Aggregate Bus Maintenance Costs

Occasional Paper

A knowledge of bus maintenance costs and how they vary with bus age is of value in a number of applications. Of particular interest to the BTE is the importance of bus maintenance costs to optimal bus replacement strategies. The report summarises the Aggregate Bus Maintenance Studies of six bus operators in Australian capital cities and isolates the major variables influencing both maintenance and servicing costs.

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BUREAU OF TRANSPORT ECONOMICS

AGGREGATE BUS MAINTENANCE COSTS - SUMMARY

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FOREWORD

A knowledge of bus maintenance costs and how they vary with bus age is of value in a number of applications. Of particular interest to the BTE is the importance of bus maintenance costs to optimal bus replacement strategies. The report summarises the Aggregate Bus Maintenance Studies of six bus operators in Australian Capital Cities and isolates the major variables influencing both maintenance and servicing costs.

This report and the individual aggregate reports were prepared by Dr J. Beck of Beck Systems Engineering with the co-operation of the State Transport Authority - Adelaide, Department of Transport - Brisbane City Council, Public Transport Commission of NSW, Melbourne and Metropolitan Tramways Board, Metropolitan Passenger Transport Trust - Perth and Grenda's Bus Services, Dandenong.

The BTE does not necessarily accept the findings of the Consultant' report, but considers that the information to be of value to bus operators and research workers in this field.

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TRANSPORT ENGINEERING BRANCH

Bureau of Transport Economics
Canberra
June 1978

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SUMMARY

Work on the evaluation of bus maintenance cost functions for use in urban transport evaluations is summarised in the report.

An analysis is made of the maintenance and servicing costs of urban transport operators in the major capital cities.

Principal conclusions of the report are summarised below.

- Bus power to weight ratio, maximum road speed, mean relative humidity, and mean annual travel have an important influence on maintenance and servicing costs of buses.

- BTE replacement evaluations could be improved by developing disaggregate functions for maintenance and servicing costs.

- BTE replacement evaluations should recognise the influence of maintenance procedures on fleet spare capacity. Methods for optimising bus replacement decisions should be developed.

- A study of the factors which influence component reliability should be undertaken with a view to
  - defining improved maintenance procedures; and
  - including reliability requirements in bus specifications.

ASSOCIATED BTE REPORTS

1. Evaluation of Bus Maintenance Cost Functions Phase 1: Work Program, June 1974.

2. Evaluation of Bus Maintenance Cost Functions, Preliminary Report, October 1974.

3. Case Study A - Bus Maintenance Costs: Municipal Tramways Trust, Adelaide.

4. Case Study B - Bus Maintenance Costs: Brisbane City Council, Department of Transport.

5. Case Study C - Bus Maintenance Costs: Public Transport Commission of New South Wales.

6. Case Study D - Bus Maintenance Costs: Metropolitan (Perth) Passenger Transport Trust.

7. Case Study E - Bus Maintenance Costs: Melbourne and Metropolitan Tramways Board.

8. Case Study F - Bus Maintenance Costs: Grenda's Bus Services.

These reports are available on loan from the Bureau of Transport Economics provided that the prior permission of the specific operator has been obtained.

CHAPTER 1 - INTRODUCTION

REASONS FOR THE STUDY

The BTE requires bus maintenance cost functions for use in urban transport evaluations.

The primary objective of the BTE evaluations has been to establish optimum replacement policies for publicly owned buses in major cities. Maintenance methods influence replacement evaluations through:

- the effect on operating costs;
- the effect on fleet availability; and
- the effect on user response and thereby revenue.

The BTE is also concerned with the operating costs of privately owned bus fleets. Models are being developed and these will incorporate maintenance cost functions.

It is estimated that at June 1974, 8800 route buses were operating in the major urban areas of Australia. Of this number, 4700 were publicly owned and the remaining buses were privately owned. Buses owned by public transport authorities collectively travelled in the year ending June 1974 more than 190 000 000 kilometres and completed approximately 430 000 000 passenger journeys. Information on the private sector is incomplete but bus travel is thought to be of the order of 130 000 000 kilometres and passenger journeys about 300 000 000. Annex A contains tables showing bus fleet composition for those operators included in the BTE case studies.

Maintenance and servicing costs are a significant component of bus operating costs. Statements by public transport authorities for the year ending June 1974 attribute 20-30% of total operating costs to the maintenance, servicing and fuelling of buses. For privately owned fleets an average of 26% of total operating cost is due to bus maintenance, servicing and fuelling.(1)

Of interest to the conduct of the study is the variation of maintenance costs with type of vehicle, vehicle travel and area of operation. The BTE had for an earlier evaluation attempted to define the relationship between maintenance cost and bus travel(2). Lack of suitable data demonstrated the need for detailed analysis of maintenance costs.

APPROACH TO THE STUDY

The study covered public transport authorities in the cities of Adelaide, Brisbane, Melbourne, Perth and Sydney. A private operator in Melbourne's Dandenong region was also included for comparison of the cost structures existing in the two sectors of the industry. Participants were:

- Brisbane City Council, Department of Transport (BCC)
- Melbourne and Metropolitan Tramways Board (MMTB)
- Metropolitan (Perth) Passenger Transport Trust (MTT-Perth)
- Public Transport Commission of NSW (PTC NSW)
- State Transport Authority, Adelaide (STA - Adelaide)
- Grenda's Bus Services, Dandenong.

The involvement of the Department of Capital Territory (DCT), the Hobart Metropolitan Transport Trust (HMTT), and regional authorities was also considered. The DCT, which operates buses in both Canberra and Darwin, was eliminated on the grounds that it was a branch of the Federal public service and as such had different funding arrangements to the participating authorities. Regional authorities were rejected from the sample on the basis of size of undertaking and state of records.

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(1) Australian Department of Transport, Private Bus and Ferry Operators in Australia, Vol 1, R & P Economic Studies Group, 1975, p. 45.
(2) Bureau of Transport Economics, A Review of Public Transport Investment Proposals for Australian Capital Cities, 1973-74.

Buses operated by the participating authorities were in the main diesel engine vehicles whereas at the time of the study, the fleet of HMTT buses mostly consisted of petrol engine vehicles. Differences between the two types of engine were thought sufficiently important to exclude the HMTT from participation.

PRELIMINARY WORK

The intended approach to the project was to derive from past records mathematical functions representing bus maintenance and servicing costs for each of the participants.

By comparing costs for each of the participants it was hoped to isolate the variables explaining the observed differences. For the immediate need of the BTE, "interim" functions for maintenance and servicing costs were developed from the limited data available at the time.(1)

An initial survey of participants was conducted to determine the feasibility of the approach outlined above. From the survey it became apparent that historical records of maintenance cost were only available in a few authorities at the level of disaggregation required for the study. Where such records existed different methods of overhead allocation made direct comparison of costs between authorities difficult. Lack of vehicle standardisation was also a problem. Forty two different bus models (June 1974 figures) existed in the total of 3455 buses operated by participating organisations, with no bus model being operated by all organisations. Leyland Leopard buses existed in the greatest number, being represented in the fleets of three participants and comprising 21% of the total vehicles.

The lack of historical records meant for some participants that maintenance and servicing costs had to be "synthesized" from records or estimates of the labour content, material content, and

(1) Bureau of Transport Economics, Evaluation of Bus Maintenance Cost Functions, Preliminary Report, unpublished, May 1974.

frequency of component maintenance and servicing activities. This placed a severe constraint on the number of vehicles which could be included in the study. Taken in conjunction with the lack of standardisation there was little possibility of isolating other than the major variables influencing maintenance and servicing costs.

An additional function of the initial survey was to nominate vehicles in each organisation which would be included in the study of maintenance costs. The choice depended heavily on the availability of engineering records. An attempt was made to ensure that for each participant at least one bus model was selected which appeared elsewhere in the study. Vehicles included in the study are shown on the footnote to Table 3.1.

The initial survey suggested that for the BTE to more fully carry out its role in bus replacement evaluations a better understanding of the operating policies of the various organisations was required. As a result of this observation the scope of the study was widened to include documentation of the maintenance and servicing procedures and facilities existing in each of the organisations.

SCOPE OF THE STUDY

- To develop bus maintenance and servicing cost functions for the participating organisations for use in BTE urban public transport evaluation.

- To document for each participant procedures and facilities used in the maintenance and servicing of buses.

- From the cost functions developed above, isolate the major factors describing differences in cost between participating organisations.

CHAPTER 2 - DATA AND ANALYSIS

Data required for the study concerned information to be used for the determination and analysis of maintenance and servicing costs, and the documentation of procedures. Table 2.1 summarises the information requirements.

Information on procedures, policies, and operating environment was readily available.

Table 2.2 shows the level of disaggregation desirable for analysis of past maintenance and servicing costs. Information on costs to an equivalent level of disaggregation was available only in the BCC and MMTB. Elsewhere costs had to be estimated from bus histories supplemented where appropriate by average fleet costs drawn from current accounting records.

For the purpose of obtaining comparative costs June 1974 was chosen as a reference time, this being the end of the financial year immediately preceding the study. Costs obtained from historical records were adjusted to June 1974 values using materials and labour escalation factors.[1][2] Costs estimated from bus histories and engineering judgement were directly evaluated in June 1974 values.

OVERHEADS

Maintenance and servicing departments in the participating organisations incurred a variety of overhead charges depending on the accounting procedures within each organisation. To adopt a uniform approach to the allocation of overheads it was decided to

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(1) Bureau of Transport Economics, Case Study B - Bus Maintenance Costs: Brisbane City Council, Department of Transport, unpublished, 1975 p. 23.

(2) Bureau of Transport Economics, Case Study E - Bus Maintenance Costs: Melbourne and Metropolitan Tramways Board, unpublished, 1976, p. 16.

TABLE 2.1 - TABLE OF INFORMATION REQUIREMENTS

Information Type	Information Requirements			Purpose
Costs	Estimation of vehicle activity costs. Historical records unavailable	Manhours Labour rates, June 1974 Materials value, June 1974 Frequency of activities Overhead Structure		Aggregate maintenance and servicing costs
	Historical records by vehicle type available	Accounting information	Structure of accounts Allocation of overheads	
		Recorded costs by activity	Materials value for period Labour value per period Vehicle travel for period	
		Cost escalation	Materials price movements Labour cost movements	
Procedures, policies and operating environment	Facilities	Garage/depot; workshop; contractors		Document-ation of procedures
	Procedures	Maintenance methods Servicing procedures Records Employee activities		
	Operating conditions	By area	Travel speeds Climate Road surface Terrain Accident rates	Analysis of aggregate costs
		By vehicle	Fuel and oil consumption Tyre lives Annual travel	
	Fleet characteristics	Replacement policy Fleet composition Vehicle ages Bus characteristics		

TABLE 2.2 - DATA CATEGORIES FOR MAINTENANCE AND SERVICING COSTS

1	Maintenance Cost
1.1	Mechanical Maintenance
1.1.1	Routine mechanical maintenance
1.1.2	Engine and block
1.1.3	Transmission and gearbox
1.1.4	Axles
1.1.5	Brakes
1.1.6	Air system
1.1.7	Suspension and steering
1.2	Electrical Maintenance
1.2.1	Routine electrical maintenance
1.2.2	Component overhaul and replacement
1.3	Body Maintenance
1.3.1	Routine body maintenance
1.3.2	Accident and collision damage
1.3.3	Body overhaul
1.3.4	Seats
2	Servicing Cost
2.1	Fuelling
2.2	Lubrication
2.3	Cleaning and Washing
2.4	Tyre Maintenance, Renewal and Retreading
3	Overheads
3.1	Maintenance and Servicing
3.2	Other

create fictitious "stand alone" maintenance and servicing departments which contributed to all activities bearing a proportion of general administrative expenditure in addition to the normal engineering overheads. The method of allocating the overheads derived in the above manner was of necessity somewhat flexible. Generally, however, overheads were assigned on the basis of bus travel.

DEFINITION OF COSTS

The expressions bus maintenance cost, bus servicing cost, and total running cost are used in the study. All three costs are expressed in terms of June 1974 values and represent cumulative expenditures for a given bus travel; bus travel being measured in kilometres from commencement of operation.

Bus Maintenance Cost is the cumulative expenditure on labour and materials for activities associated with the inspection, replacement, repair and overhaul of mechanical, electrical and body components. An allowance for engineering overheads and a proportion of general expenditure is included in the bus maintenance costs.

Bus Servicing Cost is the cumulative expenditure on labour and materials associated with the fuelling, lubrication, cleaning and washing of buses. Also included are labour and materials for the maintenance, retreading and renewal of tyres. Allowances for overheads associated with these activities and proportion of general expenditure, are also included in the bus servicing cost.

Total Running Cost is the sum of bus maintenance and bus servicing costs.

METHODS OF ESTIMATING COSTS

Bus Maintenance Costs

The accounting records of the BCC and MMTB were organised to show annual maintenance expenditures for groups of buses having the same model chassis. From these records it was possible to escalate past expenditures to June 1974 values and obtain the relationship between bus travel and cumulative maintenance cost for each model bus considered in the study.

The above approach could not be applied to buses operated by Grenda's Bus Services, STA Adelaide, MTT-Perth, and PTCNSW due to a higher level of aggregation in the accounts of these operators. For Buses operated by these participants, the approach taken was to synthesize maintenance costs for each bus model from records or estimates of the frequency, materials content, and labour content of component maintenance activities.

Bus Servicing Costs

The method used to derive bus servicing costs was common to all participants. Accounting records for the year ending June 1974 were used to establish labour costs for fuelling, lubricating, tyre maintenance, and bus cleaning activities for each organisation on a cost per kilometre basis. Materials costs were obtained from recorded consumptions for each model bus. Labour and materials costs were then combined to obtain the relationship between bus travel and cumulative servicing cost.

CHAPTER 3 - COMPARATIVE RESULTS

Cumulative maintenance and servicing costs for the buses considered in the study are summarised in Table 3.1. Cumulative total running costs are shown in Table 3.2. Table 3.3 shows maintenance, servicing, and total running costs for each of the buses in terms of dollars per thousand kilometres for 100 000 kilometre increments of bus travel. Reference to specific organisations have been removed from the tables and replaced with a numbered code, to maintain the confidentiality of the data sources.

Experience with the AEC Reliance 590, Leyland Leopard, and Leyland Panther for Operator 2 was limited, and results could not be quoted for the full range of the tabulations.

Costs shown in Table 3.3 approximate the local gradient of the corresponding cumulative cost function. Servicing costs are seen to remain substantially constant with bus travel. This observation is supported by the logarithmic plots of cumulative servicing cost shown in Figures 3.1 and 3.2; gradients of the plotted functions lie in the range 0.98 to 1.03. The low initial values of the incremental servicing costs shown in Table 3.3 are principally due to the cyclic nature of tyre renewal.

Incremental values of bus maintenance cost, and therefore total running cost, summarised in Table 3.3 exhibit cyclic variations due to major mechanical and body overhauls. Figures 3.3 and 3.4 show logarithmic plots of cumulative maintenance cost with the cyclic variations removed, and demonstrate an underlying trend in which maintenance costs increase faster than bus travel.

Results for Operator 2 Panthers need more explanation. Maintenance costs for these buses were derived from annual expenditues and travel for all Panther buses, however the Panthers were commissioned over a three year period causing a wide range of bus ages in the sample. It is believed that this effect unfavourably biased the calculation of average annual expenditure per bus and therefore maintenance costs which were derived from this figure.

TABLE 3.1 - SUMMARY OF CUMULATIVE MAINTENANCE AND SERVICING COSTS

Bus Travel in Kilometres	VAM 70	AEC Vehicles				Leyland Leopard			Leyland Panther						Hino
	6V (1)	2R	5R4	5R6	1R6	2L/A	2L/B	3L	2P/C	2P/B	2P/A1	2P/A2	6P	4P	4H
	Cumulative Maintenance Cost in June 1974 Dollars														
100 000	2 900	10 200*	9 600*	9 600*	4 200	8 200*	8 400*	7 400	10 100*	10 100*	10 200*	10 100*	4 000	3 500	3 100
200 000	7 800	21 600*	20 300*	20 400*	9 800	17 800*	18 100*	16 900	18 200*	18 100*	18 500*	18 100*	9 400	8 000	7 600
300 000	12 100	33 400*	31 600*	32 900*	15 300	27 900*	28 500*	29 600	n.a.	n.a.	n.a.	n.a.	16 000	12 800	12 300
400 000	18 800	n.a.	43 800*	46 000*	21 900	n.a.	n.a.	40 500	n.a.	n.a.	n.a.	n.a.	23 100	19 800	18 800
500 000	22 100	n.a.	59 200*	60 000*	29 400	n.a.	n.a.	54 100	n.a.	n.a.	n.a.	n.a.	29 000	26 200	25 200
600 000	n.a.	n.a.	78 000*	74 000*	35 700	n.a.	n.a.	65 000	n.a.	n.a.	n.a.	n.a.	n.a.	29 700	28 500
	Cumulative Servicing Cost in June 1974 Dollars														
100 000	3 900	9 300	7 900*	8 200*	6 400	9 800	9 800	8 200	9 600	9 900	9 900	9 700	4 500	5 700	5 800
200 000	8 000	18 700	15 800*	16 100*	12 900	19 500	19 700	16 500	19 700	20 000	19 900	19 600	9 500	11 800	12 000
300 000	12 300	28 300	23 800*	24 000*	19 700	29 400	29 900	24 800	30 000	30 700	30 200	29 700	14 400	17 900	18 300
400 000	16 300	n.a.	31 600*	32 000*	26 700	n.a.	n.a.	33 100	n.a.	n.a.	n.a.	n.a.	19 400	24 000	24 500
500 000	20 400	n.a.	39 200*	39 400*	34 000	n.a.	n.a.	41 400	n.a.	n.a.	n.a.	n.a.	24 200	30 100	30 700
600 000	n.a.	n.a.	47 300*	47 500*	41 300	n.a.	n.a.	49 700	n.a.	n.a.	n.a.	n.a.	n.a.	36 100	37 100

NOTE: * Denotes cost obtained by interpolation; n.a. Denotes cost not available in this range.

(1) Bus Code

6V = Operator 6 VAM70
2R = Operator 2 Reliance 590
5R4 = Operator 5 Regal MKIV
5R6 = Operator 5 Regal MKVI
1R6 = Operator 1 Regal MKVI
2L/A = Operator 2 Lepoard Depot A
2L/B = Operator 2 Leopard Depot B
3L = Operator 3 Leopard
2P/C = Operator 2 Panther (ZF trans) Depot C
2P/B = Operator 2 Panther (ZF trans) Depot B
2P/A1 = Operator 2 Panther (ZF trans) Depot A
2P/A2 = Operator 2 Panther (SCG trans) Depot A
6P = Operator 6 Panther (SCG trans)
4P = Operator 4 Panther (SCG trans)
4H = Operator 4 Hino

TABLE 3.2 - SUMMARY OF CUMULATIVE TOTAL RUNNING COSTS

Bus Travel in Kilometres	Total Running Cost in June 1974 Dollars														
	VAM 70	AEC Vehicles				Leyland Leopard			Leyland Panther						Hino
	6V(1)	2R	5R4	5R6	1R6	2L/A	2L/B	3L	2P/C	2P/B	2P/A1	2P/A2	6P	4P	4H
100 000	6 800	19 500*	17 500*	17 800*	10 600	18 000*	18 200*	15 600	19 700*	20 000*	20 100*	19 800*	8 500	9 200	8 900
200 000	15 800	40 300*	36 100*	36 500*	22 700	37 300*	37 800*	33 400	37 900*	38 100*	38 400*	37 700*	18 900	19 800	19 600
300 000	24 400	61 700*	55 400*	56 900*	35 000	57 300*	58 400*	54 400	n.a.	n.a.	n.a.	n.a.	30 400	30 700	30 600
400 000	35 100	n.a.	75 400*	78 000*	48 600	n.a.	n.a.	73 600	n.a.	n.a.	n.a.	n.a.	42 500	43 800	43 300
500 000	42 500	n.a.	98 400*	99 400*	63 400	n.a.	n.a.	95 500	n.a.	n.a.	n.a.	n.a.	53 200	56 300	55 900
600 000	n.a.	n.a.	125 300*	121 500*	76 000	n.a.	n.a.	114 700	n.a.	n.a.	n.a.	n.a.	n.a.	65 800	65 600

NOTE: * Denotes cost obtained by interpolation; n.a. Denotes cost not available in this range.

(1) Refer to Table 3.1 for Bus Code.

TABLE 3.3 - INCREMENTAL MAINTENANCE, SERVICING AND TOTAL RUNNING COSTS

Bus Travel in Kilometres	VAM 70	AEC Vehicles				Leyland Leopard			Leyland Panther						Hino
	6V(1)	2R	5R4	5R6	1R6	2L/A	2L/B	3L	2P/C	2P/B	2P/A1	2P/A2	6P	4P	4H
	Maintenance Cost in June 1974 Dollars per Thousand Kilometres														
100 000	29	102*	96*	96*	42	82*	84*	74	101*	101*	102*	101*	40	35	31
200 000	49	114*	107*	108*	56	96*	97*	96	81*	80*	83*	80*	54	46	46
300 000	43	118*	113*	125*	55	101*	104*	127	n.a.	n.a.	n.a.	n.a.	66	47	46
400 000	67	n.a.	122*	131*	66	n.a.	n.a.	109	n.a.	n.a.	n.a.	n.a.	72	71	65
500 000	33	n.a.	154*	140*	75	n.a.	n.a.	135	n.a.	n.a.	n.a.	n.a.	59	63	64
600 000	n.a.	n.a.	188*	140*	63	n.a.	n.a.	110	n.a.	n.a.	n.a.	n.a.	n.a.	35	33
	Servicing Cost in June 1974 Dollars per Thousand Kilometres														
100 000	39	93	79*	82*	64	98	98	82	96	99	99	97	45	57	58
200 000	41	94	79*	79*	65	97	99	83	101	101	100	99	49	61	62
300 000	42	96	80*	79*	69	99	102	83	103	107	103	101	49	61	62
400 000	41	n.a.	78*	80*	70	n.a.	n.a.	83	n.a.	n.a.	n.a.	n.a.	50	61	62
500 000	41	n.a.	76*	74*	73	n.a.	n.a.	83	n.a.	n.a.	n.a.	n.a.	48	61	62
600 000	n.a.	n.a.	81*	81*	73	n.a.	n.a.	83	n.a.	n.a.	n.a.	n.a.	n.a.	60	64
	Total Running Cost in June 1974 Dollars per Thousand Kilometres														
100 000	68	195*	175*	178*	106	180*	182*	156	197*	200*	201*	198*	85	92	89
200 000	90	208*	186*	187*	121	193*	196*	178	182*	181*	183*	179*	103	106	108
300 000	86	214*	193*	204*	123	200*	206*	210	n.a.	n.a.	n.a.	n.a.	115	109	109
400 000	107	n.a.	200*	211*	136	n.a.	n.a.	192	n.a.	n.a.	n.a.	n.a.	122	132	128
500 000	74	n.a.	230*	214*	147	n.a.	n.a.	219	n.a.	n.a.	n.a.	n.a.	107	125	126
600 000	n.a.	n.a.	269*	221*	136	n.a.	n.a.	193	n.a.	n.a.	n.a.	n.a.	n.a.	95	97

NOTE: * Denotes cost obtained by interpolation; n.a. Denotes cost not available in this range.

(1) Refer to Table 3.1 for Bus Code.

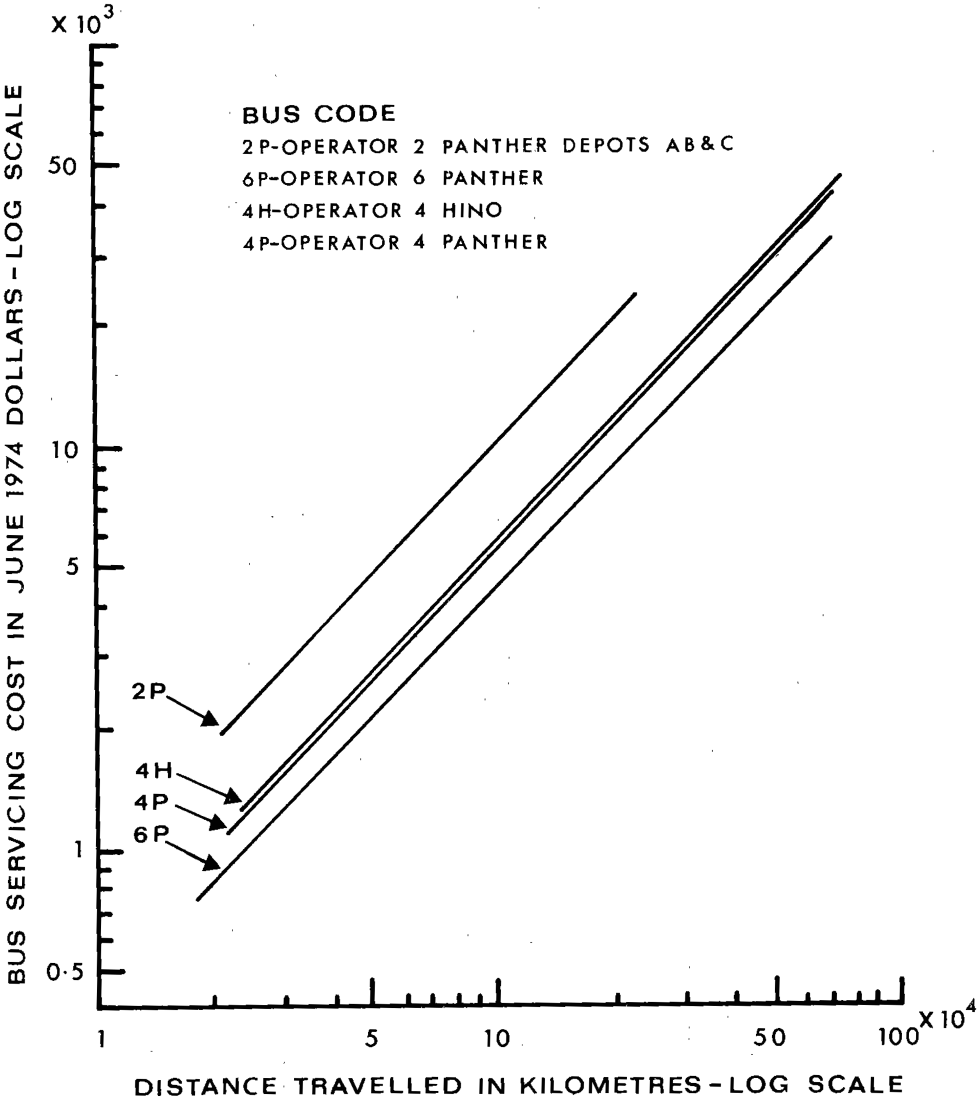

FIGURE 3·1
CUMULATIVE BUS SERVICING COSTS FOR
REAR ENGINE BUSES

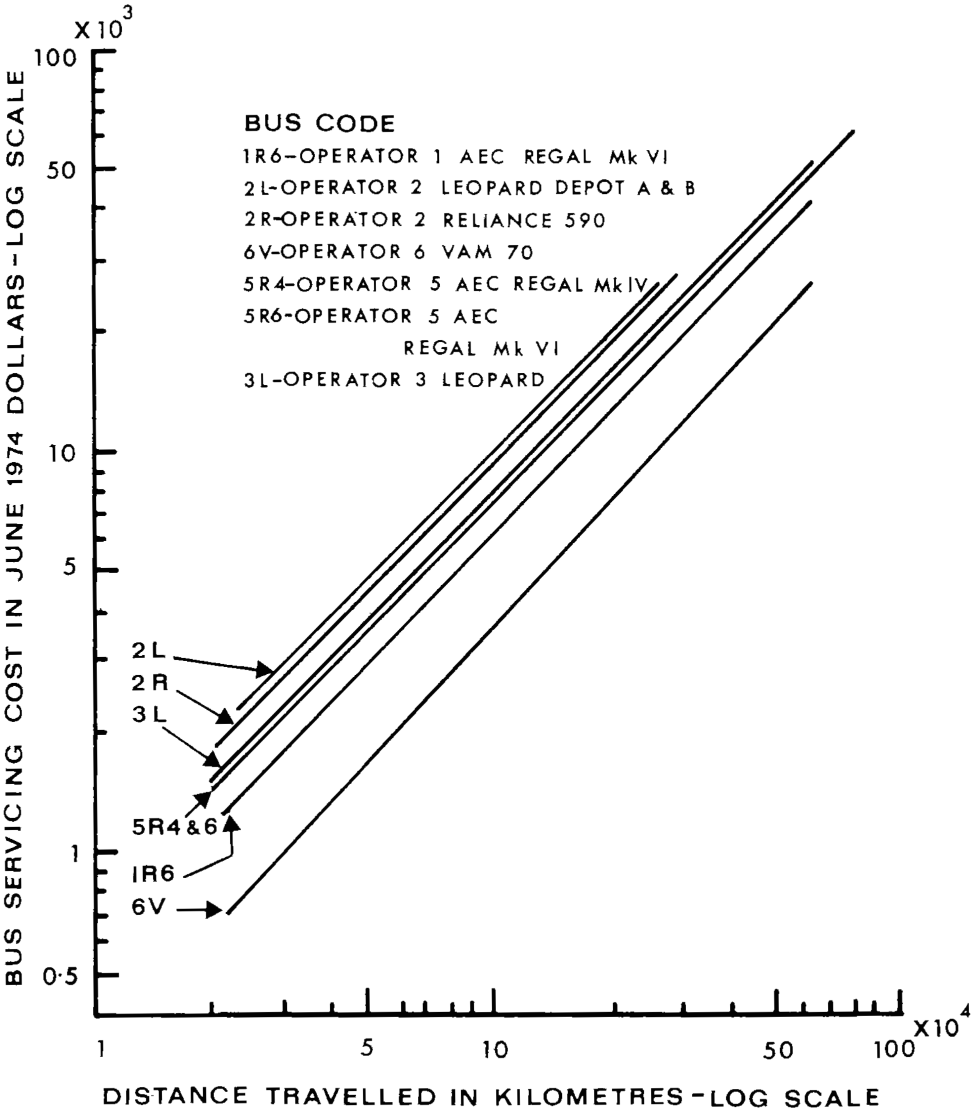

FIGURE 3·2
CUMULATIVE BUS SERVICING COSTS FOR UNDERFLOOR ENGINE BUSES

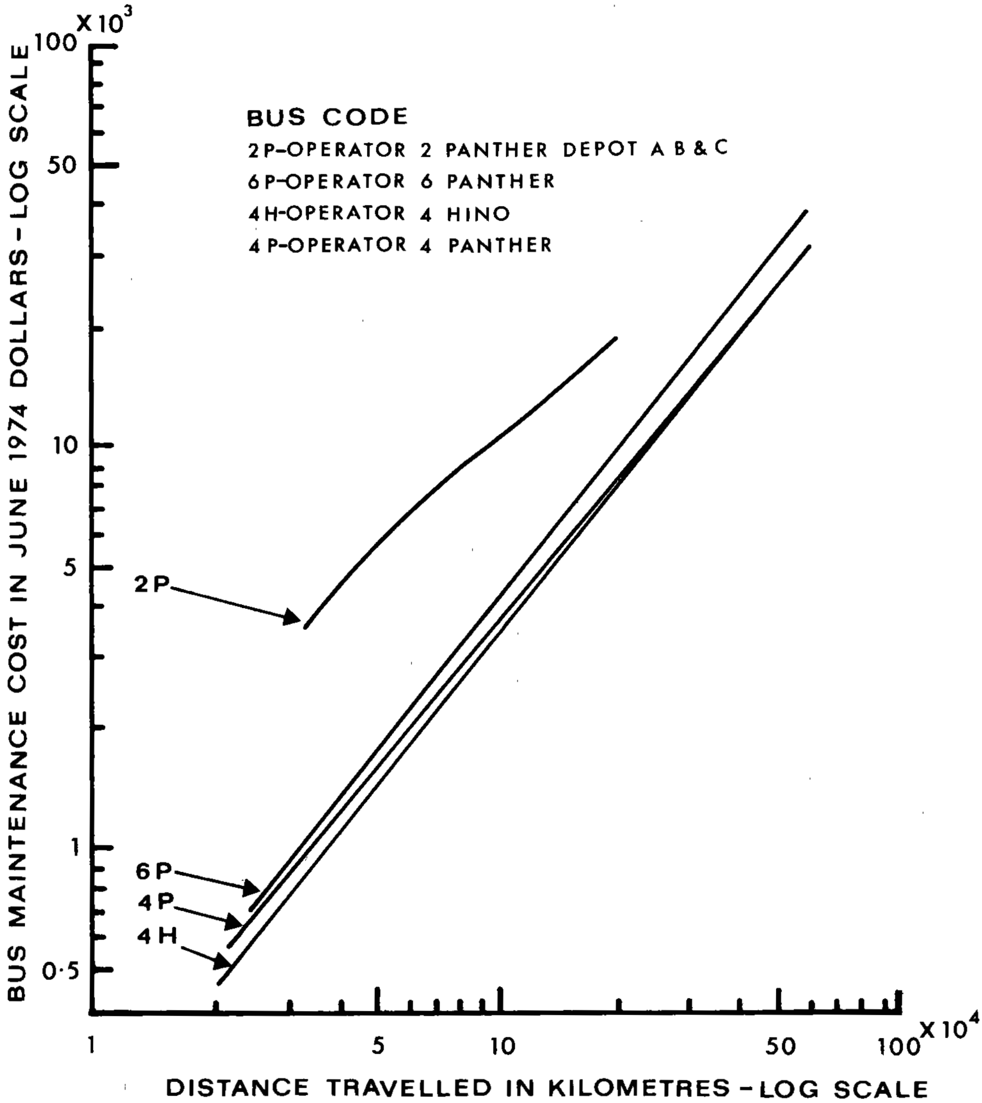

FIGURE 3·3
CUMULATIVE BUS MAINTENANCE COSTS
FOR REAR ENGINE BUSES

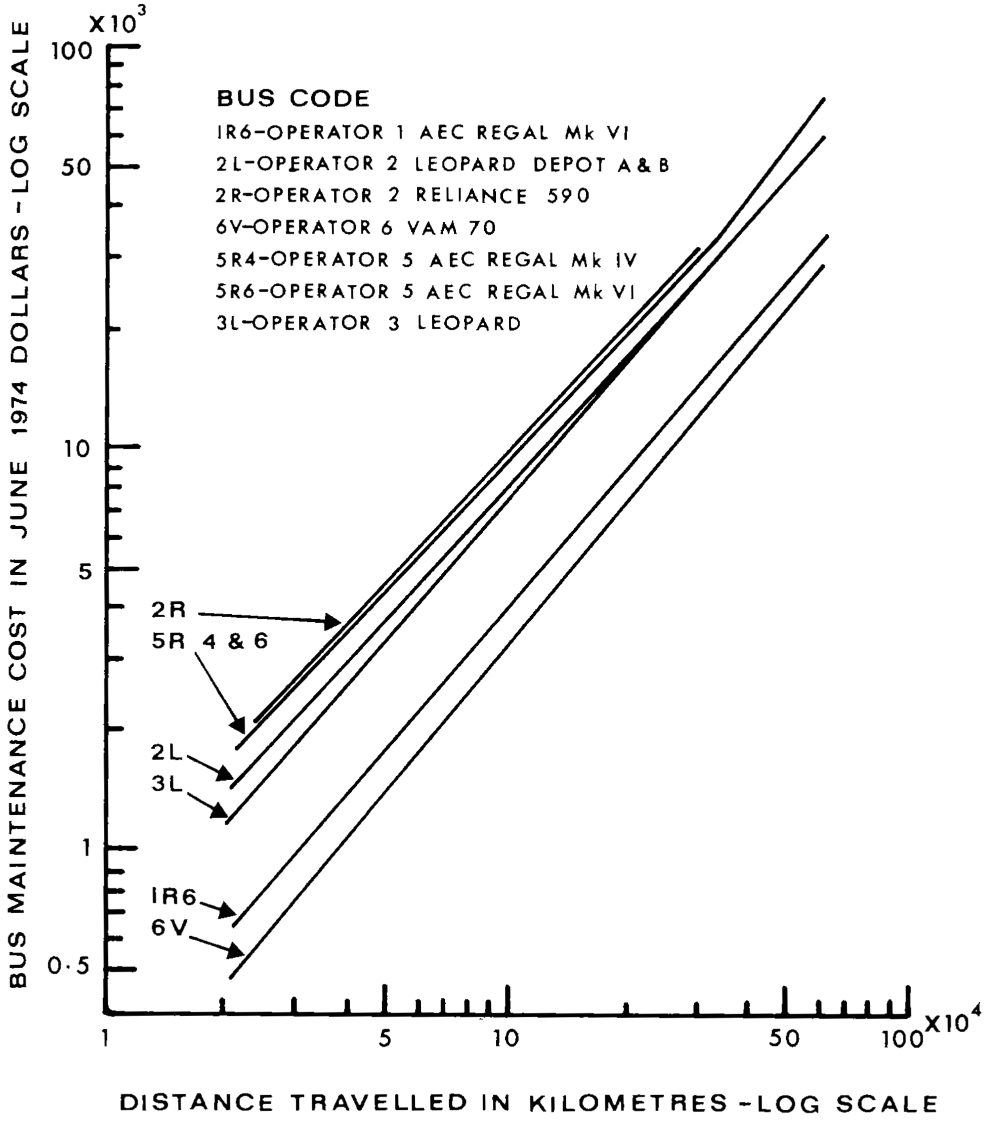

FIGURE 3·4
CUMULATIVE BUS MAINTENANCE COSTS FOR UNDERFLOOR ENGINE BUSES

ANALYSIS OF MAINTENANCE AND SERVICING COSTS

In an attempt to explain statistically the differences in cumulative maintenance and servicing costs apparent in Table 3.1, observed costs were logarithmically transformed and relationships between important variables sought. To allow cyclic maintenance and servicing activities to settle to a defined pattern the main analysis was carried out at a bus travel of 300 000 kilometres. A further analysis at 500 000 kilometres was undertaken to check for relative changes in the importance of variables.

The variables selected for regression were:

- vehicle power to weight ratio (P) because of its relationship to the duty of a bus; and

- the ratio of annual fleet travel to the active number of buses in service[1] (A) due to the calendar nature of routine maintenance and servicing activities.

A third variable, bus maximum road speed (S), was found important in the explanation of bus maintenance costs. Maximum road speed is a function of rear axle ratio and an important consideration in matching a bus to its operating environment.

Climatic variables were also considered in the analysis of bus maintenance costs.

Mean relative humidity (H) proved more significant than maximum humidity, mean ambient temperature, maximum ambient temperature, or annual rainfall in the regression of transformed bus maintenance costs.

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(1) Active number of buses is defined as those vehicles which are utilised during the year.

TABLE 3.4 - SUMMARY OF STATISTICAL ANALYSIS FOR CUMULATIVE BUS SERVICING COSTS

Item of Regression	Regression Equation (1)	Sample Size	Standard Error of Regression	Multiple Correlation Coefficient	Notes
Logarithm of cumulative servicing cost at 300 000 km.	$\log C_S = 5.7772 - 0.07273P - 0.01718A$ (0.01004) (0.01282) (0.00169)	11	0.03301	0.97	Operator 2 Leopards and Panthers averaged over depots
Logarithm of cumulative servicing cost at 500 000 km.	$\log C_S = 6.1578 - 0.07228P - 0.02053A$ (0.01093) (0.01240) (0.00384)	8	0.03093	0.96	Operator 2 Reliance, Panther and Leopards not included in sample

NOTE: $\log C_S$ = logarithm to base 10 of cumulative servicing cost C_S in June 1974 Dollars.
P = power/laden weight, kilowatts/tonne.
A = total fleet travel in thousands of kilometres/number of active buses in the fleet.(2)

(1) Numbers shown in brackets below coefficients represent coefficient standard errors.
(2) Excludes buses held in storage or used for driver training.

TABLE 3.5 - SUMMARY OF STATISTICAL ANALYSIS FOR CUMULATIVE BUS MAINTENANCE COSTS

Item of Regression	Regression Equation[1]	Sample Size	Standard Error of Regression	Multiple Correlation Coefficient	Notes
Logarithm of cumulative maintenance cost at 300 000 km.	$\log C_M = 4.9707 - 0.1165P - 0.008126S$ $(0.01208)\ (0.01726)\ (0.00250)$ $- 0.007332A + 0.02065H$ $(0.00400)\ (0.00384)$	10	0.03821	0.98	Operator 2 Leopards averaged over depots and Panthers not included in sample
Logarithm of cumulative maintenance cost at 500 000 km.	$\log C_M = 5.5785 - 0.1156P - 0.006380S$ $(0.01176)\ (0.01610)\ (0.00221)$ $- 0.01390A + 0.01828H$ $(0.00522)\ (0.00346)$	8	0.03327	0.98	Operator 2 Reliance, Panther and Leopards not included in sample

NOTE: $\log C_M$ = logarithm to base 10 of cumulative maintenance cost C_M in June 1974 Dollars.
P = power/laden weight, kilowatts/tonne.
A = total fleet travel in thousands of kilometres/number of active buses in the fleet.[2]
S = maximum road speed of bus, kilometres/hour
H = mean relative humidity.

(1) Numbers shown in brackets below coefficients represent coefficient standard errors.
(2) Excludes buses held in storage or used for driver training.

TABLE 3.6 - COMPARISON OF ACTUAL AND PREDICTED CUMULATIVE MAINTENANCE AND CUMULATIVE SERVICING COSTS

Bus Code (1)	Bus Parameters (2)				Cumulative Maintenance Cost, ($) (3)				Cumulative Servicing Cost, ($) (4)			
					300 000 km		500 000 km		300 000 km		500 000 km	
	P	A	S	H	Actual	Predicted	Actual	Predicted	Actual	Predicted	Actual	Predicted
6V	11.0	50.0	84	69	12 100	11 600	22 100	21 700	12 300	13 100	20 400	21 700
2R	9.4	35.3	59	67	33 400	33 200	N.R.	N.R.	28 300	30 700	N.R.	N.R.
5R4	8.3	46.9	68	69	31 600	34 000	59 200	62 300	23 800	23 300	39 200	39 400
5R6	8.8	46.9	68	69	32 900	29 800	60 000	54 600	24 000	21 500	39 400	36 200
1R6	8.6	47.7	75	56	15 300	14 700	29 400	29 300	19 700	21 500	34 000	36 100
2L	9.9	35.3	57	67	28 200	30 000	N.R.	N.R.	29 700	28 200	N.R.	N.R.
3L	9.8	40.3	64	69	29 600	27 400	54 100	54 800	24 800	23 600	41 400	41 900
2P	9.4	35.3	57	67	N.R.	N.R.	N.R.	N.R.	30 200	30 700	N.R.	N.R.
6P	10.6	50.0	69	69	16 000	17 100	29 000	30 200	14 400	14 000	24 200	23 200
4P	9.0	48.8	87	62	12 800	13 700	26 200	27 400	17 900	19 200	30 100	32 000
4H	9.7	48.8	83	62	12 300	12 300	25 200	24 100	18 300	17 100	30 700	28 500
Maximum error (Actual-Predicted)					+3 100		+5 400		+2 500		+3 200	

NOTE: N.R. = No Result

(1) Refer to Table 3.1 for bus codes.
(2) Parameters P, A, S and H defined in Table 3.5.
(3) Predictions based on regression equations of Table 3.5 with parameters P, A, S, and H.
(4) Predictions based on regression equations of Table 3.4 with parameters P and A.

Table 3.4 summarises the results of the analysis for cumulative bus servicing costs and Table 3.5 shows results for cumulative bus maintenance costs. Multiple correlation coefficients reflect the extent to which regression equations explain the variability in transformed costs.

Servicing Costs

The variables (P) and (A) account for most of the observed differences in transformed cumulative servicing costs. Further, there is little difference in the weightings of (P) and (A) with increasing bus travel. Table 3.6 demonstrates that the derived regression equation for cumulative servicing cost predicts costs within a maximum error of 10.4% of actual cost.

Maintenance Costs

Variables (P) and (H) proved to be important in the explanation of transformed bus maintenance costs. Further, the coefficients of these variables exhibited little change at the two levels of bus travel. It is probable that mean relative humidity (H) is a proxy for the many climatic variables which influence component operating temperatures and deterioration rates.

The variables (A) and (S) were found to have a high correlation (0.84 for the total sample of buses). Due to the emergent significance of (A) with increasing bus travel the separate effects of (S) and (A) were sought. The results of Table 3.5 demonstrate the increasing significance of mean annual travel (A) at higher levels of bus travel. The change in the coefficient of maximum road speed (S) with bus travel is thought to result from the reduced sample at 500 000 kilometres.

Further analysis was undertaken in an effort to improve the accuracy of the regression. Engine position, route distance, vehicle age, and size of fleet were coupled in turn with the variables (P), (A), (S), and (H). None of the additional variables improved the ability of the regresseion equations to predict transformed maintenance costs.

Table 3.6 compares actual cumulative maintenance costs with costs predicted from the regression equations of Table 3.5. Table 3.6 demonstrates that the regression equations at 300 000 and 500 000 kilometres based on variables (P), (A), (S), and (H) predict cumulative maintenance costs with maximum deviations from actual costs of 9 per cent.

Other Sources of Variation

Servicing costs for Operater 2 buses shown in Table 3.1 reflect differences in fuel consumption, oil consumption, and tyre lives due to vehicle type and area of operation. For Leyland Panther buses these factors were responsible for 4 per cent of the variation in vehicle servicing costs. It seems therefore, that route conditions are a significant factor contributing to the unexplained variance in the regression of cumulative servicing costs.

Annex B gives a brief resume of the traffic conditions and other regional factors for each of the six operators studied.

Prices paid for fuel and tyres also introduced small variations in servicing costs. For example, the June 1974 net cost of fuel to the 6 operators varied from 0.079 to 0.082 dollars per litre. Prices of new 1000x20x12 ply tyres also varied from 60 to 81 dollars between operators.

The larger unexplained variance of cumulative maintenance costs is understandable in terms of the accuracy of the estimated cost functions. The use of historical expenditures in the case of BCC and MMTB vehicles compared with estimates of expenditure for other organisations probably introduced systematic variations to the results.

Other factors not accounted for in the regression of cumulative maintenance costs are:

- inherent differences in bus design, component reliability, and route conditions;
- vehicle age and the range of bus technology represented in the sample;
- fleet composition and size;
- the differing organisational and administrative structures of participants;
- the differing maintenance philosophies and methods of control adopted by participating organisations;
- Differing prices of engineering labour and materials.

OBSERVATIONS ON PRACTICES

Engineering Control

BCC was the most thorough organisation in its approach to engineering control collecting cost information on a vehicle type basis and engineering statistics on a vehicle type and depot basis. Other organisations adopting similar approaches were the MMTB and MTT - Perth.

Vehicle Maintenance Forecasting

To gain forward information on vehicle maintenance requirement, MTT - Perth operates sample groups of newer vehicles on routes where they accumulate higher than normal travel. This has been found to be particularly useful in the planning of vehicle modifications. It has also proved useful in defining component lives.

Engine Monitoring

Chassis dynamometers have been used for some time by MTT - Perth and Grenda's Bus Services. Both organisations regularly schedule dynamometer checks for the monitoring and adjustment of engines.

Component Condition Monitoring

Condition monitoring to detect incipient failures is a well established practice in the aircraft and chemical industries. Much greater use could be made of the technique in bus operations to give increased vehicle availability due to the extension of overhaul and inspection intervals.

Another practice worth consideration is the use of self diagnostic circuitry. Potential areas for application are fuel, air and electrical systems.

Apprentices

All organisations participated in apprentice training. The extent to which apprentices engaged on productive activities varied due to differing union requirements. Grenda's Bus Services enjoyed the greatest use of apprentice labour.

Bus Contracts

PTCNSW specifies minimum service lives and inspection intervals for a selection of components in bus tender documents. This approach is beneficial since it leads to component life cycle costing, and its reliability and minimum life specifications are an important means of conveying operational requirements to manufacturers.

Bus Servicing

All organisations have developed reasonably efficient facilities for the fuelling and night cleaning of buses. Hand washing of buses was still in use in a few organisations. Results from MTT - Perth indicate a 50 per cent reduction in man-hours per bus using bus washing machines.

Grenda's Bus Services had negotiated contracts for the supply of bus tyres on a fleet travel basis, the tyre supplier carrying out all tyre maintenance and inspection activities. The benefits of this approach include:

- reduced inventories of tyre materials;
- reduced tyre inspection and maintenance establishments; and
- elimination of record keeping associated with warranty claims.

Another possible area for the use of contractors is bus cleaning.

CHAPTER 4 - CONCLUSIONS

ANALYSIS OF COSTS

Power to weight ratio and the average annual travel per bus were shown to be important determinants of bus cumulative servicing costs.

Power to weight ratio, average annual travel per bus, bus maximum road speed, and mean relative humidity were identified as the major variables influencing cumulative maintenance costs.

ACCOUNTING PRACTICES

Accounting practices and their use as a means of engineering control differ between the participating organisations. Specific difficulties encountered in the study were:

- a high level of aggregation of accounts usually at the level of fleet expenditure;
- the different approaches of participants to the allocation of overheads;
- different definitions of accounting classifications for each organisation.

Standard accounting classifications and the adoption of avoidable costing concepts would have enabled direct comparisons to have been made between the expenditures of bus operators.

TREATMENT OF OVERHEADS

The treatment of overheads adopted in the study proved clumsy when dealing with the various overhead structures of the participating organisations. Some errors could have entered the study particularly in the assignment of general expenditure.

Further work should seek to compare organisations on the basis of assignable and non-assignable overheads.

DISAGGREGATE STUDY OF MAINTENANCE COSTS

As the study progressed the disadvantages of using a single cost function to represent the maintenance cost of a bus became evident. These were:

- a single cost function is an aggregation of component maintenance costs and as such prevents comparison at the component level;
- a single cost function is difficult to adjust for future movements in the prices of labour and materials; and
- a single cost function cannot be readily adjusted for changes in maintenance methods required for new generation buses.

These difficulties could be avoided and better bus replacement models developed if maintenance functions were defined for individual components. The BTE should seek to follow the work of the current study with a study of disaggregate bus maintenance costs.

FUTURE WORK

Cost Performance Criteria

The regression equations for bus maintenance and servicing costs derived in the study represent average cost performance under current practices for given values of annual travel, power to weight ratio, maximum road speed, and mean relative humidity. The equations could prove useful as a benchmark for comparing the efficiency of individual organisations, and buses within a fleet.

Work should be undertaken to establish the feasibility of this approach.

Component Reliability and Maintenance Cost

Maintenance costs presented in the study reflect current maintenance methods. As new generation buses are introduced a continual review of component operating performance is needed to enable procedures to be adopted which minimise the cost of maintenance.

Further work should be undertaken to:

- relate component reliability and maintenance costs to service conditions and operating philosophies;
- design efficient methods for the collection and analysis of service histories to define minimum cost maintenance methods and servicing procedures; and
- determine the value and means of including reliability requirements in new bus specifications.

Optimal Bus Replacement Strategies

Maintenance procedures influence bus availability and therefore the effective spare capacity within a fleet. Consideration in bus replacement evaluations has not been given to the potential to reduce fleet spare capacity.

Current BTE evaluation procedures need to be extended to define bus replacement strategies which optimise maintenance procedures, fleet spare capacity, and the timing of bus replacement decisions.

ANNEX A

FLEET COMPOSITION

TABLE A.1 - FLEET COMPOSITION, STA ADELAIDE BUSES, EXCLUDING RECENT ACQUISITIONS FROM PRIVATE OPERATORS, JUNE 1974[3]

	Engine Capacity Litres	Tare Mass Tonnes	Laden Mass Tonnes	Engine Position	Gearbox Type	Number of Passengers		Age in Years
						Seated	Standing	
Leyland								
Worldmaster	11.1	8.86	14.58	U/F	Pneumocyclic[1]	40	50	16
A.E.C.								
Regal MK IV	9.6	9.05	14.77	U/F	Electro-pneumatic[1]	40	50	18
Regal MK VI	11.3	8.75	13.77	U/F	Electro-pneumatic	46	33	11
Swift 5P5R	11.3	8.98	14.00	Rear	ZF 2HP 45	46	33	2-4
Daimler								
Roadliner	9.6	9.19	14.21	Rear	Allison MP41	46	33	5
Deutz								
Magirus[2]	8.5	8.49	13.51	Rear	ZF 2HP 45	46	33	5
Mercedes								
ON1517[2]	8.7	8.70	13.72	Rear	Voith Diwabus 200S	46	33	5

NOTE: U/F = Mid-underfloor engine; Rear = Rear underfloor engine.

(1) Wilson semi-automatic gearbox.
(2) Experimental vehicle with power steering.
(3) Refer 3. Associated BTE Reports.

TABLE A.2 - FLEET COMPOSITION, PTCNSW, SEPTEMBER, 1974[5]

	Engine Capacity Litres	Tare Mass Tonnes	Laden Mass Tonnes	Body Type	Gearbox Type	Number of Passengers Seated	Number of Passengers Standing	Age in Years
Leyland								
Titan (OPD2)	9.8	7.94	12.64	F.E.D.D.[1]	Preselector	61	13	21-26
Tital (OPD2)	9.8	7.60	11.03	F.E.S.D.[2]	Preselector	31	23	22
Tiger (OPSU)	9.8	8.36	12.80	U/F.S.D.[3]	Preselector	43	27	19-21
Export Royal Tiger	11.1	7.86	12.30	U/F.S.D.	Pneumocyclic	43	27	13-17
Leopard (PSU3/RT)	9.8	6.97	11.41	U/F.S.D.	Pneumocyclic	43	27	7
Leopard (PSU3/2R)	11.1	8.41	12.85	U/F.S.D.	Pneumocyclic	43	27	4-7
Leopard (PSU3A/2R)	11.1	8.39	12.77	U/F.S.D.	Pneumocyclic	42	27	0-5
Atlantean (PDR1A/1)	11.1	9.33	13.84	R.E.D.D.[4]	Pneumocyclic	66	5	1-4
A.E.C.								
Regal MK III	9.6	8.14	12.84	F.E.D.D.	Preselector	61	13	22-27
Regal MK III	9.6	7.45	10.88	F.E.S.D.	Preselector	31	23	23
Regal MK IV (9821E)	9.6	8.27	12.71	U/F.S.D.	Preselector	43	27	20
Regal MK IV (9823E)	11.3	7.83	12.27	U/F.S.D.	Monomatic	43	27	13-17
Reliance	9.6	6.73	11.18	U/F.S.D.	Monomatic	43	27	-

NOTE: This tables includes 210 buses from Newcastle fleet.

(1) Front engine double deck bus.
(2) Front engine single deck bus.
(3) Mid-underfloor engine single deck bus.
(4) Rear vertically mounted engine double deck bus.
(5) Refer 5, associated BTE reports.

TABLE A.3 - FLEET COMPOSITION, B.C.C., JULY 1974[3]

	Engine Capacity Litres	Tare Mass Tonnes	Laden Mass Tonnes	Engine Position	Gearbox Type	Number of Passengers		Age in Years
						Seated	Standing	
Daimler								
Daimler	8.5	8.03	11.24	Vert/F[4]	Preselector[1]	37	26	21-22
Gardner	8.6	8.48	11.85	Vert/F	Preselector	39	27	25-26
A.E.C.								
Regal MK III	9.6	8.00	11.26	Vert/F	Preselector	38	26	22-26
Regal MK IV	9.6	8.26	11.83	U/F	Preselector	43	27	19
Regal MK IV	11.3	7.82	11.39	U/F	Preselector	43	27	14
Regal MK VI	11.3	8.07	11.69	U/F	Dana-Spicer 184 Torque Converter	43	28	11
Reliance 470	7.7	7.06	10.58	U/F	Electro-pneumatic[2]	42	27	11
Reliance 590	9.6	7.36	11.29	U/F	C.A.V. Automatic	39	38	8-9
Leyland								
Worldmaster	11.1	8.02	11.64	U/F	Electro-pneumatic[2]	43	28	13
Royal Tiger Cub	9.8	7.75	11.37	U/F	Pneumocyclic(2)	43	28	11
Leopard	11.1	7.79	11.72	U/F	Electro-pneumatic	39	38	9
Leopard	11.1	8.02	12.10	U/F	Electro-pneumatic	40	40	7-8
Panther	11.1	8.47	12.70	Rear	Electro-pneumatic	39	44	6-7
Panther	11.1	8.47	12.70	Rear	ZF2HP45	39	44	5-6

(1) Wilson Preselector.
(2) Wilson S.G.G.
(3) Refer 4, associated BTE reports.
(4) Vert/F = Vertical front.

TABLE A.4 - FLEET COMPOSITION, MTT PERTH, JUNE 1974 (6)

	Engine Capacity Litres	Tare Mass Tonnes	Laden Mass Tonnes	Engine Position	Gearbox Type	Number of Passengers: Seated	Number of Passengers: Standing	Age in Years
A.E.C.								
Regal MK IV	9.6	8.86	13.43	U/F	12 with Preselector (1) 11 with Electro-pneumatic (2)	49	23	15-23
Regal MK VI	9.6	8.41	12.79	U/F	Electro-pneumatic (2)	46	23	9-12
Albion								
Viking	6.1	6.07	10.20	Front	5 Speed Manual	43	22	9
Daimler								
Freeline	10.6	8.38	12.76	U/F	Preselector (1)	45	24	16-20
Roadliner	9.6	8.29	12.35	Rear	Electro-pneumatic (2)	43	21	7
Hino								
RC 520P	10.2	8.92	12.86	Rear	Electro-pneumatic (3)	41	21	) 1-5
		9.07	13.45	Rear	Electro-pneumatic (3)	45	24	)
Leyland								
Royal Tiger	9.8	8.55	13.12	U/F	4 Speed Manual	49	23	21-23
Worldmaster	9.8	8.61	12.99	U/F	Electro-pneumatic (2)	46	23	) 10-19
	11.1	8.43	13.00	U/F	Electro-pneumatic (2)	49	23	)
Tiger Cub	6.5	6.71	10.33	U/F	Electro-pneumatic (2)	38	19	7-9
Leopard	11.1	8.19	12.57	U/F	40 with Electro-pneumatic (2) 10 with Voith Diwar Automatics	46	23	5-6
Panther	11.1	9.06	13.00	Rear	Electro-pneumatic (2)	41	21	) 1-6
		8.93	13.31	Rear	Electro-pneumatic (2)	45	24	)
Mercedes								
0.305	11.0	8.94	12.88	Rear	Mercedes 3 Speed Automatic	41	21	0
Due for Retirement (5)								
A.E.C. Regal MK III								21-24
Guy Arab								22
Leyland OPS4								24

(1) Wilson Preselector.
(2) Wilson S.C.G.
(3) Wilson S.C.G. manufactured under licence by Hino.
(4) Includes evaporative cooling unit. Without evaporative cooling unit height is 2.98 metres.
(5) These buses are to be retired in the near future.
(6) Refer 6, associated BTE Reports.

TABLE A.5 - FLEET COMPOSITION, M.M.T.B. AT JUNE 1974[3]

	Engine Capacity Litres	Tare Mass Tonnes	Laden Mass Tonnes	Engine Position	Gearbox Type	Number of Passengers Seated	Number of Passengers Standing	Age in Years
Active Buses								
A.E.C.								
Regal MK III (One-man operated)	9.6	8.23	12.04	Front	Preselector[1]	32	28	20-23
Regal MK III (Two-man operated)	9.6	8.89	13.97	Front	Preselector	41	39	20-23
Regal MK IV	11.3	8.03	11.84	U/F	Semi-Automatic[2]	31	29	17-18
Regal MK VI	11.3	8.30	12.11	U/F	Automatic	31	29	9-10
Buses in Storage or Used for Training								
Leyland Tiger OPS 1								24
AEC Regal MK III (Two-man operated)								20-23

(1) Wilson preselector.
(2) Wilson S.C.G. with electro-pneumatic controls.
(3) Refer 7, associated BTE reports.

TABLE A.6 - FLEET COMPOSITION, GRENDA'S BUS SERVICES, JUNE 1974 [5]

	Engine Capacity Litres	Tare Mass Tonnes	Laden Mass Tonnes	Engine Position	Gearbox Type	Number of Passengers		Age in Years
						Seated	Standing	
Bedford								
SB5	5.4			Front	Manual [4]	34		8-11
Vam 5	5.4			Front	Manual [2]	34		8
Vam 70	7.6	5.90	9.71	Front	Manual [2]	34-36		3-6
A.E.C.								
Regal MK IV (ex-MTT Adelaide)	9.6			U/F	Wilson S.C.G.	42		14
Leyland								
Royal Tiger Cub	9.8			U/F	Wilson S.C.G.	40		10
Worldmaster (ex-MTT Adelaide)	11.1			U/F	Wilson S.C.G.	42		14
Panther Cub	6.6			Rear	Wilson S.C.G. [3]	33		5
Panther	9.8			Rear	Wilson S.C.G. [3]	33		6
Panther	11.1	8.48	12.29	Rear	Wilson S.C.G. [3]	33		6

(1) Buses licensed according to seating capacity; total passengers seated and standing approximately 60.
(2) Five speed with synchromesh.
(3) Direct coupled to engine.
(4) Five speed constant mesh.
(5) Refer 8, associated BTE reports.

ANNEX B

TRAFFIC CONDITIONS AND REGIONAL FACTORS FOR OPERATORS STUDIED

The following is an extract of traffic conditions and regional factors from the six separate case studies performed by the BTE.[1] Information on the gradients, average speed, number of stops per kilometre and the collision rates have been included as a means of comparing the different operators physical environments.

S.T.A. ADELAIDE

Adelaide roads are relatively straight within a radius of 10 kilometres from the city centre. The paving is also generally good.

Travel speeds vary from 6 to 8 kilometres per hour within 1 kilometre of the main city but increase to 19 to 24 kilometres per hour elsewhere. A timetable speed of 20 kilometres per hour is generally used in the Adelaide area. The S.T.A. has standardised on a figure of 3 passenger stops per kilometre.

More than 90 per cent of the travel of the main fleet of S.T.A. buses is over flat terrain. The maximum grade encountered in the operation of the main S.T.A. fleet is 6.7 per cent and this extends for a distance of 0.2 kilometres.

A number of the routes recently acquired from private operators are in the Adelaide Hills area and the proportion of flat running has therefore been reduced if the entire fleet is considered. One of the steepest grades covered by these newly acquired routes is 17.4 per cent, over a distance of 0.1 kilometres.

The collision rate of S.T.A. buses with stationary objects and other vehicles has varied little over the past five years averaging between 1.6 and 1.9 collisions per hundred thousand kilometres.

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(1) Refer Associated BTE Reports, page x.

The average rate for the year ending June 1974 was 1.7 collisions per hundred thousand kilometres.

B.C.C. BRISBANE

A number of Brisbane bus routes operate through the city area where travel speeds average 6 to 9 kilometres per hour. Generally for off-peak services to the main city area the travel speed varies between 18 and 21 kilometres per hour while peak services have travel speeds in the range 12 to 17 kilometres per hour. Outbound services from the city have travel speeds from 12 to 18 kilometres per hour during off-peak times and 8 to 12 kilometres per hour during peak times.

The number of bus stops average 4.0 to 4.4 per kilometre in the suburban areas and 2.5 to 3.1 per kilometre in the city area.

Buses cover a variety of terrain from flat to hilly and it is estimated that over 40 per cent of bus travel occurs on grades greater than 10 per cent with grades of 20 per cent being common.

The frequency of collisions which resulted in bus change-overs averaged 1.5 collisions per 100 000 km with inner city collisions occuring at a higher than average rate, possibly due to the heavier traffic conditions.

P.T.C. N.S.W. SYDNEY

Traffic conditions in Sydney hamper the operation of buses. Travel speeds in the city area average 8.4 to 11.1 kilometres per hour depending on the route and whether the journey is into or out of the city. For services, other than in the city area, a timetable speed of 19.3 kilometres per hour is generally used.

The P.T.C.N.S.W. is aiming to standardise on a figure of 2.5 passenger stops per kilometre and an attempt is being made to improve travel times by introducing express services and exclusive bus lanes.

The density of traffic has some bearing on the collision rate. The number of collisions averages 250 per month and 80 per cent of these collisions require a bus change-over. This represents a rate of 4.0 collisions per 100 000 kilometres for bus change-overs.

Sydney terrain varies from very hilly in the Eastern and Northern suburbs to flat in the southern and western suburbs. More recent buses purchased by the P.T.C.N.S.W. are capable of taking off unloaded from a grade of 25 per cent. It is estimated that 20 per cent of bus operations occur on grades steeper than 4 per cent with many up to 8 per cent. Buses are also required to operate on gradients up to 14 per cent for distances of several hundred metres. A feature of Sydney is that many of these gradients occur in congested areas.

M.T.T. PERTH

Traffic conditions in Perth are generally favourable for bus operations. Within the city area travel speeds vary between 6 and 14 kilometres per hour. Outside the city area travel speeds show a marked increase with the length of trip. This trend can be explained by the lower traffic densities in the outer suburban areas and the Trust's policy of operating express buses to the city from these regions. A tabulation of travel speed versus length of trip is given below.

Length of Trip (Kilometres)	Travel Speed Kilometres per Hour	
	Heavy In-Peak Travel	Light Off-Peak Travel
5 to 9.9	14-17	17-22
10 to 14.9	18-21	23-25
15 to 19.9	23-25	27-30
20 to 24.9	25-31	29-36
25+	Up to 43 kilometres per hour	

The number of passenger stops in the Perth metropolitan area usually averages 2.5 stops per kilometre. On a few routes the figure is as high as 4 stops per kilometre.

Approximately 95 per cent of bus travel in the Perth Metropolitan area is over flat terrain. At Scarborough to the north of Perth, there are a few grades with slopes from 12 to 16 per cent.

The incidence of reported collisions with vehicles and road-side objects for the year ending June 1974 averaged 2.6 per hundred thousand kilometres. Some of the reported collisions were of a minor nature and the frequency of collisions resulting in an engineering defect was 1.7 per hundred thousand kilometres.

M.M.T.B. MELBOURNE

M.M.T.B. bus services do not run through the city centre but terminate at strategic points near the centre. Thus travel speeds in the city area tend to be relative high compared with other Australian capitals,averaging 13 to 16 kilometres per hour within six kilometres of the city centre. Travel speeds for trips in excess of sixteen kilometres average 19 to 23 kilometres per hour during peak times and 21 to 32 kilometres per hour during off-peak times.

Bus stops normally average 3 to 4 per kilometre. However, on the longer Warrandyte - City run the number of stops varies between 2 to 3 per kilometre.

From the point of view of bus operation, conditions in the Melbourne metropolitan area are generally favourable. The terrain varies from generally flat in the west to moderately hilly in the east. The steepest grade encountered by buses during normal route operation is 13 per cent.

The incidence of reported collisions with vehicles and road-side objects for the year ending June 1974 averaged 5.4 per hundred thousand kilometres. It is thought that less than one quarter of these collisions would be sufficiently serious to warrant a bus change-over.

GRENDA'S BUS SERVICES - MELBOURNE

Grenda's Bus Services is one of five main private operators in the Melbourne area, and is the largest in terms of numbers of buses and fleet travel but ranks second in terms of passengers carried. The company is based at Dandenong and serves the South East portion of Melbourne. Ninety five per cent of the travel of its route buses is over flat terrain with the steepest grade encountered being 12 per cent.

At June 1974, there were 128 vehicles in Grenda's bus fleet with a further 11 on order. Of these vehicles 69 were used for route work and the remainder used for tour and charter operations.