

TRANSPERTH'S BUS REPLACEMENT MODELLING PROCESS
SOME COMMENTS ON THE INPUTS AND OUTPUTS

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ABSTRACT

Transperth's bus replacement decisions are aided by a computerised model which calculates, for any given set of conditions, the net present value of the total cost of owning and operating the bus fleet.

This paper presents an overview of the various input items required for the modelling process and the significance and sensitivity of the results of the process.

Emphasis is placed on changes in maintenance costs which are likely to result under various possible bus service life scenarios. These changes have a significant impact on the results of the modelling process and are difficult to estimate.

The modelling process indicates that, under current conditions, the optimum bus replacement level for Transperth is in the range of 45 to 55 buses per year, or 5-6% of the total fleet per year.

TRANSPERTH'S BUS REPLACEMENT MODEL: INPUTS AND OUTPUTS

1 INTRODUCTION

Transperth's bus replacement decisions are aided by a computerised model developed and subsequently enhanced by Coopers & Lybrand WD Scott.

Approaches which had previously been adopted tended to apply conventional investment appraisal principles to bus purchase decisions. Transperth's bus replacement model is based on the notion that, in the case of a public transport operator, the annual purchase of new buses should be regarded as recurrent expenditure rather than a discrete capital investment.

Accordingly, the model calculates, for any given set of conditions, the net present value of the total cost of owning and operating the bus fleet.

This paper presents an overview of the various input items required for the modelling process and the significance and sensitivity of the results of the process. The algorithms and other technical aspects of the model, including the rationale for not adopting one of the conventional investment appraisal approaches, are described in a companion paper by Dr Peter Bath.

The various items of input required to operate the model can, from the user's point of view, be classified into four broad categories, namely:

- . Data relating to the existing bus fleet;
- . Current operating costs and those which are likely to be incurred in the future, assuming no significant change in the service life of buses in the fleet;
- . Changes in the maintenance cost structure which are likely to result under various possible service life scenarios; and
- . Details of the operating environment for each year of the selected time frame to be addressed by the model.

The paper places emphasis on the third category as changes in maintenance costs are difficult to estimate and have a significant impact on the results (outputs) of the modelling process.

The input required for each of the above categories is discussed in Sections 2 to 5. The results and

sensitivities of the modelling process are summarised in Sections 6 and 7.

2 DATA RELATING TO THE EXISTING FLEET

The following, describing the physical state of the fleet in the base year, are input:

- . The number of buses in each group (ie original contract group);
- . The average cumulative distance travelled by buses in each group; and
- . The merit ranking of each bus group.

The merit ranking of bus groups is determined corporately taking into account factors such as age, current operating cost and reliability, and to a lesser extent, passenger and driver preference. During the simulation process, the model "retires" the specified number of buses from the group which has the lowest merit ranking.

3 OPERATING COSTS ASSUMING CONSTANT SERVICE LIFE

The model derives total operating costs from four cost categories, namely:

- . Age-related costs, comprising the cost of "body docks" which are carried out every five or six years;
- . Total distance-related costs, comprising the cost of "major mechanical overhauls" which are usually carried out every 100,000-300,000 kilometres depending on the type and age of bus;
- . Annual distance-related costs, consisting of "running costs" which are incurred on an on-going basis and include regular servicing, repairs, on-going maintenance, breakdown recovery and defect rectification; and
- . Fuel costs, which involve the fuel consumption rate of, and annual distance travelled by, each bus group as well as the cost of fuel.

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Current operating costs for the fleet in terms of these categories are derived by statistical methods from the bus costing reports and other information held by Transperth.

This information is input in such a way that as the age of each bus group reaches the appropriate number of years, a body dock cost is calculated for each bus in the group. Similarly, mechanical overhaul costs are computed at appropriate distance intervals, and running and fuel costs are calculated for each year based on the distance travelled in that year.

It should be noted that the level of body dock, major mechanical overhaul and running costs (referred to as maintenance costs), reflects existing and past maintenance policy, particularly in relation to the service life of buses.

A lagged relationship exists between the number of buses replaced each year (which determines the service life) and the level of maintenance costs. The lag referred to is likely to be of several years duration.

Over the past seven years, during which time the fleet size has remained more-or-less constant, some 45 buses per year have been replaced. Replacement practices in earlier years have been such that buses have generally been retired at more than 20 years of age. Based on the size of the fleet in these years, this is also equivalent to a current annual replacement of approximately 45 buses.

It has therefore been assumed that Transperth's current maintenance costs are the result of an annual replacement programme of 45 buses (or an average service life of 20 years).

4 CHANGES IN THE MAINTENANCE COST STRUCTURE DUE TO DIFFERENT SERVICE LIVES

If the number of buses to be replaced is significantly greater, or less than, 45 per year, Transperth's maintenance cost structure will alter. The model therefore has the provision for maintenance cost change factors to be input by the user for each level of bus replacement to be simulated by the model.

4.1 Effect of Zero or Low Level of Bus Replacement on Maintenance Costs

Transperth's current operating policy is to run new buses "flat out" for the first few years of their lives. During this time, these buses travel 80,000-100,000 km per year. As the buses age, the annual distance travelled declines until just prior to disposal when buses travel 15,000-25,000 km per year.

This policy could not be continued in a situation in which no buses were being replaced if only because, within a few years, the newest buses in the fleet would have accumulated a total distance equal to that accumulated by the oldest buses.

In the context of no replacement or replacement at a low level, it would be necessary to move to a policy of operating all buses over the same annual distance of 50,000-60,000 km.

The low maintenance costs presently observed for "old" buses arise from the fact that they are given a light work load. An increase in the load placed upon them could be expected to increase the amount of wear and tear to which they are subjected. To maintain the level of service offered by Transperth to the travelling public, it would be essential that these buses be maintained in a serviceable condition.

Transperth has also had considerable success in reducing the maintenance costs of buses by extending the interval between major overhauls. It seems unlikely that these extended intervals could be continued in the knowledge that the service life of the buses is to be extended indefinitely.

There is little data available as to the costs involved in maintaining a fleet of buses to meet a constant service level for an indefinite period (ie the zero replacement option). However, maintenance costs could be expected to rise considerably for the older buses, especially as it would probably be necessary to set up a manufacturing operation to produce parts no longer available for obsolete buses. It would also probably be necessary to introduce shift work for maintenance in order to ensure that sufficient buses were available to meet the morning peaks.

Transperth has previously studied the costs of rebuilding old buses to extend their service life. The general conclusion of these studies is that rebuild

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costs to extend the service life of an old bus (ie 20 years of age or more) by 7 years would be 50-80% of the cost of a new bus.

In practice, under conditions of no replacement or low-level replacement, Transperth would not perform major bus remanufactures at intervals of several years at a time. Instead, a greater amount of work would be done on a continuous basis. Accordingly, it has been assumed that running costs would be affected to a greater extent than major mechanical overhauls, which in turn would be more significantly affected than body dock costs.

All things considered, the additional annual cost per bus associated with the zero-replacement option can be assumed to be between 7% and 11% of the cost of a new bus. For the purposes of deriving a "most likely" case the mid point, that is 9%, was selected.

The best fit, corresponding with an increase in costs of 9% of the cost of a new bus (ie at the zero replacement level) and the relativities expressed above, was found to be:

- An increase in body dock costs of approximately 80% per dock;
- An increase in the cost of major mechanical overhauls of 170%; and
- An increase in running costs of 340%.

It should be emphasised that increases in maintenance costs of this magnitude are consistent with available information on the costs of extending the service life of buses indefinitely.

Various sensitivity tests were performed on these and other assumptions. Sensitivities are discussed in Section 7.

4.2 Effect of Increased Levels of Bus Replacement on Maintenance Costs

If the level of bus replacement were to increase above 45 per year, the retirement age of buses would decrease, which would allow the cost of maintaining the fleet to be reduced.

Very little information is available concerning the effect on maintenance costs of reducing the service life of buses significantly. However, certain limits on the reduction in maintenance costs can be reasonably assumed.

With regard to the running cost components, even if every bus in the fleet were replaced every year, for example, a certain level of costs would remain. The remaining costs would include those associated with breakdown recovery, accident recovery and repair, lubrication and servicing. Hence the maximum reduction in running costs would be somewhat less than 100%; say 85%. It has been assumed that this maximum reduction would be reached when several hundred buses, say 900, per year are replaced. (These numbers are not critical as the curve of changes in running costs becomes very flat after 150 buses per year).

For replacement levels in excess of 45 buses per annum, provided the retirement age is such that at least one mechanical dock is carried out on each bus, the reduction in mechanical dock costs would be considerably less than 100%. As indicated in the previous section, for any low levels of bus replacement, the change in mechanical dock cost has been set at half the change in running costs. This two-to-one relationship between changes in running costs and changes in mechanical dock costs, is assumed to also hold for replacement levels of more than 45 buses per year.

4.3 Combined Effect of Different Levels of Bus Replacement on Maintenance Costs

Changes in body dock costs resulting from an increase or decrease in the retirement age of buses, are taken into account automatically within the model. It is possible for this to be done because body dock costs are related to a fixed time interval regardless of the annual task performed.

Changes in mechanical overhaul and running costs, being distance-related, have to be fed into the model for each level of bus replacement. This is because the cost rates would begin to change immediately if it were decided to alter the retirement age of buses for a considerable number of future years. Short term changes in retirement age would not be expected to have a significant effect on these cost rates.

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As stated previously, the changes in running costs associated with replacement levels of zero, 45 and 900 buses per annum are assumed to be + 340%, 0% and - 85% respectively.

Portrayed graphically, these three coordinates provide a useful guide to the nature of the relationship between changes in running costs and the level of bus replacement. "Least favourable" and "most favourable" curves can be crudely estimated graphically. (The least favourable curve being that which gives rise to the least number of buses to be replaced, and vice-versa). Figure 1 represents the 0-to-100-buses-per-annum portion of the total relationship described above.

The "most likely" curve is assumed to be approximately half way between the least and most favourable curves. For simplicity it is assumed to be linear between 0 and 45 buses per year. This causes a slight discontinuity in the curve, especially between 30 and 45 buses per annum. However, sensitivity tests indicate that the adoption of a smoother curve would be unlikely to have a material effect on the results.

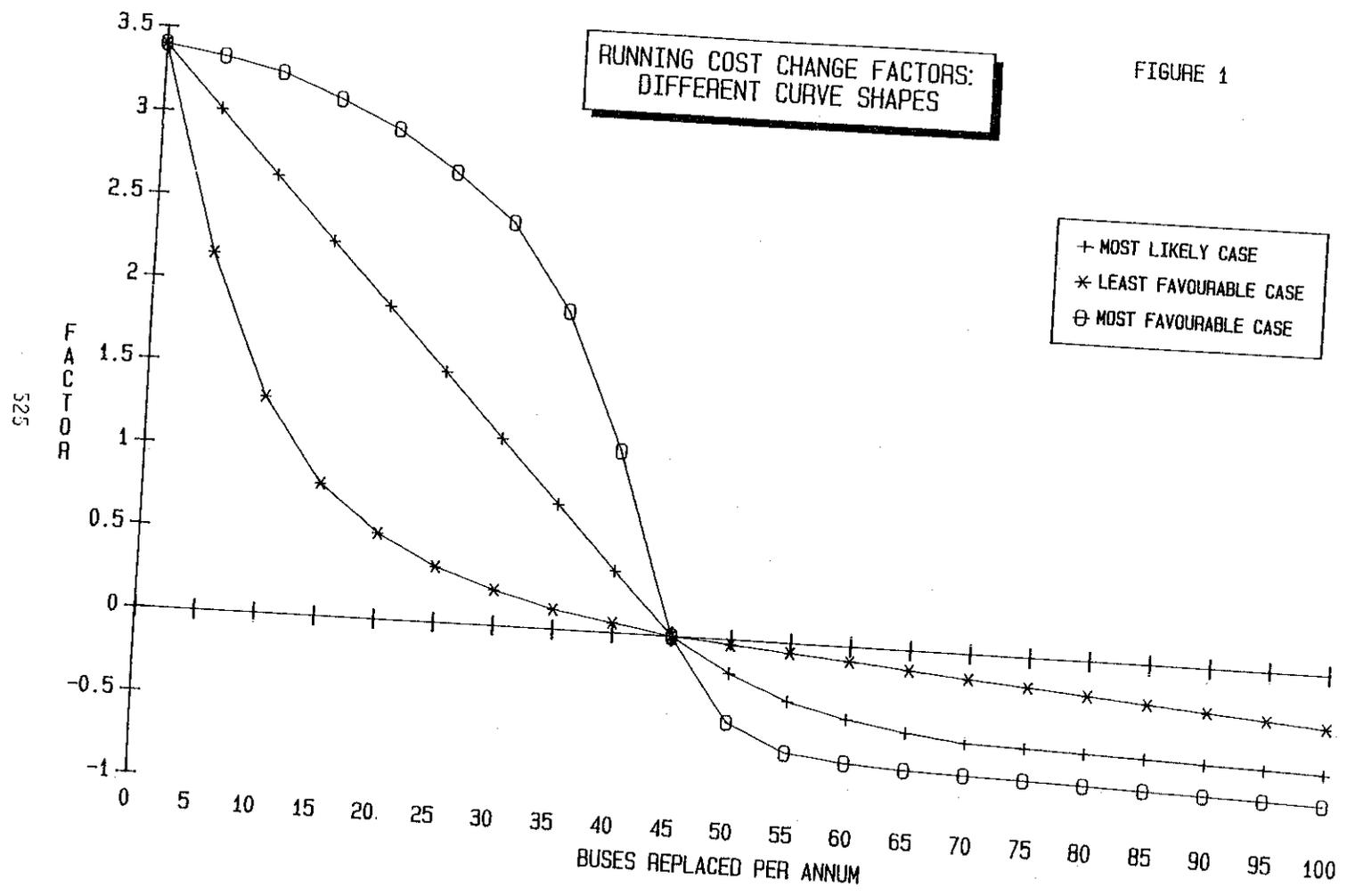
The foregoing discussion relates to changes in running costs. In principle, the same would apply to changes in mechanical dock costs, except that the magnitude of the changes would be proportionately (50%) less.

5 DETAILS OF THE OPERATING ENVIRONMENT

The following items, which relate to the operating environment, are input for each year to be addressed by the model:

- . Interest rate;
- . Separate inflation rates for bus capital costs and fuel, running and body dock costs;
- . Number of peak buses;
- . Annual distances to be travelled by broad bus groups and in total; and
- . Discount rate.

The required input data normally becomes available a number of months after the end of the base year. Consequently, when the model is run, a reasonable



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indication is generally available regarding initial movements in the interest rate and the various inflation rates. A reasonable estimate for the first year can therefore usually be made. Official estimates of future interest and inflation rates, to the extent they are available, have to be relied upon for the next few years.

Derivation of the base year capital cost of new buses, both articulated and rigid, is straight forward. For future capital costs of buses, forecasts of movements in the exchange rates between the Australian dollar and the currencies of those countries from which Transperth imports bus chassis, have to be taken into account.

In practice, from about the fifth year onwards, a common inflation rate is used each year for bus capital costs and fuel, running and body dock costs; and a constant real interest rate is generally applied to each year's inflation rate to derive a nominal interest rate for that year. The discount rate for each year is generally set equal to the nominal interest rate for that year.

6 RESULTS OF THE "MOST LIKELY" CASE

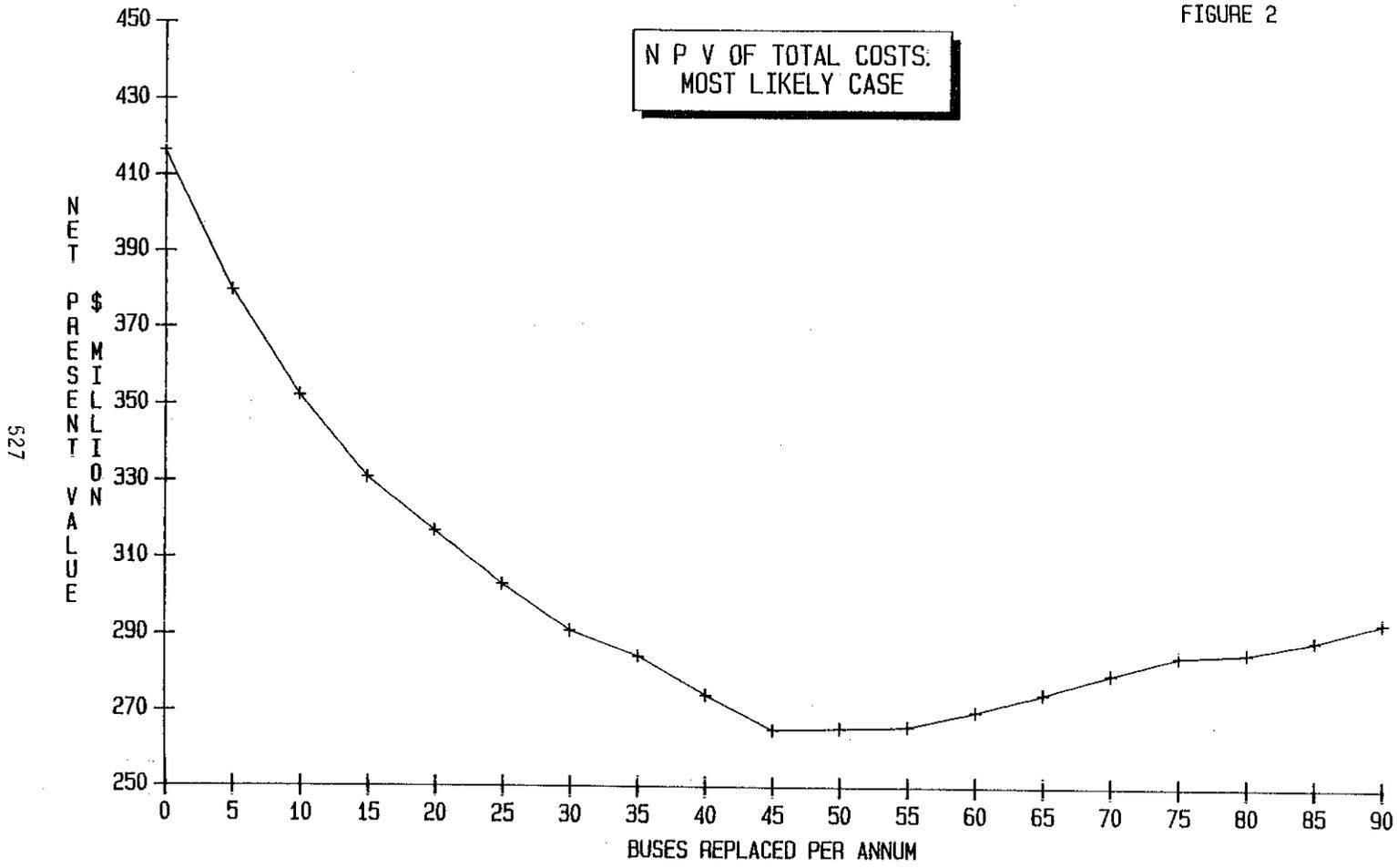
For any given set of assumptions including:

- . Number of buses to be replaced per year;
- . Factors to increase/decrease the base mechanical dock costs and running costs;
- . Interest rates;
- . Inflation rates;
- . Capital cost of buses; and
- . Discount rates

the model calculates the net present value (NPV) of the total cost of owning and operating the fleet for any specified number of years.

Based on a period of 20 years and the assumptions made for the "most likely" case, the NPV of the total cost associated with different levels of bus replacement are shown in Figure 2.

FIGURE 2



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It can be seen that the minimum NPV of total cost corresponds with an annual replacement level of 45 buses. However, it is also apparent that the NPV for 50 and 55 buses is not significantly higher than that for 45 buses. The optimum bus replacement level is therefore in the range of 45 to 55 buses per year.

Figure 2 also indicates that the cost associated with low replacement levels (eg between 0 and 20 buses) is considerably greater than the cost associated with high levels of replacement (eg 90 buses).

These results suggest that Transperth's bus replacement policy over the years has tended to be at the conservative end of the optimum range.

7 SENSITIVITY OF THE ASSUMPTIONS

7.1 Relativities Between Changes in Body Dock, Mechanical Dock and Running Costs

Various relationships have been examined and it has been found (provided the total annual increase in costs for the zero replacement option remains approximately 9% of the cost of a new bus) that although the magnitude of the NPV's of total costs may alter, the point at which the minimum occurs does not shift significantly.

7.2 Magnitude of the Change in Body Dock Costs

The optimum bus replacement level was found to be insensitive to variations in the change in body dock costs.

7.3 Magnitude of Changes in Mechanical Dock and Running Costs

The results of the following sensitivity tests are illustrated in Figure 3.

To test the sensitivity of the model's results to different magnitudes of the mechanical dock and running cost factors, the factors were doubled and halved.

Doubling the maintenance cost factors essentially causes maintenance costs to increase relative to capital costs, thus creating a situation which is more favourable to higher levels of bus replacement.

Accordingly, it was found that, using the doubled factors, the optimum replacement level moved from 45 to 55 buses per year.

Halving the factors primarily causes maintenance costs to decline relative to capital costs, causing the curve of NPV of total costs to become flatter, particularly in the 0-to-45-buses-per-year portion. However, using the halved factors, the optimum level remained at 45 buses per year.

A third sensitivity was also tested. For this test, the halved factors were scaled down further until the optimum replacement level began to shift from 45 buses per year to less than 45 buses per year (ie until the curve to the left of 45 buses per year became horizontal).

The running cost factors which achieved this result ranged linearly from 128% for zero buses to 0% for 45 buses. The mechanical dock cost factors were half the running cost factors.

This means that provided the running cost factor is 128% or more, and the mechanical dock factor 64% or more, for a replacement level of zero buses, then the optimum replacement level will be 45 or more buses per year.

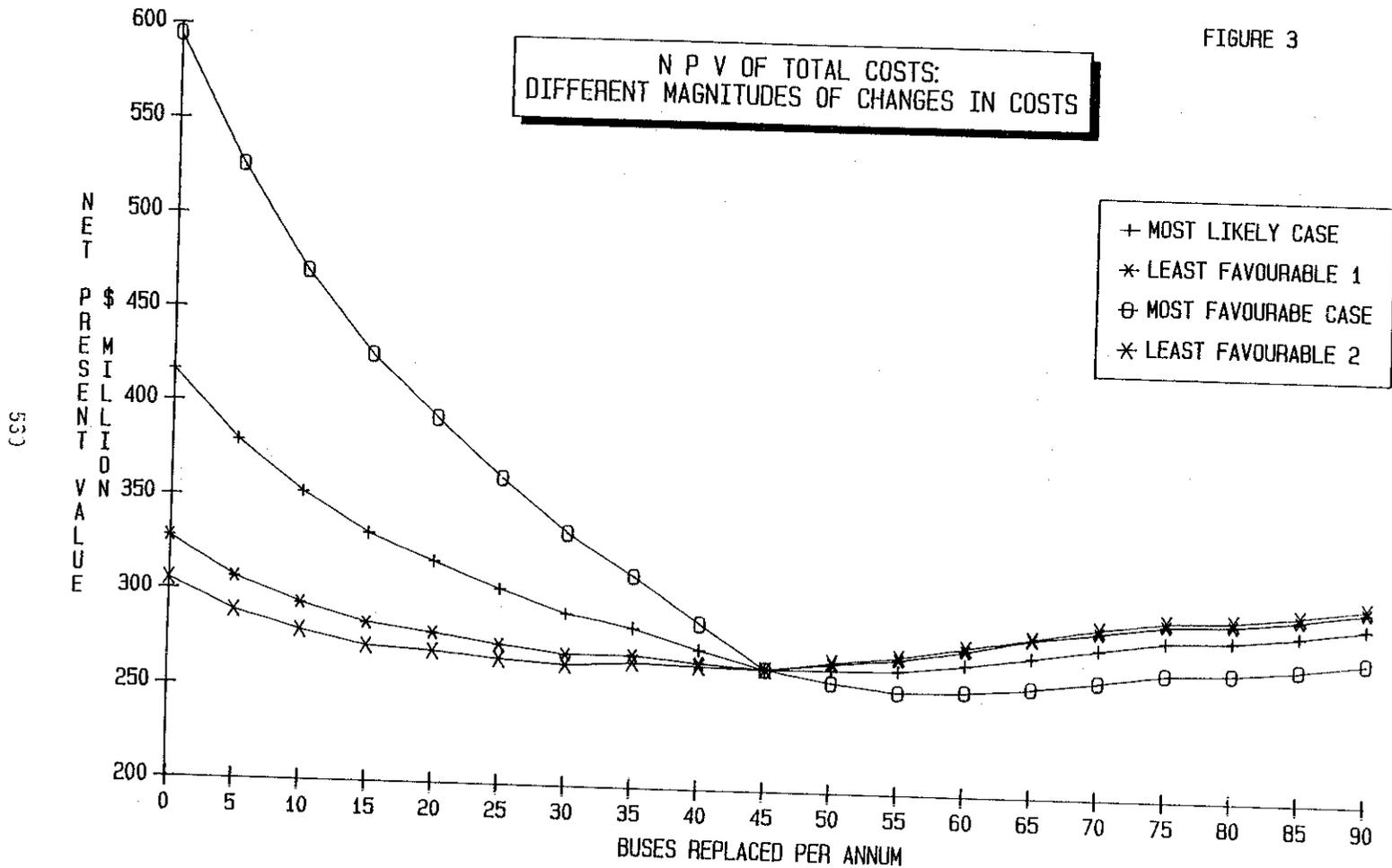
In Figure 3 the "Most Favourable Case", "Least Favourable 1" and "Least Favourable 2" represent the situation with the factors doubled, factors halved and factors causing the minimum point to begin to move towards the origin, respectively.

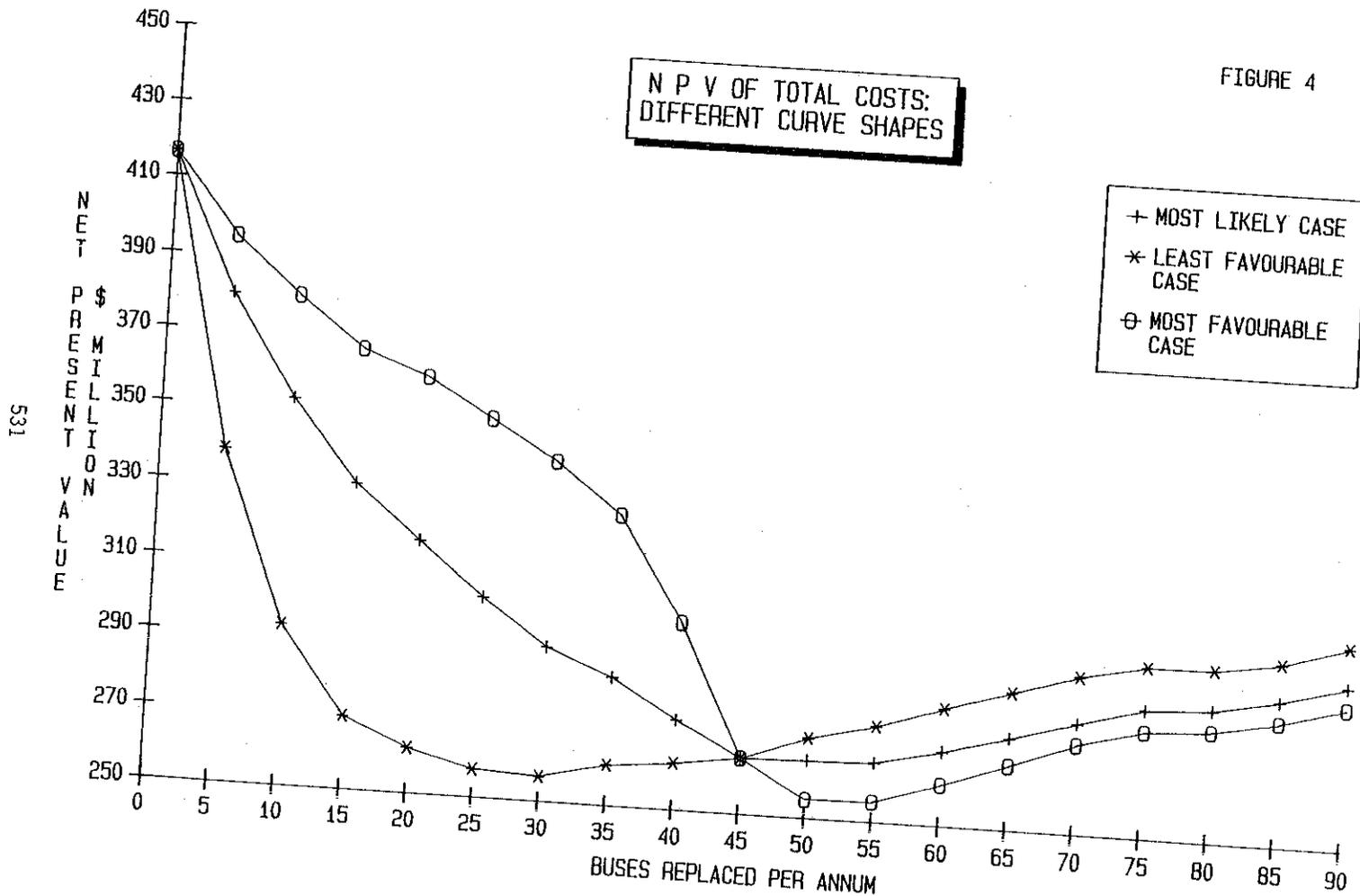
7.4 Shape of the Curve of Factors Relating to Mechanical Dock and Running Cost Changes

The relationship between the shape of the curve of factors for the "most likely", "least favourable" and "most favourable" sets of factors was indicated in Section 4.3 (Figure 1).

Results obtained by using the "least favourable" and "most favourable" sets of factors are shown in Figure 4.

It can be seen that, using the least favourable set of factors (which factors are somewhat extreme) the optimum level of replacement is still as high as 25 to





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30 buses per year. It should be noted that the NPV of the total cost associated with 30 buses p.a. is only some 3% less than that associated with 45 buses p.a.

Using the most favourable factors, the optimum level becomes 50 to 55 buses p.a. and replacement levels of between 5 and 40 become much more costly.

7.5 Interest and Inflation Rates

The most likely case was based on interest rates falling gradually to 9.0% in 1994/95 and remaining at 9.0% thereafter. Inflation rates were assumed to fall to 6% in 1989/90 and remain at that level in the remaining years. This meant that the real interest rate for the latter years was 2.8%.

For the sensitivity test, an interest rate of 14.0% and an inflation rate of 7.0% were used for all years. It is considered highly unlikely that such a high rate of real interest (6.5%) would apply for the next 20 years.

The results are presented in Figure 5. (The least favourable case is based on interest and inflation rates of 14.0% and 7.0% respectively).

It can be seen that the optimum replacement level under both the most likely case and least favourable case is broadly 45 to 55 buses p.a.

7.6 General Comments

Generally, for any given set of "likely" assumptions, the NPV of total cost associated with different levels of replacement, increases relatively sharply on either side of the minimum NPV point. In such cases sensitivity tests on any one of the variables generally tend to alter:

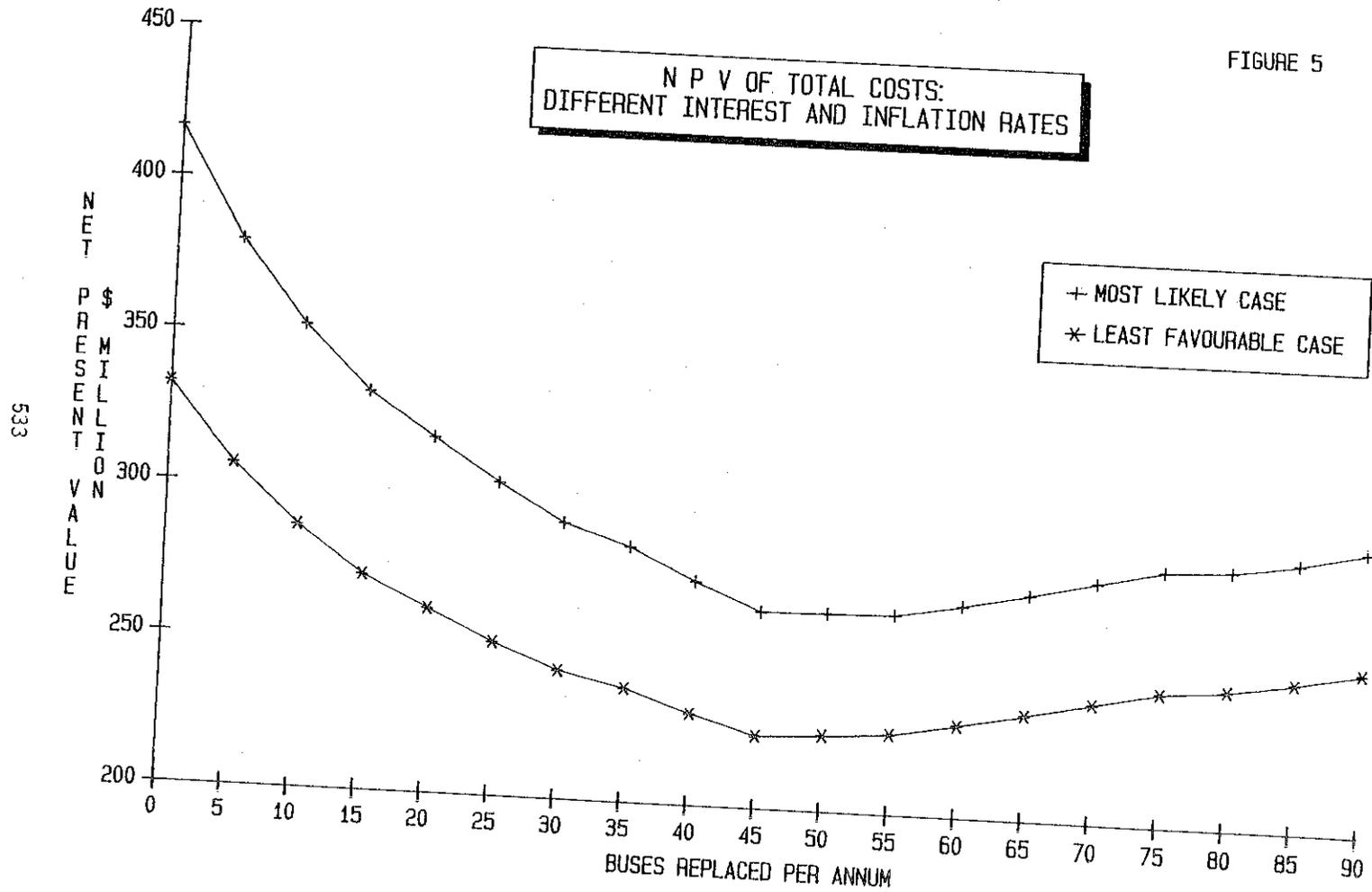
- the rate at which total NPV increases on either side of the minimum point; and/or
- the range of total NPVs

without significantly changing the number of buses required to achieve least cost.

In cases where the curve of NPV of total costs is relatively flat, sensitivity tests tend to have a greater effect on the number of buses required to achieve least cost. Such cases, especially those in which the optimum number of buses becomes significantly

N P V OF TOTAL COSTS:
DIFFERENT INTEREST AND INFLATION RATES

FIGURE 5



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less than 45 per annum, are considered to be outside of the "more likely" range of cases.

8 SUMMARY AND CONCLUSIONS

- (i) Under the present unfavourable conditions characterised by high capital costs of buses and high interest rates, the optimum replacement level is approximately 45 to 55 buses per annum. This is equivalent to 5-6% of the total fleet of some 900 buses.
- (ii) Based on conservatively estimated costs of rebuilding buses, the equivalent increases in maintenance costs at the zero bus replacement level are 340% for running costs and 170% for mechanical dock costs.
- Even if these cost increases are halved, the optimum replacement level remains at 45 to 55 buses per year.
- The optimum bus replacement level only begins to fall below 45 per annum when cost increases of 128% for running costs and 64% for mechanical dock costs (for the zero replacement level) are used.
- (iii) The bus replacement modelling process is not by any means an exact science. The model itself performs a vast number of complex calculations quickly and accurately. However, most of the input assumptions are unavoidably subjective and much of the input base data is weak.
- (iv) Transperth is taking steps to improve the accuracy of its cost data relating to bus types and plans to conduct more research into the effect on total maintenance costs of different levels of bus replacement.
- (v) Attempting to isolate the costs associated with an individual year's bus replacement level is not meaningful. A decision made for a particular year will have a minimal effect on costs in the year concerned, but will have a substantial effect on costs for many subsequent years.

- (vi) Bus purchases should not be regarded as isolated items of capital expenditure. Transperth should be regarded as being in the business, amongst other things, of buying (new) and selling (old) buses. The essential question should be: How many buses should be bought (and sold) each year to minimise the total costs of owning and operating the fleet.

Alternatively, the whole bus fleet can be regarded as a single, large item of capital equipment. Replacement buses can then be regarded as component parts for this equipment. If the 'component parts' are not replaced, more preventative maintenance and repairs would need to be carried out on the 'equipment'. The important question should then be: To what extent should the 'component parts' be replaced each year to minimise the total cost associated with the 'equipment'.

- (vii) Total costs associated with low bus replacement levels are likely to be substantially higher than for replacement of 40-60 buses per year. Replacements of 0-30 buses per year are always likely to cost considerably more than 40-60 per year; and replacements of 30-40 buses per year are unlikely under foreseeable future conditions to cost less than 40-60 per annum.
- (viii) If the real capital cost of buses were to decline, and/or other key factors change favourably, it is possible that replacements in excess of 55 per year would cost less than 45-55 per annum.
- (ix) Broadly speaking, within the range of 40-65 buses per year, the variation in NPV of total costs is small in relative terms.

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