of the data in effect we could say the existing road system has optimal capacity, however the use of this capacity could be improved by charging the tolls given in Table 4.2. Speed would increase by 3%, as a result of the decreased number of vehicles giving a better level of service to road users. The toll in the

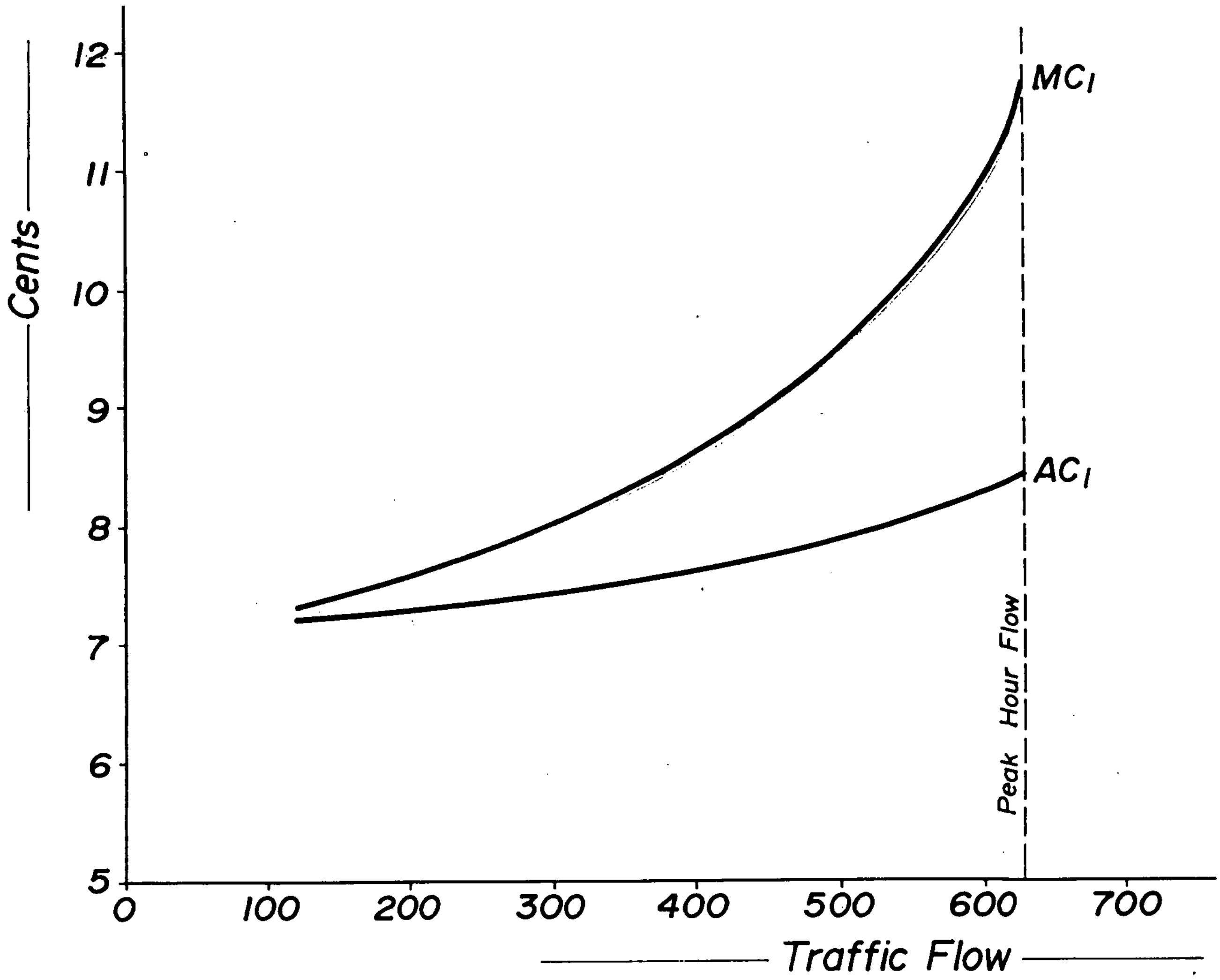

Fig. 4.3 Existing Road User Costs in Adelaide.

peak period of 2.5 cents/vehicle km represents 18.75 cents per trip at the average trip length of 7.5 kms (Appendix D), or 19.5 cents/litre if it was collected as a fuel tax.

TABLE 4.2
Results of the Road Pricing Model at 5% Interest Rate

Time Period	Traffic Flow (veh/lane hr)	Speed (kmh)	Average Cost (c/veh km)	Marginal Cost (c/veh km)	Toll (c/veh km)
1 (Peak)	582	39.4	8.2	10.7	2.5
2 (Near Peak)	395	42.4	7.6	8.5	0.9
3 (Day)	336	43.2	7.5	8.2	0.7
4 (Day)	322	43.3	7.4	8.0	0.6
5 (Night)	125	45.1	7.2	7.3	0.1

Table 4.3 gives similar data when a 7% interest rate is used. Due to the higher cost of road provision that the 7% interest rate implies, more benefits are required to justify the extra capacity, thus the road system decreases by 8%, still close to the existing capacity. Traffic flows and speeds are higher indicating a lower level of service than if a 5% interest rate is used. The tolls are also higher, giving a cost of 21.75 cents per trip at the average trip length, or a fuel tax of 22.8 cents/litre.

TABLE 4.3
Results of the Road Pricing Model at 7% Interest Rate

Time Period	Traffic Flow (veh/lane hr)	Speed (kmh)	Average Cost (c/veh km)	Marginal Cost (c/veh km)	Toll (c/veh km)
1 (Peak)	610	38.8	8.2	11.3	2.9
2 (Near Peak)	414	42.2	7.7	8.7	1.0
3 (Day)	354	42.9	7.5	8.3	0.7
4 (Day)	338	43.1	7.5	8.2	0.7
5 (Night)	133	45.1	7.2	7.3	0.2

Sensitivity Tests

Sensitivity testing of the parameter values input to the model was undertaken at the 5% interest rate. As noted above some of the data inputs are based on evidence which is the best available but limited. If a particular parameter value has a significant effect on the model results and is not based on actual evidence in Adelaide there would be cause for concern. As can be seen from Table 4.4 this is the case for the level of service parameter (m) which defines the shape of the speed flow curve. However the effect on system capacity is only significant if m is increased by 10%, and not when it is decreased. This result is expected as the closer m becomes to 1 the more concave the curve becomes; at high V/C ratios a small change in speed will be associated with a large change in the V/C ratio. As the m value used (0.85) is at the high end of the evidence available for urban arterial roads in Australia (see Appendix C) it is unlikely to effect the results in practice.

TABLE 4.4
Sensitivity Tests on Individual Parameters in Road Model
5% Interest Rate (1)

Change in parameter:	+10%		-10%	
Effect on:	Existing System Capacity(%)	Optimum Peak Toll(c)	Existing System Capacity(%)	Optimum Peak Toll(c)
Parameter				
Road Cost	-4.7	2.7	0	2.5
Road Life	0	2.5	-	-
Level of service (m)	-19.5	2.4	+3.5	3.4
Lane Capacity	-7.7	2.3	0	3.2
Free Flow speed	-5.0	2.5	0	2.8
Value of time	0	2.7	-	-
Traffic	0	2.9	-	-
Elasticities	-	-	0(1)	2.9

Notes (1) The optimal situation is a decrease of 1.2% in system capacity from the existing and a peak toll of 2.5 cents/ vehicle km.
(2) Low values of -0.13 in peak and -0.4 in non-peak. See Appendix C.

Table 4.4 shows that a 10% increase in lane capacity causes a 7.7% decrease in road system capacity. This may seem incongruous, but simply reflects the fact that if more vehicles use a particular lane (lane capacity is higher) then fewer lanes are required for the same number of vehicles (road system capacity is lower). The result for a 10% decrease in lane capacity is slightly different: the road system capacity does not alter but a higher toll is charged to improve the use of the road system.

The changes in the peak toll as a result of varying the parameters do not, as one would expect, match with the changes in road system capacity. The peak toll in the base case, with a 5% interest rate, was 2.5 cents/ vehicle km (Table 4.2), the largest increase is to 3.4 cents when the level of service parameter (m) is decreased by 10%. This increase occurs despite a small increase in road system capacity (3.5%). The peak toll only decreases when system capacity decreases significantly due to a 10% increase in m or in lane capacity.

There is more change in the results when more than one parameter is varied. The results of several sensitivity tests are given in Table 4.5. If all parameters are increased 10% (column 1), the model indicates that the existing road system should be reduced by 21.6%; on the other hand if all parameters are reduced 10% (column 2) the effect is small, indicating once again the effect of increasing the m value.

TABLE 4.5
Sensitivity Tests on Combinations of Parameters in Road Model
5% Interest Rate*

Parameter	% Change in Parameter			
	1	2	3	4
Road cost	+10	-10	+10	-10
Road life	+10	-10	-10	+10
Level of service (m)	+10	-10	0	0
Lane capacity	+10	-10	+10	-10
Free flow speed	+10	-10	+10	-10
Value of time	+10	-10	-10	+10
Traffic	+10	-10	-10	+10
Elasticities	-	Low	-	Low
Effect on Existing System Capacity (%)	-21.6	5.6	-30.5	23.4
Optimum Peak Toll (c)	2.3	3.4	2.6	3.2

* See Notes to Table 4.4.

As indicated in Table 4.4 some parameters have a positive effect on the size of the road system and others a negative effect. Model runs were therefore carried out varying the parameters up or down depending on the direction of their effect on the size of the road system, with m=0.85. These can be regarded as the polar "worst" situations although neither appear to be likely:

- a decrease of 30.5% in the existing road system if all parameters with a positive effect are underestimated by 10% and all parameters with a negative effect are overestimated by 10% (column 3); and
- an increase of 23.4% in the existing road system if all parameters with a negative effect are overestimated by 10% and all parameters with a positive effect are underestimated by 10% (column 4).

The final sensitivity test undertaken involved including the value of land as a benefit if the road system was reduced. As one would expect the result was a decrease in existing road system size, by 10.6%. As was argued earlier (page 49) the benefit (when reduction occurs) is expected to be less than the cost (when expansion occurs) so the effect is not too severe.

INPUT DATA FOR THE PUBLIC TRANSPORT MODEL

The section reports the input data for the public transport model, full details of the derivation of which are given in Appendix D. The STA provide bus, rail and tram services in Adelaide. The tram mode accounts for only 3% of passengers and is ignored in the model application. If it was included the number of elasticity values required would increase significantly to thirty. As it is, including both bus and rail as separate modes requires twenty elasticity values. The link between the road and public transport models is the optimum road capacity from the road model. This is used in the public transport second best pricing model rather than the existing road capacity to determine what public transport fares should be charged to optimize the use of both the road and public transport systems.

There are four basic data inputs to the public transport model which are discussed below.

Marginal Social Cost of Road Use

The same speed flow relationship as used in the road model is used to measure road congestion costs. The traffic flow and capacity data are input as passenger km/hour rather than vehicles/hour. Existing traffic flow is obtained from traffic assignments, and capacity is derived using the optimum V/C ratio resulting from the Keeler and Small model. The relevant data is given in Table 4.6 for interest rates of 5% and 7%. The free flow speed and level of service parameter (m) are the same as used in the road model.

TABLE 4.6
Peak Hour Traffic Flow Data for Adelaide

Traffic Flows (pass km/hour)	Interest Rate 5%	Interest Rate 7%
Existing	1,430,808	1,430,808
Capacity	2,480,482	2,324,524
Critical Capacity	2,319,251	2,173,430

Public Transport Demand Data

Passenger km/hour data were derived from traffic assignments and count data to represent existing demand. Existing adult fares are the base prices input to the model, i.e. the assumption is made that all passengers pay the average adult fare. This is obviously not the case but is not too unrealistic as reimbursement, representing the difference between adult and concession fares, is paid by the government to the STA for concession riders except children [3]. Using this technique overestimates revenue, but as children represent only 15% of riders it should not be too severe[4].

[3] Child fares are reimbursed to half the adult fare.

[4] B. Crouch, Patronage Report 1982/83 Financial Year, STA Corporate Planning Department (Adelaide 1983), p. 16.

The demand data is given in Table 4.7 for the peak and interpeak periods. It can be seen that public transport travel is approximately 10% of total peak hour road travel in terms of passenger km. The lower fares at interpeak times reflect the differential fares in operation on STA services. The lower rail fares reflect the longer average journey length of rail trips and the zone fare system which has large zones and the same fares for bus and rail trips.

TABLE 4.7
Public Transport Demand Data

	Passenger km/hour	Fares (c/pass km)
Bus		
Peak	140,580	8.4
Interpeak	87,567	6.0
Rail		
Peak	69,160	5.0
Interpeak	31,033	3.6

Public Transport Operating Costs

The public transport operating cost data is based on marginal cost rates developed for bus and rail services and regularly updated. The rail costs are understated relative to bus costs due to the differing methodologies employed and the more difficult task of estimating rail costs. The marginal costs can be viewed as medium-term: 17% of costs are treated as fixed, the capital costs of rail track are ignored, and annualized values for rollingstock are included.

As with the road model, interest rates of 5% and 7% are used to calculate annualized rollingstock costs. These costs only apply in the peak period in accordance with peak load pricing theory. The marginal operating costs per passenger km for bus and rail services at peak and interpeak periods are given in Table 4.8. Rail costs are higher than bus costs in the peak, and bus and rail costs in the interpeak period are the same.

TABLE 4.8
Public Transport Marginal Operating Costs

Service	Cost per Pass Km (cents)
Bus	
- peak 5%	21.8
7%	22.4
- interpeak	5.1
Rail	
- peak 5%	23.8
7%	26.4
- interpeak	5.1

At the higher interest rate, the peak rail costs increase more than the peak bus costs due to the higher cost of rail rollingstock. If rollingstock costs are omitted the rail cost falls below the bus cost: this is often used as an argument for increased rail services but it only holds if changes in services are such that increased rollingstock are not required, or if it is not intended to replace the existing fleet [5].

Elasticities

Elasticities are used to measure the effect on demand as a result of price changes. As with the road model constant elasticities are used implying convex demand curves. There are twenty elasticity values required; they are given in Table 4.9. The elasticities of demand for peak car travel with respect to the public transport prices have the most effect in the model. Unfortunately no data on these elasticities specific to Adelaide was available; the values used are derived from other studies and adjusted for Australian conditions. The values used are similar to those used by Glaister and Lewis although there is an argument that their values should be higher due to the more extensive coverage of public transport services in London.

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[5] In 1984 the STA called tenders for 20 new railcars with possible extension to 100. The existing fleet is 164 railcars.

TABLE 4.9

Elasticities of Demand used in the Public Transport Pricing Model

Demand for:	With respect to price of:			
	Peak Bus	Off-Peak Bus	Peak Rail	Off-Peak Rail
Peak bus	- Ø.15	Ø.Ø1	Ø.Ø2	Ø.ØØ5
Off-peak bus	Ø.Ø1	-Ø.45	Ø.ØØ5	Ø.Ø2
Peak rail	Ø.Ø2	Ø.ØØ5	-Ø.2	Ø.Ø1
Off-peak rail	Ø.ØØ5	Ø.Ø2	Ø.Ø1	-Ø.57
Peak car	Ø.Ø27	Ø.ØØ9	Ø.ØØ6	Ø.ØØ2

The public transport own price elasticities are based on Adelaide data and should be relatively reliable. The other values are guesses but appear reasonable when compared with values used by Glaister and Lewis. The values may appear low, however the model applies to the whole urban transport network and only 9% of all trips in Adelaide are made by public transport. If a subset of trips, i.e. work trips to the central area, were considered one would expect higher elasticity values.

RESULTS OF THE PUBLIC TRANSPORT MODEL

The second-best pricing model is based on that proposed by Glaister and Lewis and described in Chapter 3. The only modification made to the model used in Adelaide was the inclusion of the speed flow relationship to measure the marginal social costs of road use. Glaister and Lewis had simply used two alternate values (see p. 38).

The public transport model estimates the optimal second-best public transport prices and the consequent level of subsidy to be paid to the public transport operator, assuming that optimal road tolls cannot be charged. The model was run for interest rates of 5% and 7% as with the road model. The results of the 5% interest run are given in Table 4.1Ø. All fares, except for interpeak bus services, are currently lower than the optimum level. Interpeak rail fares should be raised by 14%, peak bus fares by 88% and peak rail fares by almost 300%. All fares would still be below marginal cost, 18% for the two interpeak fares, 28% for peak bus fares and 17% for peak rail fares. The lower amount for peak rail fares probably results from the lower car cross elasticity for rail fares compared to that for bus fares.

TABLE 4.10
Results of the Public Transport Pricing Model
5% Interest Rate

Service	Marginal Cost (c/pass km)	Fares (c/pass km)		Demand ('000 pass km)		Subsidy ($'000)	
		Existing	Optimal	Existing	Optimal	Existing	Optimal
Car							
- peak				1,430.8	1,463.0		
Bus							
- peak	21.8	8.4	15.8	140.6	131.0	23,547	9,771
- interpeak	5.1	6.0	4.1	87.6	105.4	(1,182)	1,559
Rail							
- peak	23.8	5.0	19.9	69.2	53.1	16,252	2,592
- interpeak	5.1	3.6	4.1	31.0	29.0	698	429
					Total Subsidy	39,315	14,351

If these optimal prices were charged, car demand and interpeak bus demand would increase by 2% and 20% respectively. Although the car demand increase is small in percentage terms it is larger in absolute terms than any of the other changes in demand, reflecting its significantly greater share of the urban travel market. All other demands would fall, with peak rail usage experiencing the largest change in percentage terms (23%). As a result of these changes in prices of and demands for public transport services, the level of subsidy would decrease by almost $25m, following changes in services levels to match the new demand. The greatest proportion of the optimal subsidy would accrue to peak bus passengers ($9.771m, Table 4.10). Interpeak bus passengers would move from a position of revenue greater than cost, (contributing profit to the STA) to a position of receiving a small subsidy. The fares are lower than cost in interpeak times as a result of the positive time switching cross elasticities as explained in Chapter 3 (page 40).

The results of the model at an interest rate of 7% are given in Table 4.11. The peak marginal costs are higher as a result of the higher interest rate. Both interpeak fares are lower than for the 5% interest rate; the peak fares however move in different directions with the peak rail fare increasing and the peak bus fare decreasing. This would result from a combination of factors: the relatively higher marginal cost of rail services as a result of the higher interest rate (see above), the lower road capacity, and the interaction of the elasticity values. There are small differences in the changes in demand but all occur in the same direction. The lower car demand results from the lower road capacity, and thus the higher marginal social cost of car use with a 7% interest rate. The optimal level of subsidy is $18.5m or 30% higher than in the 5% interest rate case; it is still over $20m lower than the existing level of subsidy.

TABLE 4.11
Result of the Public Transport Pricing Model
7% Interest Rate

Service	Fares (c/pass km)	Demand ('000 pass km)	Subsidy ($'000)
Car			
- peak		1,459.9	
Bus			
- peak	14.8	132.4	12,629
- interpeak	3.9	108.3	2,007
Rail			
- peak	21.3	52.3	3,352
- interpeak	3.9	30.1	557
Total			18,545

The most important result of the model runs is that even when the second-best pricing considerations are accounted for, public transport fares are well below economically efficient levels. The model also indicates that the peak/off-peak fare differential should be increased such that the peak fare is three to four times the level of the off-peak fare. The existing differential in Adelaide is approximately 40%.

Sensitivity Tests

Sensitivity testing of parameters in the model was undertaken at the 5% interest rate (see Table 4.12). Again the model is most sensitive to the value of the level of service parameter (m) in the speed flow curve. The effect is greater in the public transport model and in the same direction: a higher value of m indicates a smaller road system (-19.5%) and a smaller subsidy to public transport (-52%). (A higher value of m is unlikely as argued above). However, in contrast to the road model, the lower m value in the public transport model causes a large effect in the optimum level of subsidy (+54.3%).

TABLE 4.12
Sensitivity Tests on Parameters in Public Transport Pricing Model

Parameter	Change in Subsidy	
	Amount ($'000)	% Change
Car cross elasticities		
+10%	15,845	+10.4
-10%	12,853	-10.4
Zero	0	n.a.
Level of service (m)		
+10%	6,891	-52.0
-10%	22,149	+54.3
Value of time		
+10%	15,714	+ 9.5
-10%	12,981	- 9.5

Two other parameters were tested: the car cross elasticities and the value of time. When increased or decreased by 10% both had approximately a 10% effect on the optimum subsidy level. The car cross elasticities used are high relative to those used by Glaister and Lewis so, if anything, the base result will cause an overestimate of the optimum subsidy level. The case, where car cross elasticities are zero, results in no subsidy and marginal costs being the optimal prices, i.e. as there is no interaction between the two modes there is no second-best justification for reducing fares below marginal cost.

Sensitivity testing has been on the two individual models - the effects of carrying through changed parameter values are discussed in the next chapter.

IMPLICATIONS FOR LEVELS OF SERVICE

The level of service on the road system is measured via the V/C ratio; at higher V/C ratios there will be more congestion and consequently a lower level of service to road users. In the public transport model changes in levels of service are inferred via the demand figures (measured in passenger km), on the assumption that reductions in demand will be met by reductions in supply of services.

The road model results indicate that the optimum V/C ratio at peak demand times is Ø.53 for the 5% interest rate case. This is 7% lower than the existing V/C ratio (=Ø.57), and represents an increase in the level of service to road users of a similar amount. For the 7% interest rate case the optimal V/C ratio is Ø.55, or a 3.5% increase in the level of service to road users. These levels of service would only be achieved if the corresponding congestion tolls were charged.

The position for road users, in terms of levels of service are made worse with the institution of second best public transport pricing. At the 5% interest rate the V/C ratio for the peak increases to Ø.59, a 3.5% decrease in the level of service. At the 7% interest rate the decrease in the level of service is 1Ø.5% (V/C ratio = Ø.63). Against these decreases in the level of service must be weighed the fact that existing road users are paying less then the marginal cost of their road use.

In the applications of the public transport model, demand is reduced on all modes except interpeak buses for both the 5% and 7% interest rates (see Tables 4.10 and 4.11). The optimum position would require some decrease in the levels of service provided as a result of reduced demand. If demand is used as a proxy for level of service provided, the percentage changes required as as shown in Table 4.13. They are similar for the two interest rates. The most significant changes required are in interpeak bus services and peak rail services.

TABLE 4.13
Changes in Public Transport Levels of Service

Service	Interest Rate 5%	Interest Rate 7%
Bus - peak	- 7%	- 6%
- interpeak	+20%	+24%
Rail - peak	-23%	-24%
- interpeak	- 6%	- 3%

CHAPTER 5 URBAN TRANSPORT FUNDING

INTRODUCTION

This chapter estimates the annual public sector urban transport budget for Adelaide based on the model results given in the previous chapter. The road model determined optimal road system capacity, and that capacity is translated into an annual cost using the estimated road cost per lane km. Similarly the optimal funding for urban public transport services in Adelaide is based on the public transport model.

These funding levels are then compared with existing funding levels for urban transport. As explained in Chapter 2 the basis for funding and accounting for roads and public transport in South Australia differ considerably; and they both differ from the costs developed and used in this thesis[1]. This presents some difficulties in attempting the comparisons herein. As described above, road construction is funded through grants carrying no interest while public transport capital is funded by loans, with depreciation based on historic costs. In contrast, the costs used in this thesis are economic costs based on a real rate of return of either 5% or 7%, and current values.

Funding levels are calculated with a 5% real interest rate unless otherwise stated. In a later section of the chapter, the 7% results are given for comparative purposes.

URBAN ROAD FUNDING

The outputs from the road model were prices (congestion tolls), levels of service (V/C ratios) and road system capacity at the optimum. The cost of providing this optimum road position will be covered by the tolls on the assumption of constant returns to scale in road construction:

[1] "Since much road expenditures are of a capital nature, the concept behind the Highways Fund can be seen to be defective in accounting principles as well as economic principles". J. Mant & N. Clark, Accountability of the Commissioner of Highways, Report to Public Accounts Committee (South Australia 1983), p.20.

"Strictly speaking, a long-run optimum highway system requires that tolls equal capital costs only if the production of highway services involves constant returns to scale" [2].

In their estimation, Keeler and Small found constant returns to scale for the Bay Area freeways, indicating that toll revenue would just cover the cost of the system capacity [3]. The evidence for Adelaide was ambiguous (see Appendix B): constant returns (costs) were found for road construction costs in terms of width (in metres) but not lanes (the proxy for capacity), where increasing returns (decreasing costs) were indicated, although not to a large extent. If the parking lane cost was attributed to through traffic constant returns would occur, i.e. the estimation would simply be in terms of width (in metres). The model was formulated on the assumption of constant returns; this should be borne in mind when considering the results presented in this chapter.

Optimum Annual Cost

The cost of the road system is divided into 3 components:

- a 5% return of the value of the land used ($5,000 per lane km);
- depreciation of the road and a 5% real return on the capital invested in construction (13,323 per lane km); and
- maintenance cost of $3,120 per lane km based on 1981/82 expenditure,

giving a total of $21,443 per lane km (page 49). This is an economic cost, not in anyway related to existing expenditure figures.

Table 5.1 shows the annual economic cost of the existing road system and of the optimal road system, based on the above costs. The figures relate only to traffic lanes in operation in the peak period.

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[2] H. Mohring, "Relation Between Optimum Congestion Tolls and Present Highway User Charges", Highway Research Record No.47, p .2.

[3] Keeler & Small, op.cit., p. 7.

TABLE 5.1
Annual Economic Cost of Existing & Optimum Road System
5% Interest Rate

Item	Road System Cost ($'000) Existing (2196 lane km)	Optimum (2168 lane km)
Land	10,980	10,840
Construction	29,256	28,884
Maintenance	6,852	6,764
Total Cost	47,088	46,488

There are a further 342 lane km of roads which are available for parking (and therefore not moving traffic) in the peak period. It is arguable whether through traffic should be allocated the cost of parking lanes. These parking lanes have a cost of $5.8m p.a.

The differences between the economic costs of the existing and optimal systems are small, as one would expect as the existing road system is only 1.2% below the optimum size (see page 53).

Comparison with Existing Expenditure

The actual amount spent by the Highways Department on urban arterial roads in 1981/82 was $21,204m for construction (including parking lanes) and net land acquisition, and $6.922m for maintenance (Table 2.4, page 11). The construction amount applies to both the inner and outer urban arterials while this thesis only considers the inner arterials which are 70% of the total on the basis of length (km) and 80% of the total in terms of lane kms (see Table 4.1). Thus if the total urban arterial system was considered, the figures in Table 5.1 could be increased by 20%.

These Highways Department construction and net land acquisition figures are the amounts actually spent in 1981/82. There is no allowance for depreciation of the road system or for a return on the funds invested in the road system. An assumption that the annual expenditure represents the depreciation of the system, i.e. enough expenditure on construction is made each year to maintain the size and quality (non-use related) of the road system, is not unrealistic [4]. Such an assumption allows a comparison with the optimum figures, with the 5% return omitted from the construction amount and the land costs ignored. (As land acquisition and land sales were almost equal in 1981/82 this is not unrealistic - see Table B.6, Appendix B). The depreciation components of the annual construction costs in Table 5.1 are $15.151m (existing sytem) and $14.957m (optimum system). These figures can be compared with the $21.204m actually spent in 1981/82, indicating that urban arterial road expenditure in Adelaide is higher than can be justified in economic terms, with the provisos given above that the Highways Department figures are for both inner and outer arterials, and include provision of parking lanes. Another constraint is the definition of capacity used in the road model, i.e. the number of lanes of road. This is a simplifying assumption and it is not possible to determine its effect. In fact road capacity is increased by many other actions, some of which are more expensive than road widening (new roads, grade separation) and others which are less expensive (traffic control measures).

The Highways Department maintenance costs are also for both inner and outer urban arterials, but not for those arterial roads maintained by local councils. The effects in terms of State expenditure almost cancel each other out with the model indicating expenditure on maintenance for the optimal inner system

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[4] This is one of the methods often used in determining an annual value of the road stock for cost recovery studies. See for example BTE, Cost Recovery in Australian Transport 1974-75, AGPS (Canberra 1977), p. 60 where it is referred to as the "incurred capital cost method".

being $6.852m (Table 5.1), and the Highways Department expenditure being $6.922m [5]. Local councils maintain 20% (446 lane km) of the inner arterials and 18% (106 lane km) of the outer arterials (see Table 4.1).

URBAN PUBLIC TRANSPORT FUNDING

Once again the results to determine the level of funding are based on a 5% real rate of return. The level of subsidy required to the STA would be $14.351m (see Table 4.10). This however only applies to weekday peak and interpeak rail and bus services; services at other times and tram services are not considered in the model. The calculation of the marginal costs also assumes 17% of the STA's costs are fixed, and thus deserving of subsidy (see page 60), and that the STA is reimbursed for the carriage of passengers at concession rates. In 1981/82 the amount of the reimbursement was $5.755m (page 20), an amount well below the difference between concession and adult fares. The method of calculating reimbursements was changed in 1982/83, to reflect more accurately the revenue "loss" incurred by the STA in carrying passengers at concession fares [6]. The amount for 1981/82 calculated on the new basis would have been $12.3m [7].

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[5] The near equality of the maintenance expenditures is not unexpected given that the cost per lane km is calculated using existing expenditure and the existing number of lane km. See Appendix C.

[6] $13.01m was reported in the STA Annual Report, 1983. The method for use in calculation is described in Report of the Working Party on Concessions & Reimbursements, Report to the Minister of Transport (South Australia 1981).

[7] Director-General of Transport, Public Transport Costs and Revenues in Adelaide, Prepared by D.J. Bray & Associates (Adelaide 1983), Appendix F.

Table 5.2 shows the accounting deficit on public transport services adjusted for the above, giving a current deficit for bus and rail peak and interpeak services of $39.325m. The optimal position based on the second-best pricing premise is $14.351m. However this road traffic related subsidy would not be the extent of the state's funding responsibility for public transport. It would also incur the reimbursement cost ($12.3m), the fixed cost component ($12.7m), and presumably the cost of the other services (i.e. tram, weekend, evening). The thesis has not been concerned with the economics or equity of continuing with those other services.

If the results of the model were adopted State funding for public transport would have been almost $25m p.a. lower than occurred in 1981/82. The reduced funding levels would be achieved by increasing public transport fares (see Table 4.10), and reducing service levels (see Table 4.13).

TABLE 5.2
Adjusted Public Transport Subsidy, 1981/82 ($'000)

Annual Report figure (1)		62,286
less	Reimbursement shortfall (2)	7,255
	Fixed Costs (3)	9,700
	Services not included (3)	12,700
		32,631
plus	Capital charges (4)	6,684
Public Transport Subsidy for Weekday Peak and Interpeak Services		39,315

Notes (1) See Table 2.6
(2) See text
(3) P.F. Amos & Starrs M.M. "Public Transport Subsidies in Adelaide" Australian Transport Research Forum (forthcoming)
(4) Differences between accounting and replacement cost capital charges.

SENSITIVITY OF THE FUNDING ESTIMATES

In Chapter 4 several sensitivity tests of the road model and the public transport model were undertaken. It was concluded that both models were particularly sensitive to the value of the level of service parameter (m) used in the speed flow curve. Further, if several parameter values were under or overestimated in the same direction there could be significantly different model results. This section reports the results of sensitivity tests in terms of annual funds if the changed parameter values are carried through from the road to the public transport model. The results of three tests, in addition to interest rates of 5% and 7%, are given:

- the value of m is decreased by 10%;
- the value of m is increased by 10%; and
- m= .85, and all other parameters are varied by 10%, either up or down, to produce a positive effect on road system capacity (column 4 in Table 4.5).

The results of these changes in model parameters are given in Table 5.3.

TABLE 5.3
Annual Transport Funding ($'000)

Cases Tested	Annual Road Cost	Public Transport Subsidy(1)	Total
A. 5% Interest rate (Base)	46,488	14,351	60,839
B. 7% Interest rate	43,551	18,545	62,096
C. m reduced by 10%	48,696	18,989	67,685
D. m increased by 10%	37,847	3,698	41,545
E. Parameters that increase road capacity varied by 10%	58,025	11,520	69,545

Notes (1) Weekday peak and interpeak subsidy only

The movements are not uniform nor in the same direction in the two models. When the interest rate is increased to 7% (Case B), the road system size and thus cost falls (6%) as it is more difficult to justify expansion with the same levels of traffic. The resulting smaller optimal road capacity, increases the optimal subsidy to public transport (29%). The higher operating costs associated with the 7% interest rate would also contribute to this effect.

When the level of service parameter (m) is decreased in both models (Case C), both road and public transport costs increase (5% and 32% respectively). Similarly when m is increased (Case D) both the road and public transport costs are reduced (19% and 74% respectively). As was argued in Chapter 4 (page 55) this is an unlikely case as m = 0.85 is at the high end of experience reported in the literature.

The final test (Case E) involved varying parameters to increase road system capacity significantly (23.4%, see Table 4.5). As a result annual road cost increases by a similar amount, and public transport subsidy reduces by 20%. This is expected as a larger road system will reduce the road congestion benefits resulting from second-best pricing of public transport.

In terms of total transport funding, the changes are not great (if the test of m increased by 10% is excluded as an unlikely case). Case E is 14% or $8.706m higher than the 5% interest rate base (Case A).

REVENUE FROM ROAD USERS

In this section an estimate of the cost recovery from urban road users is made. If the results of the road model with respect to prices were implemented, and there were constant returns to scale in road building, then revenues from road users would equal costs; neither is achieved in the framework of this thesis. It is thus of interest to determine the effect on the State budget, if the model results were to be implemented. In determining cost recovery, only the State budget is considered: Commonwealth road grants are considered as revenue from road users to the State [8]; and use by urban road users of local roads is omitted.

Roads in South Australia are currently funded from Commonwealth grants and charges on road users, either for ownership or use of vehicles. State sources of funds for the Highways Department were given in Table 2.3, from which the relevant road user charges (excluding collection costs) are $40,209 from Registration and Licence Fees and $23,737 from the Fuel Levy.

These collections are not recorded in such a way that a split between urban and rural users is easily possible. An estimate is made in Table 5.4 based on various data sources. The registration and licence fees are based on a study done in South Australia on 1978/79 data, where it was estimated that 68% of these fees were paid by urban road users [9]. The fuel levy is apportioned based on data from the 1982 Survey of Motor Vehicle Usage for Australia [10]. The Commonwealth road grant of $16.66m (page 7) is for both rural and urban arterials: the portion to urban arterials in the table is based on the total percent (Commonwealth and State sources) spent on arterial roads (Table 2.4).

Table 5.4 shows that there is an estimated $57.674m in revenue from urban road users compared with the optimum annual cost of $46.488m (Table 5.3). It appears that existing revenues more than cover the

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[8] There is no hypothecation of Federal fuel excise to road funding; the amount of Federal road grants is less than excise collections.

[9] Director-General of Transport, Adelaide Urban Transport Pricing Study Interim Report, Prepared by R. Travers Morgan Pty. Ltd. (South Australia 1980), Appendix C.

[10] Australian Bureau of Statistics, Survey of Motor Vehicle Usage: Twelve Months ended 30 September 1982, Cat. No. 9208.0.

economic costs of urban road construction and maintenance in Adelaide. As was pointed out in Chapter 2 there are other costs associated with urban road use not specifically considered in this thesis: road accident costs, traffic policing costs, road safety expenditure. The other factors to consider are that general administration costs of the Highways Department are ignored in the model ($10.843m in 1981/82 - see Table 2.5) and the revenue from the fuel levy for the use of local roads is included as revenue to the State from the use of arterial roads.

TABLE 5.4
Estimated Revenue from Urban Road Users, 1981/82

	Revenue ($'000)	
	Total S.A.	Estimated Urban
Registration & Licence Fees	40,209	27,342
Fuel Levy		
- petrol	18,277	16,921
- diesel	5,460	4,773
Commonwealth grant	16,660	8,638
Total	80,606	57,674

The annual urban road costs include depreciation and a rate of return on capital invested, neither of which now occur. Thus if current revenues do fall short of the required level of funds (with these other costs included), it would not necessarily be appropriate to increase charges on motorists, alternatives would be:

- to provide loan funds to the Highways Department [11];
- to make reimbursement payments for concessions on registration and licence fees from general State revenue, as occurs for the public transport services of the STA. Concessions on road charges amounted to over $10m in 1981/82 (see page 13); or

[11] This method of funding was adopted in S.A. in 1982/83, with $4m of loan funds being provided to the Highways Department.

- to increase the fuel levy to the extent indicated by the toll in the lowest demand time on the road system. It is not possible to charge congestion tolls which vary by time of day using a fuel levy, but the lowest charge determined could be charged to all road users. The optimum toll in time period 5 was Ø.1 cent/vehicle km, or 1.18c/litre [12].

If the last option for raising revenue was adopted then the cost of fuel in non-urban areas would also increase by 1.18 c/litre. It would seem equitable that these funds be spent on rural roads, assuming that existing revenue from rural road users covered the cost of their provision [13].

The above analysis of what is basically cost recovery from road users, in no way invalidates the pricing conclusions drawn earlier. Only the fuel levy can be regarded as a price for the use of the road system. Alternatively the existing road charges may be considered a two-part pricing system: registration and licence fees the payment for entry to the system and the fuel levy the payment for use of the system [14].

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[12] Since 1981/82 the cost of petrol has been increased by at least 1c/litre by the Commonwealth Government and 1.Ø2c/litre by the S.A. Government.

[13] It seems unlikely that revenue from rural users does cover the cost of rural arterial roads. Expenditure on urban and rural arterials are similar (see Table 2.4), but 63% of revenue is from urban road users (see Table 5.4). See also D.N.M. Starkie, "Cost Recovery: and Investment Perspective" in Starkie et.al., Pricing and Cost Recovery in Long Distance Transport, Martinus Nijhoff (The Hague 1982).

[14] R.W. Boadway, Public Sector Economics, Winthrop Publishers (Cambridge, Mass. 1979), p. 159.

SUMMARY

This chapter has estimated the optimum annual economic costs of the urban arterial road and public transport systems in Adelaide. An attempt was made to compare these economic costs with the accounting costs presented in Chapter 2. It appears that existing urban arterial road construction and maintenance spending is at about the optimum level (perhaps a little on the high side), and public transport spending $25m higher than the optimum.

These general conclusions are qualified by the following:

- only construction and maintenance of urban arterial roads for through traffic were considered in the road model;
- traffic lanes were used as the measure of road capacity while there are other means of varying the capacity of roads; and
- only weekday peak and interpeak bus and rail public transport services were considered. The reduction in existing public transport expenditure can be considered a minimum as there could be economic justification for reducing tram services, and rail and bus services at other time periods.

CHAPTER 6 CONCLUSIONS AND QUALIFICATIONS

INTRODUCTION

This chapter summarises the results of the analysis, and puts them in perspective by outlining the qualifications to the models and the input data used in the models.

SUMMARY OF CONCLUSIONS

The major conclusions of the analysis are that:

- The existing inner urban arterial network in Adelaide is close to the optimum size. At a real interest rate of 5% the optimum system is only 1.2% smaller than that which currently exists (page 53).

- The use of the urban arterial road network could be improved by the imposition of relatively small congestion tolls. A toll of 2.5 or 2.9 cents/ vehicle km in the peak demand times would ensure a more efficient use of the optimum road system. The toll is the difference between the marginal private and social cost of vehicle travel in Adelaide. The toll implies a cost of 19 or 22 cents for the average journey in Adelaide depending on the interest rate used (page 54).

- It is not clear whether existing funding levels for roads are at an efficient level (page 7Ø). The existing systems of funding roads and the accounting practices of the Highways Department make comparisons with economic annual costs difficult (page 68).

- Expenditure on public transport services is well above economically efficient levels. A reduction of $2Ø-25m in the public transport subsidy can be justified, even taking into account second-best arguments (page 63).

- The existing level of subsidy to public transport results from a combination of high service levels and low fares (more particularly the latter). Rail fares are further from optimum levels than bus fares (page 59). Levels of peak rail services are significantly higher, and levels of interpeak bus services are significantly lower than optimum (Table 4.13).

QUALIFICATIONS TO THE MODELS USED

The road model was adapted from one developed for a freeway system. The use of the model for urban arterial roads, which are of a more diverse nature than freeways, can be criticized. The data are necessarily averages for the whole system, and probably represent few arterials on the ground in Adelaide. Further, the model assumes that road capacity can only be varied by the addition or substraction of through traffic lanes. This is a restrictive assumption. The road model assumes constant returns to scale in road construction although the conclusion based on Adelaide data was ambiguous.

Several items are excluded from the road model, although these could be included if appropriate data were available. For example, it is assumed that travel time is the only component of travel cost that varies with road use; in congested situations fuel consumption might increase, and in less congested situations fewer road accidents might occur. Other externalities of road use, such as air and noise pollution, and visual intrusion, are ignored in the application of the model [1].

Heavy vehicles are treated in the model in terms of passenger car units through their effect on traffic flow. This appears to be an improvement in the technique adopted by Keeler and Small which was to simply exclude them. However, there is a case for arguing that these heavier vehicles add more to the cost of roads than their equivalent passenger car units. This comment applies particularly to maintenance expenditure [2].

Both the road model and the public transport model allow for time switching elasticities; in this thesis the feature was not used in the road model due to lack of data.

[1] D.B. Lee, "Net Benefits from Efficient Highway User Charges" Transport Research Record No. 858, p. 16.

[2] See for example F.N. Affleck & Associates, Road User Charges in Australia. An Assessment of the Existing System and Guidance for Future Policy, Report to ATAC (1976); and Country Roads Board, Avoidable Cost of Truck Operation, Report to ATAC (1977).

The public transport model uses only private marginal costs of operating public transport services. In particular the time costs of public transport users are omitted; this is in contrast to the road model where time costs of road users determine exclusively the prices charged. This omission may cause a different optimal subsidy level to public transport services; it is not possible to determine to what extent or in what direction. As with the road model other externalities are excluded, except that in the case of public transport it is generally claimed that the externalities are positive [3].

QUALIFICATIONS TO THE DATA USED

The data used varies considerably in quality. The public transport data in general can be relied on with more confidence than the road data. This is due in part to much research into demand and cost levels having been undertaken in Adelaide in recent years. On the other hand, data on the cost and operation of the urban arterial road system is not readily available. As a result, much of the input data is drawn from other sources in Australia or overseas.

The items of data in which least confidence is held are the elasticity values (in both the road and public transport models), and the speed flow curve. Neither of the models are particularly sensitive to the elasticity values (within plus or minus 10%) so this is probably not too serious a problem. Both models, on the other hand are sensitive to the shape of the speed flow curve, which highlights a need for more information on the relationship between speeds and volumes on urban arterial roads in Adelaide.

The quality of the data does not detract from the general conclusions of the thesis given above. It may however affect the specific price and funding levels for urban transport services.

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[3] For a discussion of the claimed positive externalities of public transport subsidies see U.S. Department of Transportation, Financing Transit: Alternatives for Local Government (1979) Chapter 2.

APPENDIX A: EXISTING TRANSPORT FUNDS

INTRODUCTION

This appendix provides historical data on transport expenditure in South Australia, and supplements data in Chapter 2. The appendix is organized on modal lines, and is restricted to roads and STA public transport services.

ROADS

Revenue

Until 1981/82 all payments from the Highways Fund whether for road construction or maintenance appeared in the Highways Department accounts, e.g. the payment to the Police Department occurred as an expenditure item, as did the net cost of providing the M.V. Troubridge service. In 1981/82 changes were made to accounting procudures:

- the payment to the Police Department no longer shows in the Highways Department expenditure, and the revenue from registration and licence fees is reduced by a similar amount;
- the road safety funds likewise do not appear as revenue or expenditure;
- M.V. Troubridge revenue appears as revenue and the expenditure as expenditure, previously the net cost was shown as expenditure;
- the Commonwealth government discontinued the 4% allowance for general administration on some road projects (arterial and local road construction, and local road maintenance) subject to Commonwealth funding. This increased the general administration expense in 1981/82; and
- land sales and rental income are shown as revenue, previously having been offset against construction expenditure.

These changes have made direct comparisons between 1980/81 and 1981/82 difficult. The figures have been adjusted where possible, but the last change mentioned above makes the "other income" figures for 1981/82 incompatible with other years. Prior to that year other income had never been greater than $3m, but in 1981/82 was over $9m. Other income includes state grants, loans, land sales, rent and STA contribution. Relevant figures are given in Table A.1 for 1968/69 to 1981/82. Table A.2 presents the same figures in real terms when adjusted by the Highways Department road construction cost index. This index has tended to increase faster than the CPI, thus the "real" figures are higher than if they had been inflated using the CPI (see Table B.1, Appendix B).

Expenditure

Road construction and maintenance expenditure by the Highways Department are presented in Table A.3 from 1968/69 to 1981/82. Maintenance expenditure increased at a faster rate over the period (316%) than construction expenditure (264%). Once again 1981/82 is not strictly comparable with previous years due to the changed accounting practices.

The composition of construction expenditure by road category is given in Table A.4 for the years 1975/76 to 1981/82. Similar data for maintenance expenditure is contained in Table A.5. The expenditure on urban arterial road construction and maintenance has been increasing as a proportion of total expenditure. The amounts expended on urban arterials and the percentage of the total expenditure is given in Table A.6. Maintenance expenditure on urban arterials has increased from 15% to 20% of the total and for construction the share on urban arterials increased from 21% to 34%.

Road Revenue, 1968/69 to 1981/82 ($'000)

Year	[1] Registration & Licence Fees(1)	[2] Police Services	[3] Road Safety(2)	[4] M.V. Trou-bridge(3)	[5] R&L Fees for Roads(4)	[6] Road Mtce Charge	[7] Fuel Levy	[8] Other Income	[9] Road Grants(5)	[10] Planning & Research
1968/69	12,533	-	-	-	12,533	2,557	-	1,243	19,432	-
1969/70	13,250	-	-	-	13,250	2,839	-	2,322	21,000	-
1970/71	14,212	-	152	-	14,060	2,958	-	1,063	23,800	-
1971/72	18,001	1,075	265	-	16,661	3,287	-	801	25,850	-
1972/73	18,829	1,145	276	217	17,191	3,401	-	1,755	28,975	-
1973/74	19,871	1,238	282	228	18,123	3,859	-	2,712	31,702	-
1974/75	25,841	1,592	582	546	23,121	4,050	-	821	31,268	724
1975/76	27,574	1,742	636	670	24,526	4,242	-	3,228	40,764	335
1976/77	40,081	2,306	1,273	665	35,837	4,716	-	681	38,800	559
1977/78	39,848	2,528	775	725	35,820	4,825	-	1,022	40,400	349
1978/79	42,352	2,738	685	1,056	37,864	4,812	-	1,690	43,207	235
1979/80	35,339	2,883	791	1,522	30,143	1,077	14,158	1,328	46,544	352
1980/81	35,586	3,023	860	1,169	30,543	50	20,167	612	51,686	228
1981/82	40,210	4,355	1,049	2,119	32,687	-	23,737	9,054	56,302	-

Source Highways Department Annual Reports

Notes: (1) Excludes collection costs.
(2) Collections in each year, expenditure may be different.
(3) Net cost = Expenditure - Revenue
(4) [5] = [1] - [2] - [3] - [4]. R&L = Registration & Licence.
(5) From the Commonwealth Government. Total Commonwealth grants = [9] + [10].

Road Revenue in Real Terms ($1982 inflated by Road Construction Cost Index)(1)

Year	Registration & Licence Fees	Police Services	Road Safety	M.V. Trou-bridge	R&L Fees for Roads	Road Mtce Charge	Fuel Levy	Other Income	Road Grants	Planning & Research
1969/69	56,026	-	-	-	56,026	11,430	-	5,557	86,866	-
1969/70	56,867	-	-	-	56,867	12,184	-	9,966	90,129	-
1970/71	54,452	-	582	-	53,870	11,333	-	4,073	91,188	-
1971/72	64,358	3,843	947	-	59,567	11,752	-	2,864	92,420	-
1972/73	59,416	3,613	871	685	54,247	10,732	-	5,538	91,433	-
1973/74	51,056	3,181	725	586	46,565	9,915	-	6,968	81,454	-
1974/75	56,298	3,468	1,268	1,190	50,373	8,823	-	1,789	68,122	1,577
1975/76	51,224	3,236	1,181	1,245	45,562	7,880	-	5,997	75,727	622
1976/77	66,469	3,824	2,111	1,103	59,431	7,821	-	1,129	64,345	927
1977/78	61,761	3,918	1,201	1,124	55,518	7,478	-	1,584	62,616	541
1978/79	60,227	3,894	974	1,502	53,845	6,843	-	2,403	61,443	334
1979/80	45,271	3,693	1,013	1,950	38,615	1,380	18,137	1,701	59,626	451
1980/81	40,558	3,445	980	1,332	34,811	57	22,985	698	58,908	260
1981/82	40,210	4,355	1,049	2,119	32,687	-	23,737	9,054	56,302	-

Source Highways Department Annual Reports.

Notes (1) See Notes to Table A.1.

TABLE A.3.
Road Construction & Maintenance Expenditure by the Highways Department 1968/69 to 1981/82 ($'000)

Year	Maintenance	Construction	Total
1968/69	8,211	23,836	32,047
1969/70	10,271	30,199	40,470
1970/71	11,575	27,355	38,930
1971/72	13,392	32,049	45,441
1972/73	11,196	33,604	44,800
1973/74	11,537	35,210	46,747
1974/75	14,963	39,180	54,143
1975/76	18,479	44,095	62,574
1976/77	19,998	53,008	73,006
1977/78	21,750	47,607	69,357
1978/79	24,430	55,477	79,907
1979/80	26,932	54,457	81,389
1980/81	30,612	61,819	92,431
1981/82	34,147	62,966	97,113

Source Highways Department Annual Reports

TABLE A.4.
Construction Expenditure by Road Category, 1975/76 - 1981/82 ($'000)

Year	National Highways(1)	Rural Roads		Urban Roads		Other(2)	Total
		Arterial	Local	Arterial	Local		
1975/76	22,560	6,667	2,516	9,327	1,259	1,766	44,095
1976/77	26,016	8,492	4,774	10,606	1,890	1,230	53,008
1977/78	18,872	9,401	4,371	10,412	2,616	1,935	47,607
1978/79	21,758	10,491	3,761	13,134	2,469	3,864	55,477
1979/80	18,972	11,423	3,560	14,751	2,744	3,007	54,457
1980/81	23,353	10,074	4,841	19,842	2,778	931	61,819
1981/82	23,814	10,152	4,773	21,204	3,023	-	62,966

Source Report of the Auditor General op.cit. 1976 to 1982.
Highways Department Annual Reports.

Notes (1) Includes Export Roads, National Commerce Roads and/or Developmental Roads.
(2) Includes MITERS (traffic engineering improvements), land & buildings and purchase of plant.

TABLE A.5.
Maintenance Expenditure by Road Category 1975/76 to 1981/82 ($'000)

Year	National Highways(1)	Rural Roads Arterial	Rural Roads Local	Urban Roads Arterial	Urban Roads Local	Other(2)	Total
1975/76	2,784	8,571	3,240	2,744	315	824	18,479
1976/77	3,115	8,617	4,198	3,009	199	860	19,998
1977/78	3,212	9,990	4,156	3,287	137	968	21,750
1978/79	4,126	10,799	3,975	4,343	145	1,042	24,430
1979/80	3,994	11,955	4,862	4,747	141	1,233	26,932
1980/81	4,199	13,477	5,620	5,664	179	1,473	30,612
1981/82	4,074	15,970	6,895	6,922	286	-	34,147

Source Report of the Auditor General op.cit. 1976 to 1982
Highways Department Annual Reports.

Notes (1) Includes Export Roads & National Commerce Roads.
(2) Land & Buildings.

TABLE A.6.
Construction & Maintenance Expenditure on Urban Arterial Roads in Real Terms (1982 $'000)

Year	Construction: Urban Arterials Amount	Construction: Urban Arterials %	Construction: Total	Maintenance: Urban Arterials Amount	Maintenance: Urban Arterials %	Maintenance: Total
1975/76	17,327	21	81,915	5,098	15	34,328
1976/77	17,589	20	87,907	4,990	15	33,164
1977/78	16,137	22	73,786	5,095	15	33,710
1978/79	18,677	24	78,892	6,176	18	34,741
1979/80	18,897	27	69,763	6,081	18	34,502
1980/81	22,614	32	70,457	6,455	19	34,889
1981/82	21,204	34	62,966	6,922	20	34,147

URBAN PUBLIC TRANSPORT

Prior to 1974 bus and tram services were operated by the Municipal Tramways Trust and rail services by the South Australian Railways, when the State Transport Authority was formed. Further, in 1975 the non-metropolitan railways were transferred to the Commonwealth Government. It was not until 1978/79 that integrated STA accounts were produced. These changes make some comparisons on a modal basis inappropriate. The figures presented are from STA accounts from 1978/79 to 1981/82, from STA and MTT accounts from 1974/75 to 1977/78, and from SAR and MTT accounts from 1968/69 to 1976/77. The SAR Annual Reports gave the costs and revenue of the suburban railways separately after allocation of joint costs. The basis of the allocation may affect rail costs in the early years of the series. Further when the railway transfer occurred the railway catering and trading section remained with the STA, these costs are included in STA accounts from 1978/79, but not prior to that date.

Total public transport revenues and costs are given in Table A.7. Tables A.8 and A.9 give bus and tram data, and rail data respectively until 1977/78 when STA integrated accounts came into operation. Modal separation is now not possible unless arbitrary cost allocations are made (this has been done in STA Annual Reports since 1981).

Of interest in the tables are the following:

- 1973/74 was the year the privately operated bus services were taken over by the STA effectively doubling the bus fleet;
- the low fares policy in the seventies is particularly evident on bus and tram services when traffic revenue remained stable, except for the increase due to the takeover of privately operated bus services;
- rail services performed relatively worse than bus and tram services until 1978/79, when integrated figures only are available;
- annual capital costs become a significant cost in the late seventies due to the rollingstock upgrading progammes and the relatively greater cost of rollingstock; and
- other revenue has become a significant factor in financial results since the late seventies.

Table A.10 gives public transport revenue, cost and deficit in real terms, i.e. the figures in Table A.7 have been inflated to 1982 $ using the CPI. The table shows that although revenue has increased 35% in real terms from 1968/69 to 1981/82, costs have increased 140% leading to an increase in the deficit of over 350%. Further it seems that much of the revenue increase is due to non-fare revenue, although it is not possible to be definite due to the mixture of data available. It should be noted that traffic revenue includes subsidy payments from the Treasury for concession riders, and charter receipts. Therefore the recovery from users of regular route services is even lower than the figures in Tables A.7 and A.10 suggest.

TABLE A.7
Bus, Tram and Rail Revenue, Cost & Deficit ($'000)

Year	Revenue			Cost			Deficit
	Traffic	Other(1)	Total	Operating	Other(2)	Total	
1968/69			8,502			12,659	4,157
1969/70			8,760			13,341	4,582
1970/71			9,000			14,646	5,645
1971/72			9,192			15,531	6,338
1972/73			9,641			17,405	7,763
1973/74			12,424			22,304	9,880
1974/75			16,213			32,860	16,647
1975/76			17,469			39,066	21,597
1976/77			20,044			46,639	26,595
1977/78			20,120			56,759	36,639
1978/79	18,105	6,445	24,550	57,448	13,594	71,043	46,493
1979/80	20,257	6,686	26,943	63,388	11,003(3)	74,391	47,448
1980/81	24,310	9,344	33,654	72,338	12,659	84,997	51,343
1981/82	28,011	9,703	37,714	84,889	15,111	100,000	62,286

Sources MTT, SAR & STA Annual Reports

Notes (1) Includes advertising, property, investment and catering and trading income.
(2) Includes depreciation, interest on loans and lease payments.
(3) Capital value of assets adjusted due to Railway Transfer.

TABLE A.8.
Bus and Tram Revenue, Cost and Deficit 1968/69 to 1977/78 ($'000)

Year	Revenue		Costs		Deficit
	Traffic	Total(1)	Operating	Total(2)	
1968/69	6,233	6,472	5,675	6,513	41
1969/70	6,448	6,697	5,892	6,702	5
1970/71	6,640	6,881	6,608	7,342	461
1971/72	6,783	6,978	6,797	7,622	644
1972/73	7,036	7,305	7,594	8,676	1,371
1973/74	9,615	9,958	10,873	12,204	2,246
1974/75	12,711	13,427	17,805	19,825	6,398
1975/76	13,459	14,454	21,225	23,676	9,222
1976/77	13,646	16,781	26,418	29,491	12,710
1977/78	13,426	16,073	31,479	35,166	19,093

Sources MTT Annual Reports
STA Annual Reports

Notes (1) Total Revenue equals Traffic Revenue plus Sundry Revenue (Advertising and Investment income).
(2) Total Cost equals Operating Cost plus Depreciation and Interest.

TABLE A.9.
Rail Revenue, Costs and Deficit 1968/69 to 1977/78 ($'000)

Year	Traffic Revenue	Cost		Deficit
		Working(1)	Total(2)	
1968/69	2,030	5,344	6,146	4,116
1969/70	2,063	5,771	6,639	4,576
1970/71	2,119	6,475	7,304	5,185
1971/72	2,214	6,956	7,909	5,695
1972/73	2,336	7,804	8,729	6,393
1973/74	2,466	9,200	10,100	7,634
1974/75	2,786	12,103	13,035	10,249
1975/76	3,015	14,168	15,390	12,375
1976/77	3,263	15,816	17,148	13,885
1977/78	4,047	19,126	21,593	17,546

Sources S.A.R. Annual Reports.
S.T.A. Annual Reports.
Reports of the Auditor General.

Notes (1) Working cost includes depreciation.
(2) Total cost = Working cost plus debt charges.

TABLE A.10
Bus, Tram and Rail Revenue, Cost and Deficit in Real Terms
(1982 $'000 inflated by CPI).

Year	Revenue			Cost			Deficit
	Traffic	Other	Total	Operating	Other	Total	
1968/69			27,875			41,505	13,630
1969/70			27,898			42,487	14,592
1970/71			27,607			44,926	17,316
1971/72			26,566			44,887	18,318
1972/73			26,270			47,425	21,153
1973/74			29,794			53,487	23,693
1974/75			32,953			66,789	33,835
1975/76			31,647			70,772	39,125
1976/77			31,417			73,101	41,685
1977/78			28,702			80,969	52,267
1978/79	24,044	8,559	32,603	76,292	18,053	94,347	61,744
1979/80	24,435	8,065	32,501	76,463	13,273(1)	89,736	57,235
1980/81	26,862	10,325	37,187	79,931	13,988	93,919	56,732
1981/82	28,011	9,703	37,714	84,889	15,111	100,000	62,286

See notes to Table A.7.

APPENDIX B: ROAD COST ESTIMATION

INTRODUCTION

This Appendix describes the data and estimation process for the road cost function for use in the optimal toll model. The data was collected from S.A. Highways Department cost records unless otherwise indicated. The function is built up from three component costs: construction, land acquisition and maintenance which are discussed in turn below.

CONSTRUCTION COSTS

Data was obtained from Highways Department Annual Reports (1968/9 to 1981/82) and Estimating Section Reports [1] on actual road construction projects for the years 1974/5 to 1980/81 for construction projects involving road widening, road construction or road re-construction. Money values from each year of the construction period were inflated to June 1982 cost levels using the Construction Cost Index maintained by the Highways Department. The index (converted to 1982 base year) is given in Table B.1 along with the CPI. The Construction Cost Index has increased at a greater rate than the CPI for the period under consideration.

Road Construction Projects

Twenty seven road construction projects in the metropolitan area were used in the estimation. The projects cover construction of new roads, widening of existing roads and reconstruction of existing roads. These are described below.

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[1] Highways Department, Direct Control Road Construction Cost Records, Prepared by Estimating Section (Adelaide 1974 to 1981).

TABLE B.1
South Australian Highways Department Construction Cost Index and Adelaide CPI (1982 base year)(1)

30th June	Index	CPI
1982	100	100
1981	87.74	90.5
1980	78.06	82.9
1979	70.32	75.3
1978	64.52	70.1
1977	60.30	63.8
1976	53.83	55.2
1975	45.90	49.2
1974	38.92	41.7
1973	31.69	36.7
1972	27.97	34.6
1971	26.10	32.6
1970	23.30	31.4
1969	22.37	30.5

(1) Source: Highways Department Annual Reports
Australian Bureau of Statistics

A. Salisbury Highway, Spains Road - Ryans Road

Length 3.6km. Sealed width 2 x 10m carriageways. Includes parking lanes on each side of the highway.

Year	Actual $('000)	1982 $
1968/69	103	460,438
1969/70	72	309,013
1970/71	57	218,391
1971/72	151	539,864
1972/73	73	230,356
1978/79	118	167,804
1979/80	66	84,550
	640	2,010,416

B. Brighton Road, Arthur Street - Stopford Road

Reconstruction and widening of 3km of 18.9m carriageway. Includes two parking lanes.

Year	Actual $('000)	1982 $
1969/70	202	866,953
1970/71	245	938,697
1971/72	47	168,037
1972/73	122	384,979
1973/74	95	244,279
1974/75	23	50,109
1975/76	63	117,035
1976/77	2	3,317
	799	2,773,406

C. Brighton Road, City of Brighton boundary - Jetty Road, Glenelg

Reconstruction and widening of 1km of 18.9m carriageway. Includes two parking lanes.

Year	Actual $('000)	1982 $
1970/71	100	383,142
1971/72	10	35,752
1972/73	18	56,800
1973/74	115	295,706
1974/75	251	546,840
1975/76	20	37,154
1976/77	3	4,975
	517	1,360,369

D. Frederick Road, Trimmer Parade - Old Port Road

Construction of western carriageway to provide 3.65km of 7.3m carriageway with a 4.3m median.

Year	Actual $('000)	1982 $
1971/72	83	269,746
1972/73	58	183,023
1973/74	3	7,708
1974/75	4	8,714
1975/76	201	373,398
1976/77	423	701,492
	772	1,544,081

E. Grange Road, Arlington Terrace - Starr Street

Widening to provide 18.9m carriageway. Includes two parking lanes.

Year	Actual $('000)	1982 $
1971/72	28	100,107
1972/73	110	347,113
1973/74	89	288,674
1976/77	124	205,638
	351	941,532

F. North East Road, Hampstead Road - Northcote Terrace

Reconstruction and widening to provide 1.2km of 18.9m carriageway.

Year	Actual $('000)	1982 $
1973/74	4	10,285
1974/75	44	95,860
1975/76	86	159,762
1976/77	20	33,167
1977/78	490	759,454
	644	1,058,528

G. Darley Road, Lower North East Road - North East Road

Reconstruction and duplication of 2.05km to provide dual 10.4m carriageways.

Year	Actual $('000)	1982 $
1973/74	50	128,469
1974/75	561	1,222,222
1975/76	469	871,261
1976/77	340	563,847
	1,420	2,785,799

H. Gorge Road, Silkes Road - Manresa Avenue

Construction of 1km on a new alignment. Dual cariageways 8.8m separated by a solid median.

Year	Actual $('000)	1982 $
1973/74	137	352,004
1974/75	80	174,292
1975/76	36	66,877
1978/79	6	8,532
1979/80	198	253,651
	457	855,348

I. Montague Road, Nelson Road - Hartman Avenue

Construction and widening to provide 0.7km of dual 7.3m carriageways

Year	Actual $('000)	1982 $
1975/76	45	83,596
1976/77	146	242,123
1977/78	299	463,422
	490	789,141

J. Lower North East Road, River Torrens - Lyons Road

Reconstruction and widening of 1.8km to provide dual 7.3m carriageways separated by solid median of 4.3m.

Year	Actual $('000)	1982 $
1977/78	15	1,616,543
1978/79	1,137	23,450
	1,152	1,639,993

K. Main North Road, Nottage Terrace - Fitzroy Terrace

Widening to provide 8.8km dual carriageways with a 1.3m median.

Year	Actual $('000)	1982 $
1977/78	108	167,390
1978/79	321	456,485
	429	623,875

L. M.R. 11, Glenalta Railway Crossing - Belair

Reconstruction and widening of 1.6km with variable pavement width.

Year	Actual $('000)	1982 $
1977/78	289	447,923
1978/79	56	79,636
	345	527,559

M. Main North Road, Nottage Terrace - Third Avenue

Widening to dual 8.2km carriageways separated by a 3m median. Includes two parking lanes or protected turns.

Year	Actual $('000)	1982 $
1977/78	24	37,198
1978/79	235	334,186
1979/80	312	399,692
1980/81	1,008	1,148,849
1981/82	245	245,000
	1,824	2,164,925

N. Fosters Road, Folland Avenue - Grand Junction Road

Reconstruction and widening of 1.2km to provide dual 6.3m wide carriageways.

Year	Actual $('000)	1982 $
1978/79	139	197,668
1979/80	109	139,636
	248	337,304

O. Penfold Road, Magill Road - The Parade

Reconstruction and widening of 1.5km to provide 13.4m wide carriageway.

Year	Actual $('000)	1982 $
1978/79	115	163,538
1979/80	280	358,698
	395	522,236

P. Flaxmill Road, Brodie Road - South Road

Reconstruction and widening of 1.1km to provide a 7.4m wide carriageway.

Year	Actual $('ØØØ)	1982 $
1978/79	299	425,199
1979/8Ø	72	92,284
	371	517,483

Q. Nottage Terrace, Main North Road - Northcote Terrace

Widening to 6.4m dual carriageways.

Year	Actual ($'ØØØ)	1982 $
1978/79	27	38,396
1979/8Ø	215	275,429
	242	313,825

R. Bridge Road, Montague Road - McIntyre Road

Reconstruction and duplication of 3.5km to provide 7m dual carriageways separated by a 3.3m median

Year	Actual $('ØØØ)	1982 $
1978/79	967	1,375,142

S. Mount Barker to Strathalbyn Road, South East Freeway - Flaxley Road

Reconstruction and widening to provide dual 6.3m carriageways separated by a solid median 3.4m wide. Includes protected turns.

Year	Actual $('ØØØ)	1982 $
1978/79	74	1Ø5,233
1979/8Ø	971	1,243,915
198Ø/81	293	333,941
1981/82	13	13,ØØØ
	1,351	1,696,Ø89

T. Lonsdale Road, Lauder Road - Sherriffs Road

Construction of 4.5km to proviide 1Ø.7m dual carriageways separated by a concrete median Ø.6m wide. Carriageways are two lanes plus a sealed shoulder.

Year	Actual $('ØØØ)	1982 $
1978/79	331	47Ø,7Ø5
1979/8Ø	965	1,236,228
198Ø/81	2,853	3,251,665
1981/82	483	483,ØØØ
	4,632	5,441,598

U. Sudholz Road, Grand Junction Road - North East Road

Construction of 1.4km to provide 7.9m dual carriageways and a 4.3m solid median.

Year	Actual $('ØØØ)	1982 $
1978/79	82	116,61Ø
1979/8Ø	3Ø	38,432
198Ø/81	1Ø8	123,Ø91
1981/82	823	823,ØØØ
	1.Ø43	1,1Ø1,133

V. Morphett Road, Anzac Highway - Cliff Street

Reconstruction and widening of 1.1km to provide 13.4m carriageway.

Year	Actual $('ØØØ)	1982 $
1978/79	7Ø	99,545
1979/8Ø	227	29Ø,8Ø2
	297	39Ø,347

W. Briens Road, Grand Junction Road - South Terrace

Widening by 3.6m on the western side of the road.

Year	Actual $('ØØØ)	1982 $
1978/79	128	182,Ø25
1979/8Ø	39	49,961
198Ø/81	4	4,559
	171	236,545

X. Holbrooks Road, River Torrens - Ashley Street

Widening of Ø.56km to 15m.

Year	Actual $('ØØØ)	1982 $
1979/8Ø	114	146,Ø41

Y. Nelson Street, Payneham Road - Magill Road

Reconstruction and widening to 2Ø.4m of pavement. Includes 3m parking lane, 1.2m bicycle track and 3m median.

Year	Actual $('ØØØ)	1982 $
1979/8Ø	1	1,281
198Ø/81	7	7,978
1981/82	978	978,ØØØ
	986	987,259

Z. Francis Street, Ocean Steamers Road - Eastern Parade

Reconstruction of 1km to 14.8m wide.

Year	Actual $('ØØØ)	1982 $
198Ø/81	6Ø1	684,978

AA. Rowells Road, Brian Street - Henley Beach Road

Reconstruction of Ø.7km to 12m wide.

Year	Actual $('ØØØ)	1982 $
1981/82	33Ø	33Ø,ØØØ

Definition of Costs

The costs include all construction costs, and service relocation, indirect and sundry costs of the projects. These last three cost categories vary considerably with individual projects as can be seen from Table B.2. Data on this aspect was only available for the projects listed in the table so no account was taken of these variations in the estimation. Construction costs include clearing, earthworks, stabilization, pavements and drainage; indirect costs include overhead, camp establishment and maintenance, supervision and transport; sundries include traffic control measures, landscaping, parking bays and retaining structures; and service re-location costs cover electricity, water & sewerage, telephone and gas services.

Data

The data used in the estimation is given in Table B.3. The width of a road is defined to include the total width of pavement construction. In some cases this includes the median and in others not, depending on what was actually constructed. Where parking lanes are provided these are included in the width as pavement is constructed for these lanes. In the case of Lonsdale Road (project T) the width includes the sealed shoulders but not the concrete median. A dummy variable to denote whether parking lanes were provided was included in the lane cost estimations (Dummy = 1 if parking lanes provided, zero otherwise). For Lonsdale Road the sealed shoulders were treated as parking lanes.

The Keeler and Small estimation included urbanization variables to determine whether the costs of construction varied with the location of the road (CBD, urban, rural). This method is not appropriate here as all roads except possibly one are classified as urban. Project S (Mount Barker to Strathalbyn Road) could be considered a rural road; estimations were undertaken with and without that project but there was little difference in the result so it is included in the final estimations (see below).

TABLE B.2
Share of Cost Categories for Selected Road Construction Projects(1)

Project	Construction	Sundries	Indirect	Services
D	74.5	6.7	15.3	3.6
E	62.2	18.6	16.7	2.5
F	50.7	11.4	12.5	25.5
G	64.3	9.7	19.3	6.7
H	64.3	9.7	19.3	6.7
I	37.3	4.9	9.9	47.9
J	52.5	16.9	14.0	16.6
K	33.8	13.7	6.3	46.3
L	63.3	11.0	19.7	5.9
M	45.6	9.9	8.8	35.7
N	79.2	4.6	15.4	0.8
O	67.4	10.6	14.3	7.7
P	71.9	7.1	16.5	4.4
Q	51.1	13.8	11.5	23.5
R	77.5	6.0	12.9	3.6
S	56.4	10.7	24.5	8.4
T	77.0	6.5	16.2	0.4
Z	70.3	7.7	15.7	6.3

Source: Highways Department, Estimating Section op.cit.
Note (1) See text for explanation of cost categories.

TABLE B.3
Data Used in Road Construction Cost Estimation

Project	Cost ($)	Length (km)	Cost/km ($)	Width (m)	No. of Lanes	Parking Dummy
A	2,Ø1Ø,416	3.6	558,448	2Ø.Ø	4	1
B	2,773,Ø46	3.Ø	924,469	18.9	4	1
C	1,36Ø,369	1.Ø	1,36Ø,369	18.9	4	1
D	1,544,Ø81	3.65	423,Ø36	7.3	2	1
E	941,532	1.15	437,922	18.9	4	1
F	1,Ø58,528	1.2	882,1Ø7	18.9	6	Ø
G	2,785,799	2.Ø5	1,358,926	2Ø.8	6	Ø
H	855,348	1.Ø	855,348	17.6	4	Ø
I	789,141	Ø.7	1,127,344	14.6	4	Ø
J	1,639,993	1.8	911,1Ø7	18.9	6	Ø
K	623,875	Ø.7	891,25Ø	17.6	6	Ø
L	527,559	1.6	329,724	Variable	2	Ø
M	2,164,925	1.65	1,312,Ø76	19.4	4	1
N	337,3Ø4	1.2	281,Ø87	12.6	4	Ø
O	522,236	1.5	348,157	13.4	4	Ø
P	517,483	1.1	47Ø,439	7.4	2	Ø
Q	313,825	Ø.5	627,65Ø	12.8	4	Ø
R	1,375,142	3.5	329,898	14.Ø	4	Ø
S	1,696,Ø89	1.85	916,8Ø5	16.Ø	4	Ø
T	5,441,598	4.5	1,2Ø9,244	21.4	4	1
U	1,1Ø1,133	1.4	786,523	15.8	4	Ø
V	39Ø,347	1.1	354,861	13.4	4	Ø
W	236,545	1.1	215,Ø41	3.6	1	Ø
X	146,Ø41	Ø.56	26Ø,787	15.Ø	4	Ø
Y	987,259	Ø.7	1,41Ø,37Ø	2Ø.4	4	1
Z	684,978	1.Ø	684,978	14.8	4	Ø
AA	33Ø,ØØØ	Ø.7	471,428	12.Ø	2	Ø
Mean Values	1,228,ØØØ	1.66	731,ØØØ	14.98	3.89	Ø.296

Estimations

The units of data used in the regressions were cost/km in millions of dollars, width in metres, and actual numbers of lanes. The first estimation was to determine the presence or absence of economies of scale in road construction. The result of the estimation was [2] (t-statistics in brackets):

$$\ln \text{cost/km} = \ln a + b \ln \text{width}$$

$$= \underset{(-5.0737)}{-2.9855} + \underset{(4.3793)}{0.9500} \ln \text{width} \qquad R^2 = 0.4442 \qquad \text{(A)}$$

The estimation indicates that there are constant returns to scale in road construction. At the 5% significance level the null hypothesis that b=1 is accepted.

To determine the cost of constructing an extra lane estimations were undertaken with the number of traffic lanes, rather than width as the dependent variable. The parking dummy was included to isolate the cost of providing separate parking lanes on arterial roads (i.e. one on each side of the road). The result of the estimation was (t-statistics in brackets):

$$\ln \text{cost/km} = \ln a + b \ln \text{lanes} + c \text{ parking dummy}$$

$$- \underset{(-5.3473)}{1.5983} + \underset{(3.5957)}{0.7825} \ln \text{lanes} + \underset{(2.2554)}{0.4271} \text{ parking dummy}$$

$$R^2 = 0.4314 \qquad \text{(B)}$$

At the 5% significance level the null hypothesis that b=1 cannot be accepted; thus we cannot conclude that there are constant returns to scale in road construction when the estimation is in terms of lanes.

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[2] Note that Project L is omitted as the width of the road is variable.

Table B.4 presents estimates of the marginal cost of a lane km of urban arterial road calculated at the margin under different assumptions. The marginal cost of an extra traffic lane is $2Ø7,ØØØ when no parking is provided and $31Ø,ØØØ when parking is provided. However the marginal cost of a lane at the average project size (3.89 lanes) is only $15Ø,ØØØ.

TABLE B.4
Cost of Constructing Traffic & Parking Lanes
Based on Equation (B).

Cost of a Marginal Lane	Cost/Lane km
when no parking provided	$2Ø7,24Ø
at the average project size	$15Ø,5Ø6
when parking is provided	$3Ø9,995

The estimations show that there are constant returns to width but not to lanes in road construction. This may result from the fact that the same width is used in a variety of lane configurations. Another factor contributing to the decreasing costs could be the cost of service relocation which is more likely to occur for wider roads. Keeler & Small obtained a function with constant returns to lanes thus marginal and averages costs were equal.

Urbanization Effects

The Keeler & Small construction cost function allows for the effect of urbanization by including variables for the percentage of each freeway project in CBD, urban and rural areas. The projects used in this estimation are all urban except possibly project S. The equations were re-estimated excluding this project to determine whether it affected the results to any extent. The results of the estimations were [3] (t-statistics in brackets):

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[3] Once again Project L is omitted.

(i) $\ln \text{cost/km} = -2.9797 + 0.9438 \ln \text{width}$
$\quad\quad (-4.9974) \quad (4.2901)$

$R2 = .4445$ (C)

(ii) $\ln \text{cost/km} = -1.6088 + 0.7722 \ln \text{lanes} + 0.4510 \text{ parking dummy}$
$\quad\quad (-5.3736) \quad (3.5408) \quad\quad (2.3595)$

$R2 = .4446$ (D)

There are only minor differences in the estimated coeficients. Table B.5 gives the estimated lane costs based on equation (D). The marginal cost of a lane when no parking is provided is similar with Project S included ($2Ø7,24Ø cf $2Ø5,112) although the differences are greater at the average project sizes and when parking is provided. As only the marginal cost of a lane is used the cost with the full data set will be used in the application of the Keeler & Small model.

TABLE B.5
Lane Costs when Project S is Excluded
Based on Equation (D)

Cost of a Marginal Lane	Cost/Lane km
when no parking is provided	$2Ø5,112
at the average project size	$146,95Ø
when parking is provided	$314,177

LAND ACQUISITION COSTS

There is no data base available in S.A. to estimate the cost of land acquisition as performed by Keeler & Small. Their approach was to estimate the proportion of land acquisition costs in total right of way costs for a sample of 57 observations[4]. Land acquisition costs are not linked to particular road projects by the Highways Department, and land is often purchased well in advance of road widening or construction.

[4] Keeler and Small, op.cit., p. 9.

A difficulty in estimating land acquisition costs occurs in the size of the parcels of land purchased. For example much extra road capacity provided in Adelaide in the last two decades has been as a result of the road widening programme, where frontages only were purchased and fences re-constructed for the residences affected. Where frontages could not be purchased, i.e. a shop existed, the whole site was purchased, the building demolished, and the smaller lot sold following the widening. In this case no attempt has been made to determine the net cost of the acquisition. Much of the road widening programme has been carried out on roads where private residences exist and thus the purchase of frontages and re-location of fences has been the most common method of land acquisition to increase road capacity.

This method of providing extra lane capacity is becoming less common as the road widening programme is wound down, and the relatively cheap alternatives on roads with residential frontages are exhausted. For example the widening of South Road, one of the major arterials in Adelaide is only just being undertaken - part of the reason being the cost of widening South Road as many commercial properties will need to be purchased. Table B.6 shows land costs and revenues of the Highways Department from 1977/78 to 1981/82. The high revenue in 1981/82 is a result of sales "resulting from a reassessment of Departmental road development plans"[5]. The costs and revenues relate to the State, not just the urban area, and is the only published data available on land costs. Officers of the Highways Department indicated that over 90% of land (by value) was acquired in the urban area.

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[5] Highways Department Annual Report 1982, p. 4.

TABLE B.6
Land Acquisition Costs & Revenues, 1977/88 to 1981/82 ($'ØØØ)

Year	Land Acquisition	Land Sales	Rental Income	Maintenance Costs
1977/78	5,486	1,625	1,429(1)	
1978/79	5,253	1,235	1,4Ø6(1)	
1979/8Ø	4,917	1,117	1,218(1)	
198Ø/81	6,947	1,829	3,Ø83	2,Ø84
1981/82	4,319	4,431	3,224	1,71Ø

Source: Highways Department Annual Reports
Notes (1) Net i.e. Rent minus Maintenance Costs

The Survey and Property Branch of the Highways Department offered to provide an estimate of the cost of acquiring land to be used in the model. As with the construction costs, the cost was expressed per lane km, and was, based on the experience of officers of the branch, a cost for an average road widening project. The cost provided was $1ØØ,ØØØ per lane km which is over 3Ø% of the construction ($2Ø6,821 estimated above) and acquisition costs. This percentage is high compared to those estimated by Keeler & Small for freeways in the Bay Area: 22% for urban-central city freeways, 2Ø% for urban-suburban freeways and 23% for rural freeways[6]. An examination of land acquisition costs relative to construction costs however supports the estimate provided for Adelaide. Table B.7 gives urban construction costs and net land acquisition costs, and the latter as a percentage of the former. Except for 1981/82 which was an abnormal year (as mentioned above) the percentage has varied from 26% to 37%, with the percentage declining over time. This may be a reflection of the winding down of the road widening programme.

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[6] Keeler and Small, op.cit., Table 2, p. 8.

TABLE B.7
Urban Arterial Construction and Land Acquisition Costs
1977/78 to 1981/82

Year	Construction(1)	Net Acquisition(2)	%
1977/78	10,412	3,861	37
1978/79	13,134	4,018	31
1979/80	14,751	3,800	26
1980/81	19,842	5,118	26
1981/82	21,204	-112	-

Notes (1) From Table A.4.
(2) From Table B.6. Land Acquisition minus Land Sales. Includes some rural purchases.

MAINTENANCE COSTS

Maintenance costs are recorded by the Highways Department for major road categories, i.e. National Highways, urban local and arterial roads, and rural local and arterial roads. As noted in Appendix A (Table A.6) maintenance expenditure on urban arterials has been increasing in real terms in recent years. This trend is likely to continue in future years for all maintenance expenditure:

> "The redistribution of financial resources between construction and maintenance resulted mainly from management decisions to reseal an increasing percentage of the State Road Network in 1981/82 and future financial years in order to clear the backlog of outstanding reseal projects which need to be undertaken to achieve the design life of roads"[7].

Maintenance expenditure by the Highways Department does not cover all urban arterial roads in Adelaide. Some roads are maintained by local councils although construction is financed by the Highways Department. Table 4.1 shows lengths (in km) and lane km of roads in Adelaide. The outer arterials have characteristics of rural roads and are not used in the

[7] Highways Department Annual Report 1982, p. 5.

congestion charging analysis. They are included for calculation of the cost of maintenance. In 1981/82 the Highways Department spent $6.922m on maintaining 732km or 2218 lane km of urban arterial roads. This represents $3,120 per lane km. Data for other years is not available. This amount used in the model, but will be an underestimate to the extent that real increases in maintenance expenditure continues. The effect however should not be large as maintenance expenditures are a small proportion of the annualized cost of roads per lane kilometre (approximately 10%). Other evidence indicates the figure may be too high - the maintenance cost used in road evaluations by the former Commonwealth Bureau of Roads varied between $1520 and $2250 per lane kilometre (updated to 1982 dollars using the road construction cost index in Table B.1) [8].

A simplification in the model is that maintenance costs do not vary with use, but only with road size. This is not too serious as "according to engineering opinions, most of the damage to a paved highway is caused by weather and time, and not by use" [9].

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[8] C. Bayley & G.J. Both, "Evaluation Procedures for Urban Arterial Road Projects", 8th ARRB Conference: Transport Planning and Economics 8, 6 Table 3.

[9] A.A. Walters, The Economics of Road User Charges, John Hopkins Press (Baltimore 1968) p. 23.

APPENDIX C: INPUT DATA FOR THE ROAD MODEL

INTRODUCTION

This Appendix describes the data (other than road cost data - see Appendix B) required as input to the optimal toll model. It covers data on the operating characteristics of the road system and the required economic parameters.

TRAFFIC FLOWS

The source of traffic flow data is Highways Department permanent count locations, and the data base maintained by the Advance Planning Branch. This data base also was the source of data on the urban arterial road stock.

Peaking Ratios

The Keeler and Small model requires as input the distribution of traffic flow over a week, expressed as a peaking ratio. A ratio for each time period to be used is required relative to the flow that occurs in the peak. One directional flows and five time periods are used.

Hourly traffic flow data was obtained from the 12 two-way permanent count stations operated by the Highways Department. The flow data is for the average weekday, Saturday and Sunday flows for 1981 as shown in Table C.1. Only weekday flows required analysis for differences in the balance of flows. The data in Table C.1 required some manipulation in order that flows of similar intensities could be grouped together and then expressed as a proportion of the peak flow. The resulting ratios and their length of occurence are presented in Table C.2.

TABLE C.1
Average Hourly Traffic Flows by Day of Week for Automatic Count Stations, 1981 (1)

Time (Hours)	Weekday		Saturday(2)	Sunday(2)
	AM Peak Direction	PM Peak Direction		
0-1	950	1,423	2,758	3,565
1-2	511	624	1,595	2,441
2-3	352	371	913	1,358
3-4	353	259	564	723
4-5	512	291	460	423
5-6	1,268	622	800	431
6-7	5,350	2,248	1,956	1,020
7-8	12,245	5,334	3,149	1,676
8-9	12,955	7,106	5,614	2,756
9-10	8,729	6,676	7,553	4,594
10-11	8,209	7,162	9.103	6,218
11-12	7,896	7,616	9,410	7,257
12-13	7,325	7,532	8,857	7,315
13-14	7,464	7,594	7,645	7,107
14-15	7,873	8,167	6,957	7,644
15-16	8,816	9,890	6,763	7,775
16-17	9,653	13,722	7,225	8,487
17-18	8,081	14,211	7,877	8,344
18-19	6,381	8,559	6,792	6,349
19-20	5,933	6,471	6,355	4,774
20-21	3,696	4,986	4,111	4,105
21-22	3.003	4,272	3,024	3,352
22-23	2,722	3,783	3,150	2,809
23-24	1,959	3,053	3,736	1,969
Total	132,236	131,972	116,367	102,492

(1) Source: Highways Department
(2) Half the hourly two way flow.

The hours for each ratio are for one directional flow on five weekdays, for example the peak flow (ratio 1.Ø) occurs for 2Ø hours in the peak direction over 5 days, or 4 hours per day (two hours in the morning and two hours in the afternoon). The ratios were then grouped to give the five ratios necessary as input to the model as follows:

Ratio	Hours of Operation per week (two way flow)
1.Ø	2Ø
Ø.7Ø (Ø.69–Ø.7Ø)	16
Ø.58 (Ø.57–Ø.58)	8Ø
Ø.55 (Ø.54–Ø.56)	34
Ø.2Ø (Ø.18–Ø.21)	186

TABLE C.2
Peaking Ratios of Traffic Flows by Time Period

Time Period	Traffic Flows: PD(1)		NPD(2)		Saturday		Sunday	
	Ratio	Hours	Ratio	Hours	Ratio	Hours	Ratio	Hours
Peak	1.Ø	2Ø	Ø.57	2Ø	Ø	Ø	Ø	Ø
Near Peak	Ø.7Ø	1Ø	Ø.58	1Ø	Ø.69	3	Ø	Ø
Day	Ø.58	25	Ø.57	25	Ø.54	8	Ø.56	9
Night	Ø.19	65	Ø.21	65	Ø.18	13	Ø.18	15

Notes (1) PD = Peak Direction
(2) NPD = Non Peak Direction

Traffic Flows per Lane Km

Along with the peaking ratios, the Keeler and Small model requires as input the peak hour traffic flow per lane km of road. Data is not kept in this form by the Highways Department. To obtain the figure the following procedure was adopted:

- the average annual daily traffic (AADT) for roads by number of lanes was obtained from the data base maintained by the Advance Planning Branch (see Table C.3).

- the AADT was adjusted to obtain an average annual weekday traffic (AAWT) flow using data in Table C.1. The Saturday and Sunday flows are 88% and 78% respectively of the weekday flow, i.e.

$$\text{AADT} = \frac{(5 + 0.88 + 0.78)}{7}\ \text{AAWT}$$

  requiring the AADT to be multiplied by 7/6.66 to be converted to an AAWT (see Table C.3).

- the data base also gave data on the composition of traffic in four categories: cars, light commercial vehicles, rigid trucks and articulated trucks. Larger vehicles affect the flow of traffic to a greater extent than smaller ones, and it is a fairly common practice to convert them to passenger car units (pcus) when trying to determine the effect on traffic flow [1]. Pcus under Australian conditions are only available for the category "trucks". The same pcu (=2) was used for rigid and articulated trucks [2]. Light commercial vehicles were assumed to effect the traffic flow to the same extent as cars [3].

- the revised AAWT flows were then converted to peak flows per lane hour. This calculation is somewhat complicated as there exist different numbers of through lanes in peak periods due to parking restrictions and clearways. For example a 4-lane road will only have 2 lanes available for through traffic if there is parking allowed in the kerb-side lane. Table C.4 gives the actual and operating dimensions of urban arterial roads. The peak operation dimensions are overstated to the extent that most parking restrictions only occur in the peak flow direction. This however should not bias the calculations as one direction flows are used (See Table C.3).

- the highest one way peak flow per lane hour occurs in the period 17-18 and represents 10.8% of the one way average weekday traffic (from Table C.1). This percentage was then applied to the one direction flows in Table C.3 and the peak operation lane configurations in Table C.4 to determine the peak hour traffic flow by road type:

  <u>2 Lane roads</u>

  6076 x 0.108 = 656 vehicles per lane hour

  <u>4 Lane roads</u>

  (11507 x 0.108)/2 = 621 vehicles per lane hour

  <u>6 Lane roads</u>

  (13912 x 0.108)/3 = 501 vehicles per lane hour

  <u>8 Lane roads</u>

  (25336 x 0.108)/4 = 684 vehicles per lane hour

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[1] NAASRA, Guide to Traffic Engineering Practice, (Sydney 1976).
[2] M.G. Lay, Source Book for Australian Roads, Ed. by K.G. Sharp ARRB (1981), p. 189.
[3] pcu=1 is used for light goods vehicles in the U.K. See F.D. Hobbs, Traffic Planning and Engineering 2nd edition, Pergamon Press (1979) p.54.

These were then averaged (over the length of each type of road) to obtain the average peak hour flow per lane:

(656 x 225 + 621 x 402 + 501 x 19 + 684 x 3)/649

= 630 vehicles per lane hour.

TABLE C.3
Traffic Flow by Size of Urban Arterials in Lanes.

	Number of Lanes				
	2	4	6	8	Average(5)
AADT	10,948	20,676	24,671	46,491	
AAWT(1)	11,507	21,732	25,931	48,864	
% Trucks(2)	5.6	5.9	7.3	3.7	5.8
& Light Commercials	7.3	2.9	3.3	3.7	4.4
AAWT (in pcus)(3)	12,151	23,014	27,824	50,672	
One direction flow(4)	6,076	11,507	13,912	25,336	

Source: Advance Planning Branch data base
Notes
(1) AAWT = 7/6.66 x AADT. See text.
(2) Rigid and Articulated
(3) 1 Truck = 2pcus. See text.
(4) Half the AAWT.
(5) Weighted by length

Traffic Flow by Time Period

The peaking ratios are applied to the average peak hour flow of 630 vehicles to obtain hourly flows in other time periods.

Time Period	Vehicles/Lane Hour
1 (Peak)	630
2 (Near Peak)	441
3 (Day)	365
4 (Day)	347
5 (Night)	126

TABLE C.4
Dimensions of Inner Urban Arterials

	Number of Lanes				
	2	4	6	8	Total
Physical Layout					
Length	121	439	86	3	649
Lane km	242	1,756	516	24	2,538
Peak Operation					
Length	225	402	19	3	649
Lane km	450	1,608	114	24	2,196

Source: Advance Planning Branch data base.

SPEED FLOW RELATIONSHIP

A speed flow relationship is used by Keeler and Small to measure the effects on traffic speed of increases/decreases in traffic flow. The resultant speed implies a time for a journey which is valued, allowing changes in time costs of a journey to be measured. The relationship between speed and traffic flow is inverse, i.e. as the flow increases the speed of vehicles decreases. The shape or form of the relationship is of importance; at low levels of traffic the effect on speed can be expected to be small and increasing at a small rate. The rate of increase will increase as the flow increases up to the capacity of the road. At this point the flow will actually decrease. This type of relationship has been identified by many [4] and used by Keeler and Small as shown in Figure C.1. As the traffic flow increases the speed falls until the point where capacity is reached and the curve bends backward, i.e. the flow decreases along with the speed.

[4] A.A. Walters, "The Theory and Measurement of Private and Social Cost of Highway Congestion" Econometrica 29, 4 (October 1961), p. 679.
C.D. Foster, The Transport Problem, Croom Helm (London 1975), p. 184.
H. Mohring, Transportation Economics, Ballinger (Cambridge Mass. 1976).

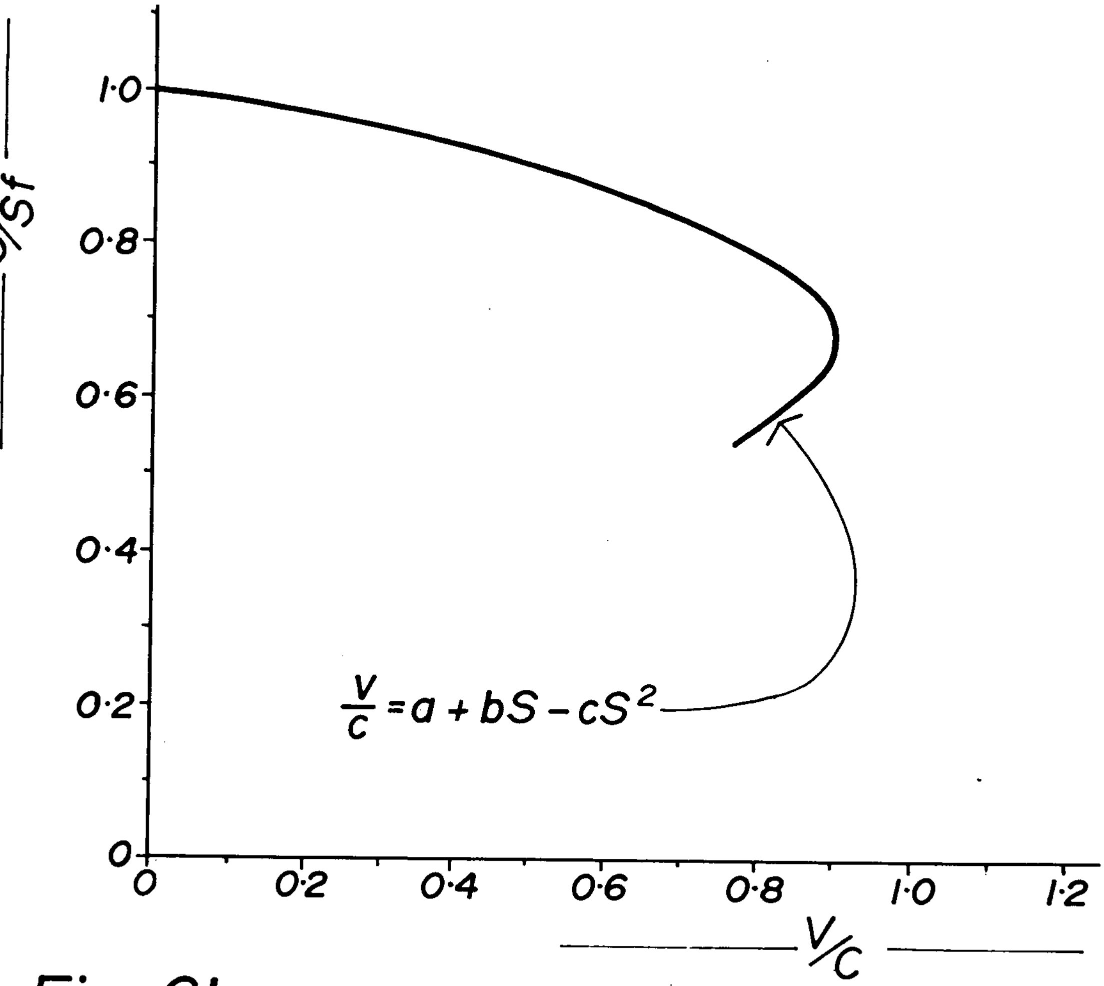

Fig. C1 *Speed Flow Curve used by Keeler & Small*

There is a need to choose a relationship calibrated to Adelaide conditions; this has not been done but one developed by Davidson [5] appears to conform to conditions on urban arterial roads:

$$S = S_f \frac{(1-V/C)}{(1-mV/C)} \qquad (1)$$

where S = speed
S_f = free-flow speed
V = traffic flow (volume)
C = capacity, and
m = service parameter

The shape of the curve is shown in Figure 4.2, for m=0.6 and m=0.9. It can be seen that where the volume capacity ratio(V/C) is one, i.e. capacity is reached, the speed is zero. This implies that the time to undertake a trip is infinity. This is an unrealistic assumption and Akcelik has proposed a

[5] K.B. Davidson, "A Flow Travel Time Relationship for Use in Transportation Planning", Proceedings 3rd ARRB Conference 3, 1 (1966) pp. 183-194.

modification to the curve [6] which is also shown in Figure C.2, as the dashed extensions. The mathematical form of the relationship is more easily explained by firstly converting Davidson's form from speed to travel time (i.e. the inverse of speed):

$$t = t_f \frac{(1-mV/C)}{(1-V/C)} \qquad (2)$$

where t = time of travel, and
t_f = free-flow trip time
other symbols are as defined in (1)

The Akcelik modification gives:

$$t = t_f \frac{1-mx}{1-x} \quad \text{for } x<x_c \qquad (3)$$

$$t = t_c + u_c\,(x-x_c) \quad \text{for } x>x_c$$

where
$$t_c = t_f \frac{1-mx_c}{1-x_c}$$

$$u_c = \left.\frac{dt}{dx}\right|_{x=x_c} = t_f \frac{1-m}{(1-x_c)^2}$$

x = V/C is the degree of saturation;
x_c = 0.85+0.10m is the critical degree of saturation above which over-saturated conditions prevail;
t_c is the travel time at the critical degree of saturation; and
u_c is the slope of the travel time function at the critical degree of saturation.

The effect of the modification is that the travel time function adopts a linear rate of increase at flows above the critical degree of saturation, but does not reach infinity. In its inverse form, speed does not reach zero, but approaches it above the critical degree of saturation (i.e. V>C).

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[6] R. Akcelik, "On Davidson's Flow Rate/Travel Time Relationship: Discussion", Australian Road Research 8, 1 ARRB (1978) pp. 41-44.

The only problem remaining for resolution is the value for m, the level of service parameter. Davidson states that m "may be regarded as a characteristic of the road or type of road so that each road type can have a different relationship between flow and delay at the same degree of saturation"[7]. The paramater requires calibration for different road types; examples given by Davidson indicate that a value in the order of Ø.8 would be suitable. Bayley & Both used a travel time curve (the inverse of a speed flow curve) of the same general shape of Davidson's. The curve was established for each link in the network with the delays specific to each link added. It is not possible to determine the m value used as this would have been different for each road. The general shape of Davidson's curve however is supported by Bayley & Both [8]. Verbal advice obtained from Akcelik suggests that a value of m=Ø.85 is appropriate, although this is at the high end of the range of values quoted by Davidson.

Capacity Determination

A required input to the speed flow relationship is the capacity of a lane of urban arterial road. The capacity of 2ØØØ vehicles per lane per hour (expressed in pcus) used by Keeler and Small [9] is the standard capacity used by traffic engineers for "ideal conditions"[1Ø]. Calculating capacity for intersections is a complicated procedure and depends on many factors[11], e.g. number and width of lanes, presence of right and left turning vehicles, composition of traffic, etc. Most important for any one approach to an intersection is the length of green time:

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[7] K.B. Davidson, "The Theoretical Basis of a Flow-Travel Time Relationship for Use in Transportation Planning" Australian Road Research 8, 1 ARRB (1978), p. 34.

[8] C. Bayley & G.J. Both, "Evaluation Procedures for Urban Arterial Road Projects" 8th ARRB Conference Proceedings 8, 6 (1976).

[9] Keeler and Small, op.cit., p. 13.

[1Ø] NAASRA, op.cit., p. 7.

[11] R. Akcelik, "Traffic Signals: Capacity and Timing Analysis" Research Report ARR 123 ARRB (March 1981).

"the capacity of any approach to any intersection is the maximum sustainable rate at which vehicles can pass through the intersection from the approach under prevailing conditions. The actual rate at which vehicles cross the stopline is the same as the capacity if the approach is fully saturated with traffic"[12].

If adjacent traffic flows are given equal time, one could expect that 1000 pcus per lane per hour would be the maximum flow through an intersection Given that phasing of signals is adjusted to give preference to the peak direction flow of traffic, the maximum flow would be somewhat higher at the peak time. However the flow can be reduced by opposing right turning traffic and left turning traffic[13], though the effect of these is reduced in Adelaide as many intersections provide separate lanes and phases for right-turning vehicles and separate lanes for left-turning vehicles. A figure of 1100 vehicles (pcus) per lane hour will be used in the model. Mid-block capacities used in road evaluations, road design and traffic assignments will be higher as intersection delays are taken into account separately [14].

Free Flow Speed

A necessary input to the speed flow relationship is the free flow speed, i.e. the speed on the network when no congestion occurs. The average journey speed on the Adelaide network was 44.07 kmh [15]. This speed covers traffic flow mainly at uncongested times as the peak is of short duration in Adelaide. Free flow speeds between 40kmh and 64kmh, are used in traffic assignments in Adelaide [16] although these apply to mid-block speeds and thus do not take account of delays of intersections. A free flow speed of 46 kmh is used in the speed flow relationship.

[12] ARRB, Australian Road Capacity Guide Bulletin no.4 (June 1968), p. 7.
[13] ibid, p. 9-10.
[14] Bayley & Both op.cit. p.36; NAASRA op.cit. p. 21; Department of Transport & Highways Department, MADBS Phase 1: Travel Surveys and Data Collection, Prepared by P.G. Pak-Poy & Associates Pty. Ltd. (Adelaide 1978), p. 144.
[15] Department of Transport & Highways Department, MADBS Phases 4 & 5: Travel Demand Projections, Prepared by P.G. Pak-Poy & Associates Pty. Ltd. (Adelaide 1978), Table 3.11, p. 30.
[16] MADBS Phase 1, op.cit., p. 144.

LIFE OF A ROAD

To calculate the annual rental value of the construction cost of a lane km or road it is necessary to have an estimate of the life of a road. The physical life of the road rather than the economic is of interest; the two do not necessarily coincide depending on whether the investment in the road was a correct decision [17]. There are many values that have been used but 25 years appears to be a fairly common value and is used by Keeler and Small [18]. Values of 15, 20 and 25 were used in a 1976 study of resource use in transport in Australia [19]. A study of relative cost recovery by road and rail between Adelaide and Melbourne used a 20 year value for the life of the road [20]. Walters [21] suggested "thirty or fifty years for modern motor highways". A longer life than 25 years may be justified in light of recent advances in road maintenance techniques, and the Highways Department agreed that 30 years is appropriate.

The land component of the cost of road provision is assumed to have an infinite life [22].

VALUE OF TIME

There has been much work on values of time and the generally accepted practice is to use a value of 25% - 33% of the average hourly wage rate for journeys to work. Values of this order of magnitude were first reported by Quarmby in 1967 [23]. An estimate of the value of time for home based work

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[17] G. Docwra, "The Public Enterprise Concept and Road Supply" Australian Transport Research Forum (Sydney 1975).
[18] Keeler & Small, op.cit., p. 9.
[19] BTE, Resources in Transport 1972-73, Prepared by Nicholas Clark & Associates (Canberra 1976) (unpublished) p. 117.
[20] P.W. Blackshaw, "Recent Developments in Australian Transport" in D.N.M. Starkie et.al., Pricing and Cost Recovery in Long Distance Transport Martinus Nijhoff (The Hague 1982).
[21] A.A. Walters, The Economics of Road User Charges John Hopkins Press (Baltimore 1968), p. 23.
[22] Keeler & Small, op.cit., p. 9.
[23] D.A. Quarmby, "Choice of Travel Mode for the Journey to Work" Journal of Transport Economics and Policy (September 1967) pp. 273-313.

trips in Adelaide gave a value of time of $1.78 which is 28% of the average hourly wage or 0.6% of the average weekly wage. The estimate was from a mode choice model estimated using a multinominal logit model [24] and compares with a value of $1.88 (updated using average weekly earnings) estimated in Perth using the preference evaluation technique [25].

Values of time for other vehicle categories recommended for use in road evaluations are shown in Table C.5. These values have been updated to December 1982 values by the BTE from original values estimated in 1971 by the Commonwealth Bureau of Roads.

TABLE C.5
Values of Time recommended for use by BTE

Category	$ per person hour
Business Car	12.98
Light Commercial	6.31
Trucks	8.02

Source: BTE, Nimpac Parameter Update (Canberra 1983) (unpublished).

It is necessary to calculate a weighted average value of time based on the composition of different vehicles in the traffic flow and the average occupancy rate. The relevant data is given in Table C.6 giving an average weighted value of time of $3.23.

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[24] Department of Transport & Highways Department, MADBS Phase 3: Travel Model Preparation, Prepared by P.G. Pak-Poy & Associates Pty. Ltd. (Adelaide 1978) pp. 8-10.

[25] Director-General of Tranpsort, Western Australia, Transport Policies for Central Perth: Review and Formulation (Perth 1976) p. 84.

TABLE C.6
Weighted Average Value of Time

Category	$ per person hour	Vehicle Occupancy	$ per vehicle hour	Percent of traffic
Private Car	1.78	1.3(1)	2.31	86.7
Business Car	12.98	1.0(1)	12.98	3.1(1)
Light Commercials	6.31	1.3(2)	8.20	5.8(3)
Trucks	8.02	1.0(2)	8.02	4.4(3)
Average Weighted Value of Time			3.23	

Notes (1) MADBS Phase 1, op.cit
(2) BTE, op.cit
(3) Table C.3.

SIZE OF THE ROAD

The average number of lanes comprising inner urban arterial roads in Adelaide is 3.38 for two way flows, and 1.69 for one way flows (Table C.4). The road pricing model is structured in such a way that either may be input depending on how the traffic flows are input: if 24 hour one way flows are input then the value of 3.38 lanes is used, or if two way flows (i.e. 48 hours of flow in a 24 hour day) are input 1.69 lanes is used. The former procedure is used although either should give the same results.

FUEL CONSUMPTION

Fuel consumption by vehicles is not an integral part of the model. It is simply used to convert the congestion toll to cents/litre on the assumption that a fuel tax would be used to collect the toll. The fuel consumption used relates to "cars and station wagons" for the whole of Australia. This may or may not be a good representation depending on the relative fuel efficiency of driving in urban and rural areas. Use of this rate also assumes that fuel consumption is the same for light commercial vehicles and cars and station wagons; and that fuel consumption for heavy vehicles is twice that for cars and station wagons, due to the use of pcus. The rate used is 12.5 litres/100 km (or 22 mpg). [26].

ELASTICITY OF DEMAND

Keeler and Small operated their model assuming independent demand, i.e. the congestion would not affect demand. The model for Adelaide allows for elasticities to be entered for each time period, and for cross elasticities between time periods. Estimates of elasticities of demand for car travel have been the most difficult input data to collect, perhaps the reason why Keeler and Small omitted them.

There is now a fair amount of data available on short run petrol price elasticities giving values between -0.1 and -0.3 [27]. Australian estimates are slightly lower at about -0.08 [28]. Only one estimate by time of day is reported, indicating that the peak elasticity is lower than for off-peak [29]. (This is also the case for public transport fare elasticities - see Appendix D). The peak elasticity reported was -0.024 and the full weekday elasticity -0.076. The latter is lower than most other aggregate elasticities, thought to be due to the inclusion of both car ownership and car usage effects in the methodology used [30].

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[26] Australian Bureau of Statistics, 1982 Survey of Motor Vehicle Usage, Australia, Twelve Months ended 30 September 1982 Cat. no. 9202.0, Table 10.

[27] ECMT Round Tables 55/56/57, The Future of the Use of the Car (Paris 1982) p. 74.

[28] -0.08 by Schou & Johnson reported in D.A. Hensher, "The Automobile and the Future" Australian Transport Research Forum (Hobart 1982) p. 736; and -0.07 by Filmer & Mannion reported in Director-General of Transport, Adelaide Urban Pricing Study: Interim Report, Appendix F.

[29] D. Lewis, "Estimating the Influence of Public Transport on Road Traffic Levels in Greater London" Journal of Transport Economics and Policy 11, 2 (May 1977) and "A Rejoinder" in Journal of Transport Economics and Policy 12, 1 (January 1978).

[30] ECMT, op.cit., p. 39

Long run petrol price elasticities have been estimated to be as high as -1.06 [31], but general evidence is that the long run effect is about double the short run, i.e. -0.2 to -0.6 [32]. As petrol price is a relatively small component of the generalised cost of urban car travel one expects the elasticities to be small. Table C.7 shows elasticities estimated from a mode choice model in Perth [33]. They are short run elasticities and show that car running cost (including petrol) and in-vehicle time elasticities are of the same order of magnitude. One would thus expect an elasticity for the petrol and time cost components of travel to be about double that of a petrol price elasticity, i.e. -0.4 to -1.2. If Lewis' finding on the relative peak and aggregate elasticities is applied to these estimates, the result would be between -0.13 and -0.38. The higher value estimates will be used in the model giving -0.38 for the peak elasticity and -1.2 for the non peak elasticity. The lower values are used in sensitivity tests.

TABLE C.7
CBD Work Trip Modal Split Elasticities

Variable	CBD Modal Split Elasticities for Car Use
Fare	-0.22
Car running cost	-0.26
Car parking cost	-0.11
Public Transport	
- in-vehicle time	0.26
- waiting time	0.06
- access time	0.12
Car	
- in-vehicle time	-0.20
- terminal time	-0.04

Source: Shepherd op.cit p. 24.

[31] Hensher, op.cit., p. 736.
[32] ECMT, op.cit., p. 74
[33] L.E. Shepherd, "A Probabilistic Aggregate Travel Demand Model" in D.A. Hensher, (ed) Urban Travel Choice and Demand Modelling ARRB Special Report No. 12 (1974). Note that mode split and ordinary demand elasticities are equal only when there is a fixed total of trips. J.H.E. Taplin, "Inferring Ordinary Elasticities from Choice or Mode-Split Elasticities" Journal of Transport Economics and Policy (January 1982) pp. 55-63.

Cross elasticities between time periods will not be used as no data is available. Further, the effect is likely to be small as one expects higher tolls in the peak period when elasticities are lower.

APPENDIX D: INPUT DATA FOR THE PUBLIC TRANSPORT MODEL

INTRODUCTION

This appendix describes the derivation and estimation process for the input data to the Glaister and Lewis model for second-best pricing of public transport services in Adelaide. The model is global, i.e. requires aggregate demand and cost data for public transport and road modes. The link between the road and public transport models is the optimum road capacity determined in the former, with some adjustment to suit the data format of Glaister and Lewis.

There are four input data requirements which are discussed in turn below:

MARGINAL SOCIAL COST OF ROAD USE

As in the road model, the marginal social cost of car use is measured via the speed flow relationship. The same mathematical form is used here, but data is entered for the whole urban arterial system in terms of passenger km/hour.

Existing traffic flow in passenger km/hour is obtained from peak traffic assignments to the urban arterial network. Actual 1977 and predicted 1981 and 1986 peak hour car passenger km/hour are given in Table D.1, along with the estimated 1982 figure following interpolation. It can be seen that the peak hour flow is expected to increase at a very small rate after a fall from 1977 to 1981.

Free flow speed and level of service parameter (m) remain the same for the public transport pricing model. Once again the value of time is used to place a monetary value on the congestion costs of road travel. The rate of $3.23/vehicle hour is used (see Appendix C).

TABLE D.1
Road Passenger Kms and Trips in AM Peak Period

Year	Passenger Kms/Hr	Number of Trips	Av. Trip Length (Km)
1977	1,571,763	184,917	8.5
1981	1,418,587	188,327	7.5
1982(2)	1,430,808	189,512	7.5
1986	1,480,753	194,325	7.6

Source: Traffic assignments.
1982 Interpolated.

Capacity (in passenger km/hour) is calculated from the optimum volume/capacity ratio (traffic flow/lane hour) determined in the road model and the existing traffic flow (in passenger km/hour) i.e.

Capacity = Existing Flow/(Optimal V/C ratio)

PUBLIC TRANSPORT DEMAND DATA

Existing travel demand and fares are the two data items required. Existing demand is input in passenger km/hour for the peak and interpeak periods. Traffic assignments for an average weekday are used to determine average trip length (Table D.2). Public transport trips were estimated to have fallen significantly from 1977 to 1981: this is a result of the performance of the travel models which have now been corrected. The interpolated 1982 figure matches well with STA patronage data: in 1982/83 bus and tram trips were estimated to be 188,000 compared with 188,312 bus trips from the traffic assignments, and rail trips 44,000 compared with 45,801. Actual 1982/83 trips by mode and time period are then multiplied by average trip length to obtain passenger km on an average weekday. These are simply divided by the hours of operation to obtain passenger km/hour (see Table D.3).

TABLE D.2
Public Transport Passenger Kms (Average Weekday)(1)

Year	Passenger Kms	Number of Trips	Av. Trip Length (km)
1977			
- rail	293,491	17,985	16.3
- bus	1,739,549	238,572	7.3
1981			
- rail	609,597	46,021	13.2
- bus	1,332,531	190,191	7.0
1982(2)			
- rail	607,698	45,801	13.3
- bus	1,328,554	188,312	7.1
1986			
- rail	600,161	44,931	13.4
- bus	1,312,765	180,978	7.3

Notes (1) Traffic Assignments except 1982.
(2) Interpolated. Number of trips is 188,000 for bus and 44,000 for rail in Crouch, op.cit.

TABLE D.3
1982 Public Transport Passenger Km/Hour (Average Weekday)

	Number of Trips(1)	Passenger Km(2)	Hours Per Day(3)	Passenger Km/Hour
Bus				
- peak	99,000	702,900	5	140,580
- interpeak	74,000	525,400	6	87,567
Rail				
- peak	26,000	345,800	5	69,160
- interpeak	14,000	186,200	6	31,033

Notes (1) Crouch, op.cit.
(2) Number of Trips by Average Trip Length from Table D.2.
(3) Peak - 7am-9am and 3pm-6pm; Interpeak - 9am-3pm.

The average fares paid by adults in 1982 on bus services was 59.4 cents in the peak and 42.9 cents in the interpeak. The average fare for rail services were 67.0 cents and 48.4 cents for the peak and interpeak respectively [1]. Fares are input as cents per passenger/km, as follows:

Bus	peak	8.4 cents/passenger km
	off-peak	6.0 cents/passenger km
Rail	peak	5.0 cents/passenger km
	off-peak	3.6 cents passenger km

The lower rail fares are due to a longer average trip length (see Table D.2) and the fact that fares are not directly proportional to distance.

PUBLIC TRANSPORT OPERATING COSTS

The model requires as input the marginal operating cost of public transport modes per passenger km. Three modes, bus, rail and tram are operated by the STA in Adelaide. Tram accounts for only 3% of STA patronage [2] and is ignored in the model. In recent years detailed costing studies of bus and rail services have been undertaken in Adelaide to identify marginal operating costs [3]. The marginal cost rates are updated regularly and form the basis of the marginal cost etimates presented below. This methodology has been criticized as being inappropriate for some cost allocation exercises, but is suitable when costs are being used to determine price levels [4].

Table D.4 shows the 1981/82 marginal unit cost rates for bus and rail services in Adelaide. The bus and rail costing studies were undertaken at different times and thus there are some inconsistencies between the

[1] B. Crouch, Patronage Report 1982/83 Financial Year STA Corporate Planning Department (Adelaide 1983).
[2] STA Annual Report 1982.
[3] Director-General of Transport, Adelaide Bus Costing Study, Prepared by R. Travers Morgan Pty. Ltd. (Adelaide 1978) (Revised 1981).
____, Adelaide Rail Costing Study, Prepared by R. Travers Morgan Pty. Ltd. (Adelaide 1980).
[4] C.A. Nash, Economics of Public Transport Longman (London 1982) pp. 32-34.

cost rates, e.g. in general there is more allocation of costs to bus than to rail services [5]. Only the maintenance costs of rail track are included in the rail track costs, while no cost is included for buses for the use of roads. In general the rail costs will be understated relative to the bus costs. There is much debate about the appropriate costs to include in marginal cost calculations and in general rail costs are more difficult to estimate[6]. Glaister and Lewis used three levels in their application of the second best pricing model. The costs used here could be interpreted as "medium run" as operating costs and rollingstock capital costs are included but costs associated with large changes in the organization size are not, i.e. depot costs, track costs, station costs, head office general expenses. The use of these costs implies that 17% of the STA's costs are fixed in the economic sense, i.e. they are not included in the marginal cost calculation [7], and they represent resource costs.

Table D.5 shows the calculation of cost per passenger km for peak and interpeak bus and rail services. Passenger km p.a. for each type of service are calculated as follows:

Peak Bus
2 services (1am & 1pm) per day x 7.1 km x 65 passengers x 251 days = 231,673.

Interpeak bus
7 services per day x 7.1 km x 50 passengers x 251 days = 623,735.

Peak train
2 services per day x 13.3 km x 375 passengers x 251 days = 2,503,725

Interpeak train
6 services per day x 13.3 km x 140 passengers x 251 days = 2,804,172.

[5] Director-General of Transport, Public Transport Costs and Revenues in Adelaide, Prepared by D.J. Bray & Associates (Adelaide 1983) p.46.

[6] C. Hendrickson & M. Wohl, "Efficient Prices for Roadways and Transit Service" Traffic Quarterly 36, 3 (July 1982); Nash op.cit. p. 41-2.

[7] Director-General of Transport, op.cit., Table 5.03.

TABLE D.4
Bus and Rail Marginal Cost Rates

Category	Bus	Rail
Crew		
- peak	$76.66 per day (1)	$454 per day (2)
- interpeak	$58.20 per day (3)	$142 per day (4)
Rollingstock		
- maintenance (5)	$7,228 p.a.	$8,657 p.a. power car $3,380 p.a. trailer
- operation	$7.70 per hour	52.1 c/km power car 19.3 c/km trailer
- capital(6)-5%	$9,476 p.a.	$60,520 p.a. power car $32,681 p.a. trailer
-7%	$10,768 p.a.	$76,610 p.a. power car $41,369 p.a. trailer
Fuel	16.0 c/km	33.8 c/km
Per Way	n.a.	3.8 c/km power car 2.9 c/km trailer

Notes
(1) 1 broken shift.
(2) 1 am + 1 pm shift for driver, guard and ticket collector. No broken shifts worked on rail services.
(3) 1 am + 1 pm - 1 broken shift.
(4) 7 hours work for driver and guard. Ticket collectors only required for 3 car plus consists.
(5) Costs that vary with ownership, not use. Attributable to peak operation.
(6) 15 year life for buses and 35 year life for power cars and trailers.

TABLE D.5
Bus and Rail Costs per Passenger Km

Service	Cost p.a.(1) ($)	Passenger Km(2)	Cost per Passenger Km (cents)
Bus			
- peak - 5%	50,530	231,673	21.8
- 7%	51,822		22.4
- interpeak	31,771	623,735	5.1
Rail			
- peak (3) - 5%	595,902	2,503,725	23.8
- 7%	662,537		26.4
- interpeak (4)	143,777	2,804,172	5.1

Notes (1) Per km costs converted to per hour costs using average speed: 20.7 kmh for bus and 39.5 kmh for rail.
(2) See text for derivation
(3) 5 car consist: 4 power cars and 1 trailer.
(4) 2 car consist: 2 power cars.

ELASTICITIES

Elasticities are used in the model to measure the effects on demand as a result of price changes, including changes in fares and the generalised cost of car travel. Constant elasticities implying a convex demand curve are used, as in the road model. The elasticities required are own price elasticities for bus and rail services by time period and cross price elasticities for car, bus and rail by time period. There is substantial evidence on the likely values of own price elasticities but little on cross price elasticities. The elasticities used are shown in Table D.6.

TABLE D.6
Elasticities Used in Glaister and Lewis Model in Adelaide

Demand for:	With respect to the price of:			
	Peak bus	Off-peak bus	Peak rail	Off-peak rail
Peak bus	-0.15	0.01	0.02	0.005
Off-peak bus	0.01	-0.45	0.005	0.02
Peak rail	0.02	0.005	-0.2	0.01
Off-peak rail	0.005	0.02	0.01	-0.57
Peak car	0.027	0.009	0.006	0.002

Own price elasticities estimated from time series analysis of all trips in Adelaide in 1979 were [8]:

Bus - 0.37 ± 0.17 (95% C.I.)
Rail - 0.40 ± 0.26 (95% C.I.)

A 1977 BTE time series analysis gave higher estimates of -0.48 for both bus and rail in Adelaide. The average elasticities for all Australian capital cities were -0.29 for bus and -0.35 for rail, indicating higher elasticities for rail than bus services [9]. A before and after study in Adelaide following a fare increase in 1981 gave the following bus elasticities for adult riders [10]:

point elasticity -0.27 + 0.24 (95% C.I.)
arc elasticity -0.31 (upper bound -0.04 and lower bound -0.60 at 95% C.I.).

An attempt was made to calculate separate elasticities for peak and off-peak periods but the data was inadequate. It did however indicate that the peak elasticity was likely to be lower than the off-peak elasticity. This is supported by evidence from other places [11]. Estimates for Sydney rail passengers are -0.1 (peak) and -0.3 (off-peak) [12], also supporting the view that peak elasticities are lower than those for the off-peak.

[8] Director-General of Transport, Adelaide Urban Transport Pricing Study: Interim Report, Prepared by R. Travers Morgan Pty. Ltd. (Adelaide 1980) Appendix F.
[9] BTE, Urban Transport Capital Requirements 1977/8 to 1979/80 (Canberra 1977).
[10] Director-General of Transport, Before/After Fares Study, Prepared by R. Travers Morgan Pty. Ltd. (Adelaide 1982).
[11] TRRL, The Demand for Public Transport, Report of the International Collaborative Study of the Factors Affecting Public Tranpsort Patronage (London 1980) pp. 118-120.
[12] BTE, Workshop on the Future of Urban Passenger Transport in Australia: Summary Report (Canberra 1978) p. 22.

Using an aggregate bus elasticity of -Ø.3 and approximately 5Ø% of ridership in the peak [13] indicates an off-peak elasticity of -Ø.15 and a peak elasticity of -Ø.45. Similarly for rail services, with an aggregate elasticity of -Ø.35 and approximately 6Ø% of ridership in the peak [14], an off-peak elasticity of -Ø.57 and a peak elasticity of -Ø.2 is indicated.

There is no evidence on cross price elasticities between bus and rail services in Adelaide. One would however expect them to be small as the public transport system is being revised in such a way that few alternative bus and rail services will remain. A value of Ø.Ø2 is used for the four cross price elasticities (peak bus with respect to peak rail, off-peak bus with respect to off-peak rail, peak rail with respect to peak bus, off-peak rail with respect to off-peak bus). A higher value may be more appropriate for rail services but as the values are small Ø.Ø2 will be used for both modes.

No estimates of elasticities exist for time switching of trips within and between modes. However when peak pricing was introduced on STA services in 1981 there was some evidence of an increase in the use of off-peak bus services relative to peak services. This effect was not evident in the before/after study mentioned above but in analysis of patronage trends a year after the fare change [15]. Service level elasticities are in general higher than fare elasticities [16], thus one would not expect people to change their time of travel as a result of a fare change to any great extent, and both their time and mode to an

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[13] Crouch, op.cit.
[14] ibid.
[15] D. Scrafton & M.M. Starrs, "Fare Structure and Levels on Public Transport Services in Adelaide" 25th U.S. TRF (Washington 1983).
[16] A.M. Lago et.al., "Transit Service Elasticities" Journal of Transport Economics and Policy (May 1981).

even lesser extent. Values of Ø.Ø1 will be used for time switching elasticities within modes and Ø.ØØ5 between modes. Once again slightly higher values could have been used for rail services.

The cross elasticities of demand for car travel with respect to the price of public transport modes are also expected to be relatively low. Public transport trips account for only 9% of all trips in Adelaide, thus large price changes would not affect total car travel demand to any great extent [17]. The car cross elasticity values have the greatest effect on the results of the model, i.e. if it is not possible to attract car trips from road to public transport there is little point in a second best pricing model. A value of Ø.22 estimated in Perth for a CBD work trip mode choice model was reported in Table C.1Ø, Appendix C. Due to the narrow range of trips considered it is higher than should be input to the Glaister and Lewis model which considers the total road and public transport networks.

Public transport accounts for 6Ø% of work trips to the CBD, and 9% of all work trips in Adelaide [18]. The Perth cross elasticity value is scaled thus:

$$0.22 \times \frac{9}{60} = 0.033$$

to give an estimate of the demand for car travel with respect to the price of public transport over the whole transport network. The value is further adjusted on the basis of the relative shares of bus and train trips (82% bus [19]) as follows:

Peak Bus	Ø.82 x Ø.Ø51 = Ø.Ø27
Peak Rail	Ø.18 x Ø.Ø51 = Ø.ØØ6

Values of one third of the peak elasticities are used for the off-peak elasticities.

[17] MADBS Phase 1, op.cit., p. 71.
[18] ibid, p. 78.
[19] ibid, p. 71.

The elasticities used by Glaister and Lewis are given in Table D.7. Their elasticities are income compensated as required by the model, however the adjustment made little difference to the values used [20]. Glaister and Lewis also comment that:

"the elasticities obtained in this way are far from definitive and in any case can only represent medium term demand responses. Long run adjustments to residential and work place location and hence to travel patterns are to be expected" [21].

The same comment applies to the elasticities in Table D.6. Ideally, long run elasticity values should be used as the whole framework for the thesis is long run.

TABLE D.7
Elasticities used by Glaister and Lewis in London

Demand for:	With respect to the price of:			
	Peak bus	Off-peak bus	Peak rail	Off-peak rail
Peak bus	-0.35	0.029	0.143	0.008
Off-peak Bus	0.04	-0.87	0.013	0.28
Peak Rail	0.14	0.009	-0.3	0.018
Off-peak Rail	0.01	0.28	0.05	-0.75
Peak Car	0.025	0.0016	0.056	0.0034

A comparison of the elasticities in Tables D.6 and D.7 indictates:

- Own price elasticities in London are higher than in Adelaide, and the rail elasticities are lower than those for bus. The London rail elasticities are for underground services; elasticities for British rail services are higher [22]. Evidence above supports the elasticities proposed for use in the Adelaide model.

- The cross price elasticities used by Glaister and Lewis are much higher than those used in Adelaide (0.14 to 0.28 compared to 0.02). The reason for this could be that there is scope for more competition bewtween bus and rail services in London. The elasticities are also higher in the off-peak relative to the peak: such an adjustment could be made in the Adelaide elasticities.

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[20] Glaister and Lewis, op.cit., p. 349.
[21] ibid, pp. 349-50.
[22] Nash, op.cit., pp. 110-111.

- The elasticities for time switching within modes are also higher in London (Ø.Ø18 to Ø.Ø5 compared to Ø.Ø1), following the higher own price elasticities. The rail elasticities could perhaps be slightly higher in Adelaide.

- The public transport for time switching and mode switching are lower in Adelaide (Ø.ØØ5 compared to Ø.ØØ8 to Ø.Ø13) Glaister and Lewis use marginally lower values in the peak relative to the off-peak.

- The car-bus elasticities are slightly higher in Adelaide and the car-rail elasticities much lower. The latter is explicable in terms of the relative system coverage in the two cities. The car-bus elasticity differences are not possible to justify and may indicate different values should be used.