1 INTRODUCTION

It is possible to locate the route of a road on the earth's surface with micrometric precision. The horizontal and vertical alignment of the road can be so carefully co-ordinated that it becomes a veritable aesthetic masterpiece. In addition, the road can be so skilfully blended into the topography that the landscape would obviously be the poorer without it. The road can also be a model of forgiveness for the stupidity of the average driver and never disappear under water, be the storm ever so severe. Truly, the skilled geometric designer can do many wondrous things. But what if this marvel of geometric virtuosity costs so much to construct that it cripples the nation's economy?

Clearly, the geometric designer, as the prime architect of the road, cannot afford to be blinded by his own expertise and must stand back to consider the economic consequences of converting his dreams on paper into reality.

There are three, and only three, questions that the designer must ask himself. These are

- ❑ Why build the road at all;
- ❑ Why build it now; and
- ❑ Why build it this way?

Each of these questions contains a subset of further questions. 'Why should the road be built at all' requires answers to further questions such as

- ❑ What is so wrong with the present road that it cannot be rectified by a relatively modest upgrade of the existing facility; or
- ❑ Shouldn't some other facility, such as a rail link, be provided instead?

'Why do it now' - which is the age-old scream of pain of the average politician - implies

- ❑ Do we want to provide excess capacity now to meet anticipated future demand?
- ❑ How confident are we of our estimate of future demand?
- ❑ How much does the required capital cost now and how much is it likely to cost in future?

'Why do it this way' reminds us of the fact that engineering problems are never blessed with single answers and that systems analysis demands the derivation of several candidate answers and an ultimate selection of a recommended solution.

The final question to be asked is "How is the engineer supposed to answer all these questions?" The short answer is "Patiently", but he does have to have some or other criterion according to which he can defend the basic concept of having the road at all and then go on to assure that what is constructed is convenient, safe and, possibly above all else, affordable.

The intention with this lecture is to provide the tools whereby the designer can answer at least some of the questions raised with regard to the affordability of the road. More importantly, it seeks to provide the designer with sufficient knowledge to be able to know when he is getting out of his depth and requires the services of a professional transport economist.

2 FUNDAMENTAL PHILOSOPHIES OF ENGINEERING ECONOMICS

(a) Decisions are among alternatives. A lack of alternatives represents a forced situation in which no decision is possible. It is therefore necessary that alternatives be actively sought, clearly defined and the merits of each exhaustively evaluated. Sight must not be lost of the "Do nothing" strategy which, after all, is also an alternative. This should, in fact, always be analysed as a base or datum level from which comparisons of consequences can be drawn.

(b) Decisions should be based on the expected consequences of the various alternatives, all of which will occur in the future

(c) It is essential to decide whose viewpoint should be adopted. A private company does not present any problem in this regard because good, healthy self-interest will make it abundantly clear whose viewpoint is of consequence. A Government Department or agency is more problematical because, if it is only the immediate annual budget that is being considered, a road may be provided for minimum initial outlay with a massive bill for maintenance thereafter. The Department concerned may take a longer-term view so that future maintenance costs are also taken into account. The major cost of a road is, however, to be found in the costs incurred by road users in operating on the facility provided. Should it not be the taxpayer's viewpoint that should be adopted rather than that of the Department? After all, it is the taxpayer who provides the budget in the first instance.

(d) Alternatives can only be compared if the consequences of their implementation are commensurable. That is, consequences should be expressed in numbers and the same units should apply to all the numbers. In economic decisions, only money units meet this requirement and even then, there is the caveat that money units of different times are not commensurable without calculation to some specified base year.

(e) Only the differences between alternatives are relevant in their comparison.

(f) Separable decisions should be made separately. Many engineering projects have a number of different possible levels of investment and these investments can also be made at different times as, for example in the case of stage construction of a facility. Each separable increment of expenditure should be evaluated separately to ensure that it produces results sufficiently favourable to pay its own way.

(g) It is essential to have at least one or, for preference, several, criteria for decision making.

(h) The primary criterion to be applied in a choice between alternative investments should be selected with the objective of making the best use of limited resources.

(i) Secondary criteria that reflect the lack of certainty about the future are helpful because the best of monetary estimates of consequences of a particular course of action are almost certainly wrong.

(j) There are always consequences of choice of alternatives that cannot be reduced to monetary terms, referred to therefore as irreducible data or factors.

3 EQUIVALENCE

Problems of economy invariably involve determining what represents the minimum outlay over an extended period of time. It is thus necessary to recognise the time value of money. Because of the existence of interest, a rand now is worth more than the prospect of a rand at some future time. In short, a bird in the hand really is worth more than two in the bush. Interest may be thought of as money paid for the use of borrowed money. This is the viewpoint of the borrower whereas the viewpoint of the lender is that interest is the return obtainable from the productive investment of capital. This rather broader view is the one typically applied in economic studies.

Equivalence can however be more easily grasped in terms of the concept of interest paid on money borrowed. A loan can be repaid in numerous different ways. Four options are listed as:

- Scheme I. A single lump sum payment at the end of the loan period, with the lump sum including both capital and interest.
- Scheme II. Payment of interest only during the currency of the loan, with a single payment of the capital at the end of the loan period
- Systematic reduction of the principal of the loan, with this method subdividing into
- Scheme III. Uniform repayment of the principal, with diminishing interest
- Scheme IV. Uniform payments where the sum of interest charged plus principal redeemed remains constant.

A simple comparison of the total payments made in respect of each repayment scheme,

assuming a loan of R 10 000 at 9 % over 10 years would show that these are

Scheme I. R 23 670

Scheme II. R 19 000

Scheme III. R 14 950

Scheme IV. R 15 580

suggesting that Scheme I is the best if the viewpoint of the lender is adopted and Scheme III the best in the view of the borrower. In fact, neither conclusion is correct because the time value of money is ignored, and an attempt is being made to compare apples and pears. Regardless of the particular series of repayments that is adopted, the fact of the matter is that they have one thing in common and that is that they all serve to secure a loan (the principal) of the same value. In short, their *Present Worth* is identical.

Stated more broadly, if a service is to be provided and various repayment schemes are on offer, these should not affect any analysis of the economics of providing the service. An intelligent decision can only be made if all schemes are converted to some common platform, which may be an equivalent present-day single payment (Present Worth) or an equivalent uniform series of payments (Scheme III above). Engineers tend to favour Present Worth because of its convenience whereas economists tend to favour the equivalent uniform series on the grounds that Present Worth ignores the costs associated with the need to borrow the money in the first instance. In essence, interest paid, particularly if the period of repayment is long and the rate of interest high, has a present worth of its own. As any homeowner who is paying off a bond can testify, this amount is substantial whereas an engineering analysis would suggest that it is, in fact, zero.

The argument of the engineers is that they are solely concerned with the relative merits of two competing schemes. *And these compete in the sense that they represent alternative ways of providing the same service*, e.g. a transportation link between two nodes. If the competition is between different services, e.g. a transportation link as opposed to a water purification scheme, a time series may be more appropriate because the basis of competition is the funding source rather than the service to be provided. A share of a finite and restricted source of funding rather than the relative merits of the competing schemes is being sought. The irreducible factors play an important role. An example is that one of the schemes may serve to directly generate future income, making future repayments easier to meet. If this future income is predictable, it could however be accommodated in a Present Worth based calculation, although the time series would probably be a more convenient method of offering comparisons. Further discussion of economic analysis will however not be covered under this course, suffice it to say that the most common approach used is that based on Present Worth.