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DEPARTMENT OF TRANSPORT

Incorporating risk in the economic evaluation of road infrastructure projects

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TITEL/TITLE INCORPORATING RISK IN THE ECONOMIC EVALUATION OF ROAD INFRASTRUCTURE PROJECTS			
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SINOPSIS:

Besluite rakende investering in padinfrastruktuur is noodwendig op verskeie aannames gebaseer. Dit beteken dat risiko inherent aan hierdie besluite is. Dit is belangrik om risiko in die evalueringsproses in ag te neem. Dit sal die proses meer geloofwaardig maak en verseker dat strategiese besluite meer verantwoordbaar is.

In hierdie studie word 'n prosedure voorgestel om risiko in ag te neem. Dit behels die identifisering van insette krities vir die ekonomiese sukses van die projek, die kwantifisering van projekrisiko en die gebruik van 'n risiko-aangepaste verdiskonteringskoers.

Sagteware wat vir hierdie doel ontwikkel is word op 'n hipotetiese stel projekte toegepas om aan te dui hoe risiko die keuse en rangskikking van potensiële projekte be-invloed.

SYNOPSIS:

Decisions involving road infrastructure investment inevitably are based on various assumptions. This means that risk is inherent in these decisions. It is essential that this risk should be incorporated in the evaluation process. This will add credibility to the process and ensure strategic decisions that are more defendable.

In this study, a procedure for incorporating risk is suggested. It involves the identification of inputs critical to the economic success of the project, the quantification of project risk and the use of a risk-adjusted discount rate.

Software developed for this purpose is applied to a hypothetical set of projects to indicate how risk affects the selection and ranking of candidate projects.

TREFWOORDE:
KEYWORDS: economic risk, sensitivity analysis, critical parameters, probability, project risk distribution, economic evaluation

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1 INTRODUCTION

1.1 BACKGROUND

The economic evaluation of road infrastructure projects is, in theory, a relatively mechanical exercise. It simply involves estimating the cost of a project and its future benefits, finding the present value of benefits, and, should the present value of the benefits exceed the present value of the costs, the project is regarded as economically viable. This is fine if we know the project's costs and future benefits with relative certainty. However, if our estimates are wrong, what initially looked like a good project can turn out to be a disaster.

Considering the magnitude of cost involved in providing and maintaining road infrastructure and the long economic lives of these assets, it is essential to ensure that investment decisions are correct. These decisions are however inevitably based on a number of assumptions regarding the project. This means that risk is inherent in the project. For the economic analysis of the project to be complete, it is essential that the risk inherent in the project should be considered in its evaluation. Project risk should be quantified and critical parameters identified. Further studies as to the validity of assumptions can then be limited to parameters identified as critical. The results thus obtained should then be used to supplement other information on the economic worth of the project. In this way it will be ensured that reliable management information is provided to the decision-maker.

At present, risk analysis as suggested in this report does not form part of program CB-Roads. In this sense, risk analysis is not applied formally to the economic evaluation of road projects in South Africa. This means that an important parameter in project selection and prioritisation is not available. In many cases, only the most likely value for each of the different parameters (variables) is used to determine project worth. "Sensitivity analysis", where performed, is normally done in isolation and does not form part of an integrated procedure for risk analysis. The absence of such an integrated procedure could lead to analysts focusing attention to less critical variables at the expense of more critical ones. Also, project risk is not formally quantified. Even where this is done "informally", the results obtained are not used in a structured manner in project selection and prioritisation.

1.2 SCOPE OF PROJECT

The economic feasibility of a project constitutes only one of several aspects to be investigated in project evaluation. Project evaluation could also involve the following types of evaluation:

- the technical evaluation, in order to determine if the project is technically feasible
- the institutional evaluation, which involves the managerial, organisational and staffing implications of alternatives
- the financial evaluation, the nature of which would depend on whether revenue-earning or non-revenue-earning projects are involved
- the social evaluation, which concerns aspects such as the income distribution effects of projects, improved health conditions, and the humanitarian effects of a compulsory population resettlement.

In this study, risk is addressed in the context of economic evaluation only. The risk of technical failure, for example, falls outside the scope of this project. So does the risk of financial failure. Only the risk of economic failure is addressed, that is the risk that the project may turn out not to be economically justified.

Further, economic risk is addressed in the context of road infrastructure only. This particularly applies to the software that was developed and which is applied in Section 6. Although the principles are widely applicable, adjustments to the software would be required in order to apply it to other types of transport projects, such as public transport projects.

1.3 STUDY OBJECTIVES

The study objectives are as follows:

- to consider techniques for risk analysis available in the government and corporate environments and to select one or more most suited for use in the context of the economic evaluation of road infrastructure projects
- to operationalise and apply this technique to a hypothetical set of projects
- to identify variables critical to the outcome of the analysis, to quantify project-specific risk and to examine how the incorporation of risk affects the justification and ranking of projects in this set of hypothetical projects
- to investigate the potential of the suggested procedure for formal application and to identify areas for further research.

It is important to note that the identification of inputs critical to the economic success of the project by means of sensitivity analyses is but one, albeit important, step in an integrated approach to the incorporation of risk in project selection and ranking. Other steps are also required to make the process complete; for this reason, sensitivity analysis in this report is discussed from the perspective of an integrated approach to project evaluation under conditions of risk and uncertainty.

1.4 STRUCTURE OF REPORT

Following this introductory section, the nature of risk and uncertainty and the measurement of risk are discussed in Section 2. The concept "risk management" is also explained. Section 3 gives an overview of rules for decision-making under conditions of risk and uncertainty, and describes techniques for dealing with risk in project selection. In Section 4 the nature of decision-making in the context of road infrastructure projects is explained, as this has a direct bearing on the procedure suggested. This is followed by a review of the suitability of the techniques explained in Section 3 for application to road infrastructure projects, and an explanation of the procedure suggested for introducing risk to their economic evaluation. In Section 5 the software developed to apply the suggested procedure is explained. In Section 6 the hypothetical set of projects is explained and the results of the application of the software to these projects are given. Section 7 contains conclusions and a discussion of problem areas emanating from the application of this procedure that warrants further research. References are listed in Section 8.

2 RISK AND UNCERTAINTY

2.1 INTRODUCTION

In this section the nature of risk and uncertainty is firstly explained. Thereafter the quantification of risk and the calculation of indices that express the degree of risk inherent in a project are discussed. Finally, a proposed structure for risk management is given. This section therefore sets the scene for the discussion of decision-making rules and techniques under conditions of risk and uncertainty in Section 3.

Risk and uncertainty are discussed from the perspective of project selection in the corporate environment, as most of the concepts originated in that enviromnent. This means that the focus will be on aspects such cost of capital, after-tax cash flows and profit. The underlying concepts nevertheless are also applicable to economic risk inherent in road infrastructure projects.

2.2 THE NATURE OF RISK AND UNCERTAINTY

Regarding the outcome of an action taken to obtain a desired result, two states of expectation can be distinguished: certainty and uncertainty (risk). Certainty refers to situations in which expectations are single-valued; that is, the firm views prospective profits in terms of a particular outcome, and not in terms of a range of alternative possible returns (Levy & Sarnat, 1982:197). Ignoring inflation and currency risk, investments with single-valued expectations would include Treasury Bills and prime commercial paper. These are usually referred to as riskless investments and payments received from these can be accurately predicted: neither their amounts nor their timing is uncertain. But in most real world situations, many investments do not meet such high standards, as they are made under conditions of risk and uncertainty. Under these conditions, the outcome will not be single-valued, but can be described in terms of an array of outcomes for which the probability of each is known/estimated; that is, in terms of a probability distribution of possible outcomes.

The following quotation from Levy & Sarnat (Levy & Sarnat, 1982:198) adds some valuable insight into the terms "risk" and "uncertainty": *"Frank Knight distinguished between "risk" .... and "uncertainty" which he defined as an option for which only the array of possible outcomes, but not their probabilities, is known. See his Risk, Uncertainty and Profit, Boston and New York: Houghton Mifflin Company, 1921, Chapter 7. The reader should note that the introduction of subjective probability has greatly diminished the significance of the distinction between risk and uncertainty. By assigning subjective probabilities to decision problems, an inherently uncertain situation can be transformed into a risky choice."* Given this view, the following formulation/condition will be accepted for the purpose of this study: firstly, that a project is *risky* if its outcome is not single-valued, but secondly: that the probability distribution of the outcome (or the probability distribution of the variables affecting outcome) can be determined (objectively or subjectively) with reasonable accuracy.

Project risk may be defined as the chance of certain occurrences adversely affecting project objectives. It is the degree of exposure to negative events and their possible consequences. As described by Franke (1986:6) and Hertz & Thomas (1984:11), project risk is characterized by the following factors:

- Initiating and subsequent events: This is what might happen and a chain of consequences
- Risk probability: How likely the initiating event will occur and the likelihood of subsequent events
- The consequence of the chain of events, normally expressed as the economic or financial loss which could result.

Risk therefore concerns both uncertainty and the result of uncertainty (Hertz & Thomas, 1984:16). The uncertainty surrounding the risk factors of a project are characterized by two main elements; the **probability** of the events taking place and the **impact** that such a contingency might have on the project.

Probability

Probability refers to the chance that some factor might take place or happen. The probability of an event (or any value of a variable) can assume any value between 0 and 1. A probability with a value of zero would suggest impossibility of occurrence whereas a probability of 1 would assume that the event will occur every time. Therefore a probability of one corresponds to certainty and any value less than 1 shows some uncertainty in the occurrence of the particular event.

Impact

The impact of an event refers to the effect the contingency of a risk factor may have, if it is to take place. Exact impact could be difficult to quantify but if categories like high, medium and low impacts are used, the decision-making process could be facilitated. The impact of an event is related to two factors namely, sensitivity and forecasting uncertainty of future values.

Rappaport (1967:441) defines sensitivity as the responsiveness of the conclusions (output) of an analysis to changes or errors in the parameter values (inputs) used in the analysis. When analysing an industry or business, much attention is paid to what are generally known as critical success factors for the specific industry or business (Jenster, 1987:102 ; Murphy, 1989:103). These factors require special attention because normally these factors carry more risk and are detrimental to the success of the business. This means that they are critical to the success of the project.

When analyzing the possible outcomes and the risk for a project in planning, certain future values need to be assumed or forecasted. By assuming and forecasting one introduces a degree of uncertainty as no one can predict the future occurrences of events with absolute certainty. Furthermore, as the term of prediction increases, so too does the uncertainty.

2.3 MEASURING RISK IN INVESTMENTS

Contemporary investment analyses identify risk with a distribution of actual returns around the mean (expected) value. Therefore, the wider the spread of alternative outcomes, the more risky the project will be. Figure 2.1 (adapted from Van Horne, 1977:347) illustrates cases where project risk ranges from "perfect certainty" to (very) risky.

The variance and standard deviation provide information on the extent of the deviation of actual returns from the expected return, and therefore they serve as measures of project risk. In this section, these concepts as well as the concepts covariance and correlation coefficient are discussed.

2.3.1 Variance and standard deviation

The variance and standard deviation measure the dispersion of profits around the mean (expected) value. It therefore provides information on the extent of the possible deviations of the actual return from the expected return (Levy & Sarnat, 1982:215).

The expected value of a project's profitability is calculated in the following manner:

$$Ex = \sum_{i=1}^{n} (P_i x_i)$$

where: Ex = expected value

x_i = i th possible outcome

P_i = probability of obtaining the i th outcome x_i

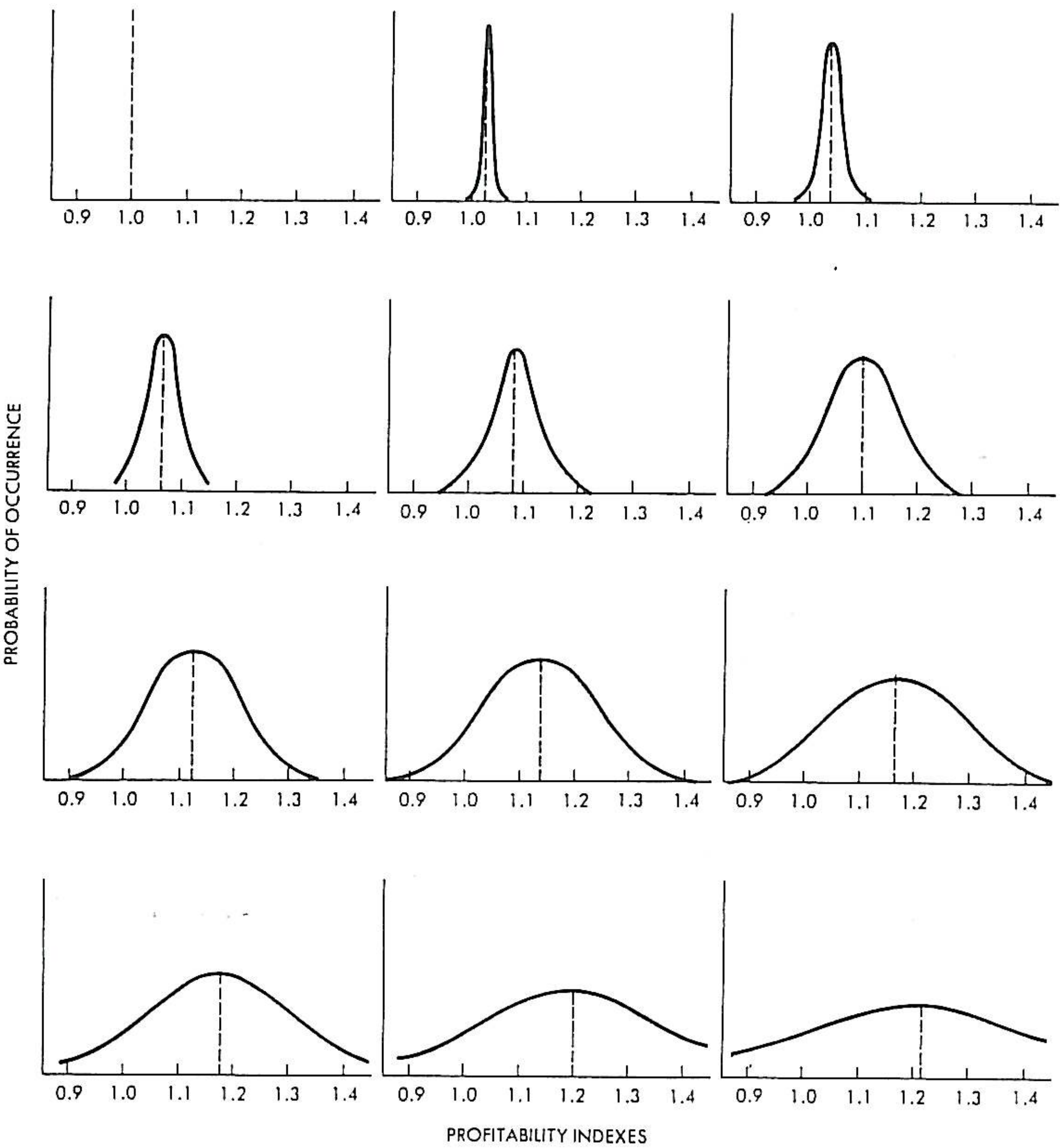
n = number of possible outcomes.

The variance of the distribution (σ^2) is given by the formula:

$$\sigma^2(x) = \sum_{i=1}^{n} P_i(x_i - Ex)^2 = E(x-Ex)^2$$

The determination of the variance involves the calculation of the deviation of each possible outcome from the expected value, in other words $(x_i - Ex)$, then raising it to the second power and multiplying this term by the probability of getting x_i, that is by P_i. The summation of all of these products serves as a measure of the distribution's variability and is called variance. The standard deviation, in its turn, is the square root of the variance.

FIGURE 2.1: PROJECTS WITH DIFFERENT RISK PROFILES



2.3.2 Covariance and correlation coefficient

For purposes of diversification one may wish to see how one investment correlates, either positively or negatively, with the returns of another investment. The two concepts which serve as quantitative measures of the relationship between the fluctuations of two random variables are covariance and the correlation coefficient (Koutsoyiannis, 1977:36 ; Levy & Sarnat, 1982:217 ; Ross & Westerfield, 1988:132). The covariance is an indicator of the direction of the dependance between two variables. This indicator, however, has the defect of being influenced by the units of measurement of the random variables (Koutsoyiannis, 1977:36). To correct this defect one can divide the covariance by the standard deviation of the variables so that the ratio is independent of the units used in measuring the outcomes. This is called the correlation coefficient which also provides information concerning both the direction and the power of the relationship between the variables.

3 OVERVIEW OF SELECTED APPROACHES TO ADDRESSING RISK IN PROJECT SELECTION

3.1 INTRODUCTION

As in the previous section and for the reasons given there, the concepts in this section are explained from the point of view of project selection and capital budgeting in the corporate environment.

For the purpose of this discussion, it is necessary to consider the goal of the firm. The primary goal of financial management is to maximise shareholder wealth (Weston and Brigham, 1981:3). In terms of the Net Present Value (NPV) technique, this means that the project with the highest NPV would be preferred. However, risk and return in most cases are inseparately linked. Consequently, both these dimensions have to be considered in decision-making. Consequently, it is necessary to consider different attitudes towards risk. Three classes of investors can be distinguished:

- the risk averter dislikes risk. His utility function, relating utility to income, will be concave
- the risk-neutral individual is indifferent towards risk
- the risk lover prefers risky projects: in his case the utility function will be convex.

The typical investor is risk averse. Accordingly, the discussion in this section will be from the premise of risk aversion.

It is further necessary to distinguish between rules for decision-making under conditions of risk and uncertainty, and techniques for handling risk. These rules will follow from the goal of the firm and its attitude towards risk. Techniques are procedures to facilitate decision-making, given these rules.

In the discussion that follows, a distinction is made between single-period and multi-period investments. With the first, the investment period is relatively short and the project outcome is known within a relatively short space of time. With the latter, the time value of money becomes important. The implications of this for approaches to addressing risk in project selection will be indicated.

3.2 APPROACHES TO ADDRESSING RISK

3.2.1 The maximum expected NPV criterion

Assume that a firm is confronted by the five alternatives given in Table 3.1. Alternative A and B represent perfectly certain investments, while alternatives C, D, E entail varying degrees of risk.

TABLE 3.1: PROJECTS WITH VARYING DEGREES OF RISK

PROJECT	NPV	PROBABILITY	EXPECTED NPV
A	8	1	8
B	10	1	10
C	-8 16 24	0,25 0,5 0,25	12
D	-4 8 12	0,25 0,5 0,25	6
E	-20 0 50	0,1 0,6 0,3	13

Source: Levy & Sarnat, 1982:200.

One may assume that the firm, or investor, should choose the alternative that yields the highest NPV. In the case of safe investments, the choice is easy: alternative B yields a higher NPV than A, and therefore would be accepted. However firms do not exclusively confine themselves to safe proposals but rather select the best of all alternatives available. However, since there is no *a priori* reason to select any one of the three possible outcomes of C, D, E, the maximum NPV criterion is rendered inoperable. Once risk is introduced, finding a suitable investment criterion is unavoidable and the maximum NPV criterion, which is appropriate in a world of perfect certainty, is of little use.

Since the maximum NPV criterion cannot cope with the entire distribution of returns one could assume that the maximum expected NPV can then be considered. From Table 3.1 it is apparent that E has the maximum expected NPV, under conditions of uncertainty, and can be adopted. Although the maximum expected NPV criterion can be applied, this is not to say that it should be applied. In many cases this criterion is inappropriate since it does not take risk explicitly into account.

Table 3.2 below shows that, although alternatives A and B yield the same expected NPV, the outcome of A is substantially less certain than that of B. The fact that their expected profits are identical illustrates the contention that the expected NPV does not take risk into account, and consequently this criterion does not provide an appropriate decision criterion when uncertainty exists. While the calculation of the expected NPV can serve as a measure of profitability, it cannot constitute a measure of risk.

TABLE 3.2: EXAMPLE OF MAXIMUM EXPECTED NPV CRITERION

	A	B
PV in recession (probability 0,2)	100	1 100
PV in boom (probability 0,8)	2 000	1 750
Expected PV	1 620	1 620
Less Initial Outlay	-1 000	-1 000
Expected NPV	620	620

Source: Levy & Sarnat, 1982:202.

3.2.2 The mean-variance rule

The "mean-variance" or "expected return-variance" rule (E-V rule) was developed by Markovitz for evaluating investments on the basis of their expected return and variance (Levy & Sarnat, 1982:215).

In terms of the E-V rule Project A will be preferred to project B if one of the following two combinations holds:

(i) The expected return of A exceeds (or is equal to) the expected return of B and the variance of A is less than the variance of B:

$$E(A) \geq E(B)\ ;\ \sigma^2 A < \sigma^2 B$$

or

(ii) The expected return of A exceeds that of B and the variance of A is less than (or equal to) that of B:

$$E(A) > E(B)\ ;\ \sigma^2 A \leq \sigma^2 B$$

Clearly, the expected return is taken as an indicator of a project's profitability and the variance serves as the index of its risk.

Consider the example in Table 3.3 below.

TABLE 3.3: E-V RULE EXAMPLE

	A		B	
	PROFIT	PROBABILITY	PROFIT	PROBABILITY
	1 000	0,5	0	0,5
	3 000	0,5	4 000	0,5
Expected profit	2 000		2 000	
Standard deviation	1 000		2 000	

Source: Levy & Sarnat, 1982:215.

Both A and B have the same expected profit. The variance of A is 1 000 000 and B is 4 000 000. In terms of the E-V rule, project A will be chosen because it has the lower risk.

It is interesting to note that the mean-variance rule forms the basis of Modern Portfolio Theory (MPT), of which models such as the Market Model, Capital Asset Pricing Model (CAPM), Arbitrage Pricing Model (APM) and Option Pricing Model (OPM) are subsets.

3.2.3 Coefficient of variation

Sometimes using the variance or standard deviation as an indicator of risk can be misleading. Obviously, the greater the variance of earnings, the greater the chance that the actual return will deviate significantly from the average or expected return. In some cases the expected profit of the proposal being considered may be so large that the proposal should be considered relatively safe even if it has a large variance.

Consider the example in Table 3.4.

TABLE 3.4: COEFFICIENT OF VARIATION EXAMPLE

	EXPECTED PROFIT	STANDARD DEVIATION	COEFFICIENT OF VARIATION
A	100	10	0,10
B	500	25	0,05

Source: Levy & Sarnat, 1982:229.

From Table 3.4 it is apparent that the expected profit of B at R500 is significantly larger than that of A at R100. B is also more risky than A, thus, the E-V rule cannot discriminate between the two proposals. One could argue that B's profitability is so high that it more than compensates for its greater risk (variability).

This unsatisfactory situation can be improved by utilizing the coefficient of variation as a means of an investment's risk.

$$\textit{Coefficient of variation} = C = \frac{\sigma}{E}$$

In Table 3.4, B has both a higher expected profit and a lower coefficient of variation and in terms of this decision rule would be selected.

Although the coefficient of variation can serve as a better measure of risk in some cases, certain other difficulties concerning risk still remain. Consider Table 3.5.

TABLE 3.5: PROBLEM ASSOCIATED WITH THE COEFFICIENT OF VARIATION

	A		B	
	PROFIT	PROBABILITY	PROFIT	PROBABILITY
	2	1	5 15	0,5 0,5
Expected profit	2		10	
Variance	0		25	
Standard deviation	0		5	
Coefficient of variation	0		0,5	

Source: Levy & Sarnat, 1982:230.

The E-V rule cannot distinguish between the two proposals: B is more profitable and more risky. However, neither can the coefficient of variation rule assist in the selection process, even though common sense indicates that B is preferable to A since even the worst outcome of B (R5) is higher than the profit offered by proposal A (R2).

3.2.4 The risk-adjusted discount rate

The rationale underlying the use of the risk-adjusted discount rate (RADR) technique is that projects which have greater variability in the probability distributions of their returns should have these returns discounted at a higher rate than projects having less variability risk. A project that has no risk associated with it would be discounted at the risk-free rate, since this is the appropriate rate just to account for the time value of money. Any project that has risk associated with it has to be discounted at a rate in excess of the risk-free rate in order to discount both for futurity (the time value of money) and for the risk associated with the project (a risk premium).

Projects that have average riskiness vis-a-vis the firm's normal operations should be discounted at the firm's cost of capital, since this figure reflects the normal risk faced by the firm. Those projects having greater than normal risk should be discounted at a rate in excess of the cost of capital; conversely, projects that exhibit less risk than that associated with a firm's normal operations should be discounted at a rate between the risk-free rate and the cost of capital. The risk-adjusted rate is found by:

$$r' = i + u + a$$

where:

r' = risk-adjusted discount rate

i = risk-free rate

u = adjustment for the firm's normal risk

a = adjustment for above (or below) the firm's normal risk

The sum of i and u is the firm's cost of capital, since that discount rate is appropriate for projects having average, or "normal" risk. The term for the abnormal risk adjustment could either be positive or negative, based on whether the project has more or less risk associated with it than the average project for the firm in question.

The risk-adjusted NPV is calculated in the following manner:

$$RAR = \sum_{t=0}^{n} \frac{R_t}{(1 + r')^t}$$

where:

RAR = risk-adjusted NPV

R_t = expected value of the distribution of cash flows in year t

r' = risk-adjusted discount rate based on the perceived riskiness of the project under consideration

n = number of years in the project's life.

In theory, the amount of risk adjustment is based on management's utility preference for risk aversion, so that this adjustment reflects management's perception of the risk associated with the project per se, its risk-return preferences, the firm's wealth position, and the impact of the project on the firm's other goals.

3.2.5 The decision tree technique

Decision trees are techniques that have been recommended to handle complex, sequential decisions over time (Brigham, 1985:380). A decision tree may be defined as a formal representation of available decision alternatives at various points through time which are followed by chance events that may occur with some probability. A ranking of the available decision alternatives is usually achieved by finding the expected returns of the alternatives, which require multiplying the returns earned by each alternative for various chance events by the probability that the event will occur and summing over all possible events.

For example, assume a firm is considering three alternative single-period investments A, B and C, whose returns are dependent upon the state of the economy in the coming period. The state of the economy is known only by a probability distribution:

STATE OF THE ECONOMY	PROBABILITY
Fair	0,25
Good	0,40
Very good	0,30
Super	0,05
	1,00

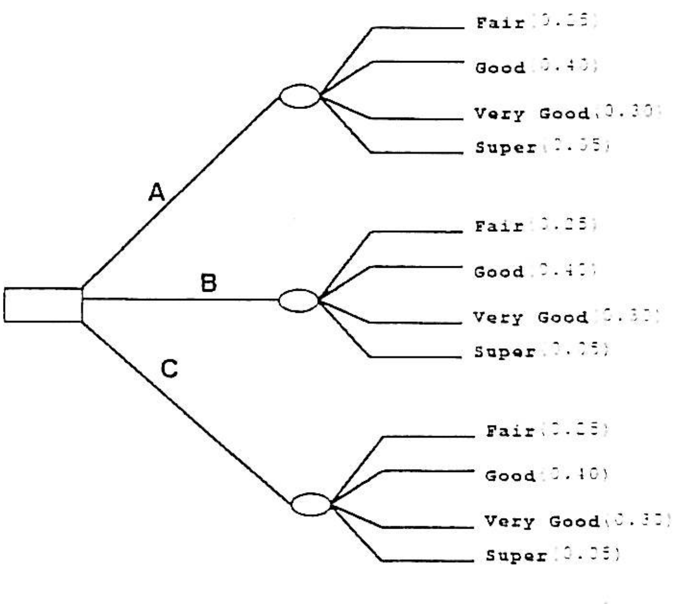
The returns for each alternative under each possible state of economy are as follows:

	STATE OF THE ECONOMY			
ALTERNATIVE	FAIR	GOOD	VERY GOOD	SUPER
A	R10	R40	R70	R90
B	-20	50	100	140
C	-75	60	120	200

The decision tree for this problem is shown in Figure 3.1.

FIGURE 3.1: DECISION TREE EXAMPLE

Decision Alternatives



Return Earned	Weighted Return
R10	R2.50
40	16.00
70	21.00
90	4.50
	$E(R_a)$ = R44.00
-R20	-R5.00
50	20.00
100	30.00
140	7.00
	$E(R_b)$ = R52.00
-R75	-R18.00
60	24.00
120	36.00
200	10.00
	$E(R_c)$ = R51.25

Notice that the somewhat standard convention of using a square node to represent decision alternatives and round nodes to show chance events has been followed. On the far right side of the tree, the returns for each state of the economy have been weighted by the probability that the state will occur. The sum of these values for all possible states of the economy is the expected return associated with each of the three decision alternatives. Thus, once the decision tree has been folded "folded back", the selection of the alternative that maximizes expected return is immediate.

DECISION ALTERNATIVE	EXPECTED RETURN
A	R44,00
B	R52,00
C	R51,25

Alternative B maximizes the expected return, alternative C is a close second, and alternative A is a rather distant third.

The decision tree analysis illustrated in the above example is an initial step in the evaluation of investments in that it assumes that the firm seeks to maximize its expected NPV. Levy & Sarnat (1982:263) point out that conceptually, risk can be incorporated into the analysis simply by assigning a utility to each monetary outcome and then choosing that branch which maximizes the expected utility. While doing this is theoretically plausible it is not practical. As an alternatively, Levy & Sarnat (1982:263) point out that the firm can examine the risk-return profile of each possible course of action in order to eliminate some branches on the basis of their expected profit and risk. By doing this the firm can then "fold back" the decision tree to find the best sequence of decisions, taking both risk and expected NPV into account.

4 SUGGESTED PROCEDURE

4.1 INTRODUCTION

In this section, attention is firstly focused on the nature of road infrastructure projects and decision-making in the public sector vis-a-vis the nature of wealth-maximising projects and decision-making in the private sector. This will enable the selection of the most appropriate techniques available in the corporate environment for application to road infrastructure projects. Having selected these techniques, the procedure suggested for applying them to road infrastructure projects will be explained.

4.2 ROAD INFRASTRUCTURE PROJECTS IN THE PUBLIC SECTOR VIS-A-VIS WEALTH-MAXIMISING PROJECTS IN THE PRIVATE SECTOR

4.2.1 Project purpose

The objectives and criteria used in project selection depend on project purpose. Given the goal of the firm, "project objective" in the private sector would be to maximise shareholder wealth by maximising the present value of after-tax net cash flows. With the road authority the project objective would be to provide and maintain identified road infrastructure needs in a cost-effective manner. With the private sector the objective therefore is to maximise profit; with the public sector it is to minimise total transport cost, which consists of the cost of providing and maintaining infrastructure, as well as road user cost. Project objectives will, without doubt, have implications for the investment criterion preferred: the private sector would typically favour the net present value (NPV) criterion. Given the objective of cost-efficiency regarding the provision and maintenance of road infrastructure, it follows that decision criteria focusing on cost (as opposed to profit), such as the present worth of cost (PWC) would have more appeal with road authorities. In Section 4.4 this criterion is therefore suggested for project selection when mutually exclusive alternatives are compared. However, as this criterion cannot accommodate differences in project scale when independent projects are compared, the benefit-cost (B/C) ratio technique is suggested for ranking independent projects.

4.2.2 Frequency of need for decision-making

In the private sector, the need for project selection may arise frequently or only on occasion. With road infrastructure projects, there would be a constant need for project selection and ranking. Decisions would have to be taken on an ongoing basis as part of the process of managing a capital asset (the national road network). Decisions would involve both the selection of the best alternative from a set of mutually exclusive alternatives, or the ranking of independent projects. Mutually exclusive alternatives are described as alternative methods of accomplishing the same objective. By definition, it follows that, if one alternative from a given set of mutually exclusive alternatives is selected, the others would not be required. Independent projects are aimed at satisfying independent needs. In this sense they can be termed complementary. From a given set of independent projects, more than one can be selected; it would even be possible to select all if all are justified.

4.2.3 Attitude towards risk and exposure to risk techniques

It is maintained that the private sector is extremely risk-conscious and tries to avoid risk. Nevertheless, sophisticated techniques for considering risk are not applied on a day-to-day basis. With the road authorities, on the other hand, risk consciousness is for all practical reasons non-existent. Risk is seldom considered in decision-making. It therefore follows that road authority officials, although they may have been exposed to risk techniques, do not apply these techniques on a day-to-day basis in decision-making.

4.2.4 Single- and multi-period investments and potential for project abandonment

In the private sector investment decisions involve both single-period and multi-period investments. Where possible, projects that prove to be the result of unwise investment decisions would be abandoned. With road authorities, investment decisions have long-term implications as it involve road infrastructure with long economic lives. Projects constitute multi-period investments, and the scope for project abandonment is limited, even where a project proved to be the result of unwise decision-making.

4.2.5 Responsibility for decision-making

In a given firm, decision-making in the private sector can be described as centralised. Investment decisions will typically be taken by management. Decision-making involving the country's road network can be described as decentralised, in the sense that various road authorities are responsible for providing and maintaining this network. There is often fierce competition between public sector authorities for available funds. This often occurs to the detriment of other main players. This could lead to a tendency to avoid the consideration of risk in project selection, as this may jeopardise the chances of getting potential projects approved.

4.2.6 Conditions giving rise to the need for decision-making

In the private sector, any prospect with a profit-making potential will necessitate decision-making. In the case of road authorities, the conditions giving rise to the need for decision-making can be described as follows: various situations where the provision of identified road needs are sub-optimal may be identified. For each such situation, various options for rectifying identified inefficiencies may be considered. From these options (ie mutually exclusive alternatives), the best one (ie the one minimising total transport cost) must be selected. In their turn, these best solutions for each sub-optimal situation become independent projects that must be ranked in terms of their economic attractiveness in order to facilitate decision-making. In the public sector, the focus therefore is on efficiency. In the case of inefficiency or sub-optimality, each unit of additional infrastructure-related expenditure (ie marginal improvements to road infrastructure) will effect a more-than-proportional reduction in use-related cost, and total transport cost will be reduced. Marginal increases in road-related expenditure will continue this process until the optimum point is reached. At this point, total transport cost is minimised. After this optimum point, each unit of additional infrastructure-related expenditure will result in a less-than-proportional reduction in use-related cost and total transport cost will increase. The objective of economic evaluation is to identify this optimum point.

4.3 PROCEDURE SUGGESTED

The procedure suggested involves the use of the following techniques:

- sensitivity analysis to rank key inputs in terms of their criticality
- simulation analysis to determine the combined effect of individual probability distributions (for each key input) on project outcome
- the risk-adjusted discount rate technique, given a project's risk profile and the risk-return relationship.

These techniques are integrated in the procedure suggested for project selection and ranking. This procedure involves three steps, as outlined below.

Determine project-specific risk-adjusted discount rate (RADR)

Identify the best alternative in each set of mutually exclusive alternatives, using the PWC criterion and project-specific RADR

Rank best alternatives (independent projects) in terms of B/C ratio relative to the corresponding null alternative in each set, using project-specific RADR for determining B/C ratio

In its turn, the procedure for determining project-specific RADR involves the following three steps:

Perform sensitivity analysis in order to rank key inputs in terms of their criticality
Determine project risk profile by performing a simulation analysis
Given project risk index and risk-return relationship, determine project-specific RADR

The procedure suggested assumes that risk will be project-specific and not alternative-specific, that is that the same risk-adjusted discount rate would apply to the alternatives in a given set of mutually exclusive alternatives. This assumption seems reasonable, as it would be reasonable to expect that the probability distribution for a given key input would be identical for all alternatives.

5 DESCRIPTION OF SOFTWARE

5.1 INTRODUCTION

In this section, the software that was developed to apply the procedure outlined in Section 4 is explained. Firstly, the effective program structure is outlined. Secondly, data requirements and the different input screens are discussed. Thirdly, the cost relationships and unit prices used in the program are discussed. Finally, program output is explained.

5.2 PROGRAM STRUCTURE

A PC program, called RISKAN, operating in the Quattro Pro for Windows environment, was developed to illustrate the application of the suggested procedure. Program RISKAN is a simplified version of program CB-Roads, but with additional features to accommodate the requirements of risk analysis. It allows the comparison of up to four alternatives (ie three alternatives plus the null alternative) in each set of mutually exclusive alternatives. The effective program structure is given in Figure 5.1.

5.3 DATA REQUIREMENTS, THE IDENTIFICATION OF KEY INPUTS AND INPUT SCREENS

5.3.1 Data requirements and input of project- and alternative-specific data

The data items typically required for the economic evaluation of road infrastructure projects are the following:

- general data, that is data pertaining to all projects, such as the discount rate, unit prices and relationships for vehicle operating cost
- situation-specific data, which consist of:
  - project-specific data, that is data relevant to a particular project, such as number of mutually exclusive projects, analysis period, ADT, traffic growth rate, vehicle occupancy rate and vehicle classification
  - alternative-specific data, that is data relevant to a specific alternative only, such as construction cost, route length, road type and terrain type.

In terms of the software, general data are system-supplied, whereas project-specific and alternative-specific data are user-supplied, as indicated in Figure 5.2.

FIGURE 5.1: PROGRAM STRUCTURE

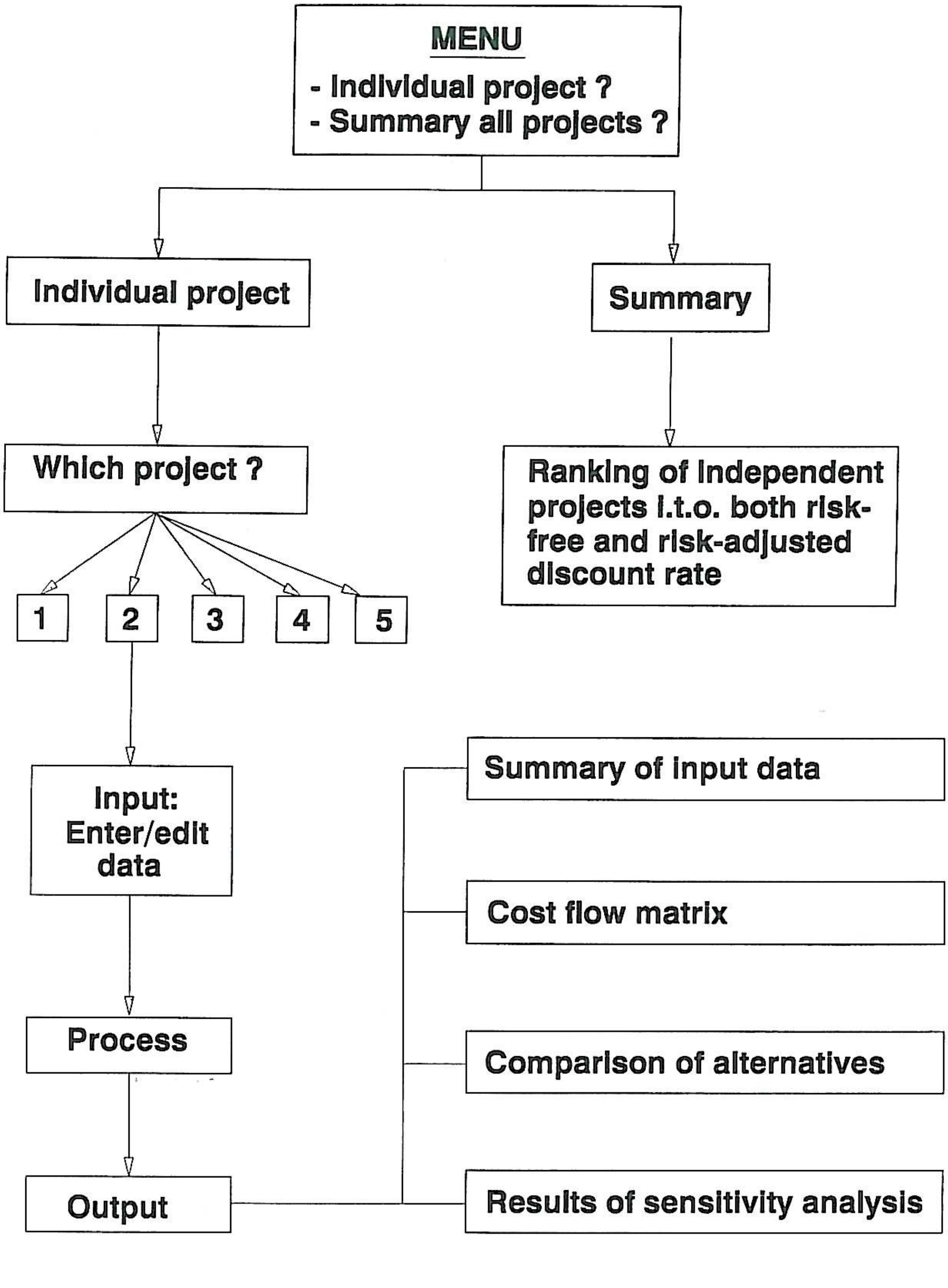
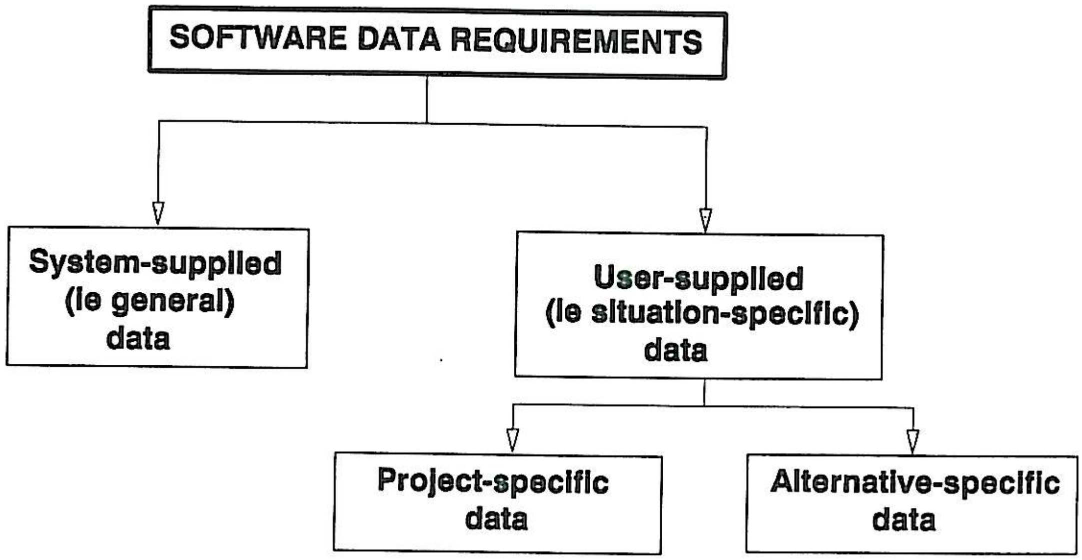


FIGURE 5.2: SOFTWARE DATA REQUIREMENTS



Specific data items required are listed in Table 5.1. Eight key inputs have been identified; they are indicated in the last column. Key inputs are defined as data (whether user- or system-supplied) of which the correctness over the entire analysis period cannot be guaranteed. They can therefore affect the outcome of the analysis (ie the success the project) and can even be critical in that respect, depending on their degree of criticality. Stated alternatively, the outcome will be sensitive to critical key inputs.

In this table, "discount rate" is listed as project-specific as its adjustment for risk will depend on the project risk profile.

TABLE 5.1: SOFTWARE DATA REQUIREMENTS

DATA ITEM	SYSTEM-SUPPLIED	USER-SUPPLIED		KEY INPUT
		PROJECT-SPECIFIC	ALTERNATIVE-SPECIFIC	
Cost relationships	X			
Unit prices	X			X
Worker/anyone split	X			X
Income distribution	X			X
Project name		X		
Number of mutually exclusive alternatives		X		
Analysis period		X		
Discount rate		X		
Annual daily traffic		X		X
Traffic growth rate		X		X
Vehicle occupancy rate		X		X
Vehicle classification		X		
Construction cost			X	X
Route length			X	
Vehicle speed			X	X
Road type			X	
Terrain type			X	
Probabilities		X	X	

Three input screens are used for capturing user-supplied data. Input Screen 1 (see Table 5.2) is used for project-specific data and Input Screen 2 (see Table 5.3) for alternative-specific data. Input Screen 3 is used for capturing the probability distribution for each key inputs. This is discussed in Section 5.3.2.

TABLE 5.2: INPUT SCREEN 1: PROJECT-SPECIFIC DATA

DATA ITEM	UNITS	NOTATION
Project name	NA	NA
Number of mutually exclusive alternatives	number	n
Analysis period	years	AP
Discount rate	decimal pa	i
Annual daily traffic	veh pa	ADT
Traffic growth rate	decimal pa	j
Veh occupancy rate: cars	persons/veh	VOR_C
Veh occupancy rate: LDVs	persons/veh	VOR_D
Veh occupancy rate: LGVs	persons/veh	VOR_L
Veh occupancy rate: HGVs	persons/veh	VOR_H
Veh occupancy rate: buses	persons/veh	VOR_B
Veh classification: cars	% of ADT	%C
Veh classification: LDVs	% of ADT	%D
Veh classification: LGVs	% of ADT	%L
Veh classification: HGVs	% of ADT	%H
Veh classification: buses	% of ADT	%B

TABLE 5.3: INPUT SCREEN 2: ALTERNATIVE-SPECIFIC DATA

DATA ITEM	NOTATION			
	ALT 0	ALT 1	ALT 2	ALT 3
Construction cost	$CON_{Alt\ 0}$	$CON_{Alt\ 1}$	$CON_{Alt\ 2}$	$CON_{Alt\ 3}$
Route length	$RL_{Alt\ 0}$	$RL_{Alt\ 1}$	$RL_{Alt\ 2}$	$RL_{Alt\ 3}$
Veh speed: cars	$Speed_{C:Alt\ 0}$	$Speed_{C:Alt\ 1}$	$Speed_{C:Alt\ 2}$	$Speed_{C:Alt\ 3}$
Veh speed: LDVs	$Speed_{D:Alt\ 0}$	$Speed_{D:Alt\ 1}$	$Speed_{D:Alt\ 2}$	$Speed_{D:Alt\ 3}$
Veh speed: LGVs	$Speed_{L:Alt\ 0}$	$Speed_{L:Alt\ 1}$	$Speed_{L:Alt\ 2}$	$Speed_{L:Alt\ 3}$
Veh speed: HGVs	$Speed_{H:Alt\ 0}$	$Speed_{H:Alt\ 1}$	$Speed_{H:Alt\ 2}$	$Speed_{H:Alt\ 3}$
Veh speed: buses	$Speed_{B:Alt\ 0}$	$Speed_{B:Alt\ 1}$	$Speed_{B:Alt\ 2}$	$Speed_{B:Alt\ 3}$
Road type	$RT_{Alt\ 0}$	$RT_{Alt\ 1}$	$RT_{Alt\ 2}$	$RT_{Alt\ 3}$
Terrain type	$TT_{Alt\ 0}$	$TT_{Alt\ 1}$	$TT_{Alt\ 2}$	$TT_{Alt\ 3}$

5.3.2 Probability distributions for key inputs

On Input Screen 3, probability distributions for each of the key inputs are provided. In Table 5.4 examples of such probability distributions are given. Each key input can have its own unique probability distribution. The confidence bands can be changed; however, they apply to key inputs collectively. In the example in Table 5.4 five confidence bands were assumed, namely:

- -30 percent deviation from most likely value
- -10 percent deviation from most likely value
- 0 percent deviation from most likely value
- +10 percent deviation from most likely value
- +30 percent deviation from most likely value.

TABLE 5.4: INPUT SCREEN 3: PROBABILITY DISTRIBUTION FOR KEY INPUTS

KEY INPUT	CONFIDENCE BANDS				
	-30 PERCENT	-10 PERCENT	0 PERCENT	+10 PERCENT	+30 PERCENT
Unit prices	3	7	80	7	3
Unit price: time	3	7	80	7	3
Unit price: accidents	5	10	70	10	5
Analysis period	0	0	100	0	0
Annual daily traffic	3	7	80	7	3
Traffic growth rate	5	10	70	10	5
Vehicle occupancy rate	5	10	70	10	5
Vehicle classification	1	4	90	4	1
Construction cost	2	8	70	15	5
Vehicle speed	3	7	80	7	3

5.4 COST RELATIONSHIPS AND UNIT PRICES USED IN PROGRAM

5.4.1 Breakdown of total transport cost

The breakdown of total travel cost for a given alternative, as calculated by the program, is given below.

Total travel cost = CON + MAI + VOC + ACC + TIM

where:

CON = facility construction cost
MAI = facility maintenance cost
VOC = vehicle operating cost
ACC = accident cost
TIM = travel time cost.

Facility construction cost is user-supplied. The other cost components are calculated by the program, using user-supplied and system-supplied data. VOC, ACC and TIM are further broken down as shown below.

VOC

$$VOC = F_{TOT} + T_{TOT} + O_{TOT} + D_{TOT} + MAI_{TOT}$$

where:

$$F_{TOT} = F_C + F_D + F_L + F_H + F_B$$
$$T_{TOT} = T_C + T_D + T_L + T_H + T_B$$
$$O_{TOT} = O_C + O_D + O_L + O_H + O_B$$
$$D_{TOT} = D_C + D_D + D_L + D_H + D_B$$
$$M_{TOT} = M_C + M_D + M_L + M_H + M_B$$

and where:

F = fuel cost

T = tyre cost

O = oil cost

D = depreciation cost

M = maintenance cost

and where:

C denotes cars

D denotes LDVs

L denotes LGVs

H denotes HGVs

B denotes buses.

ACC

$$ACC = ACC_{fatal} + ACC_{serious} + ACC_{slight} + ACC_{damage\text{-}only}$$

where:

ACC_{fatal} = cost of fatal accidents

$ACC_{serious}$ = cost of serious accidents

ACC_{slight} = cost of slight accidents

$ACC_{damage\text{-}only}$ = cost of damage-only accidents.

TIM

$$TIM = TIM_C + TIM_D + TIM_L + TIM_H + TIM_B$$

where:

TIM_C = travel time cost for cars

TIM_D = travel time cost for LDVs

TIM_L = travel time cost for LGVs

TIM_H = travel time cost for HGVs

TIM_B = travel time cost for buses.

5.4.2 Variables used in calculating cost components

The program calculates cost components as a function of different variables, as indicated in Table 5.5. In this table the terms have the meanings defined in Table 5.2 and Table 5.3. Terms not defined in these tables are defined below.

VT = vehicle type

UP = unit price

OC = accident property cost.

TABLE 5.5: VARIABLES USED FOR CALCULATING COST COMPONENTS

COST COMPONENT	CALCULATED AS A FUNCTION OF
CON	User-supplied
MAI	RL, ADT, j
VOC: F	VT, RT, TT, RL, ADT, j, %veh type, UP_{fuel}
T	VT, RT, TT, RL, ADT, j, %veh type, UP_{tyres}
O	VT, RT, TT, RL, ADT, j, %veh type, UP_{oil}
D	VT, RT, TT, RL, ADT, j, %veh type, $UP_{new\ vehicle}$
M	VT, RT, TT, RL, ADT, j, %veh type, $UP_{new\ vehicle}$
ACC	RT, RL, ADT, j, $UP_{accidents}$, OC
TIM	RL, speed, VOR, ADT, j, %VT, UP_{time}

5.4.3 Sources of cost relationships and unit prices

The sources of cost relationships and unit prices used in the program are given in Table 5.6.

TABLE 5.6: SOURCES OF COST RELATIONSHIPS AND UNIT PRICES

ITEM	SOURCE	NOTE
MAI	CB-Roads	See Appendix A
VOC	Program COSTDATA	See Appendix B
ACC	CB-Roads	See Appendix C
TIM	NA	See Appendix D
Unit prices	Program COSTDATA	See Appendix E

5.5 PROGRAM OUTPUT

There are five output files. These are discussed below.

5.5.1 Output file Costcalc

This file gives a breakdown of total transport cost for each mutually exclusive alternative in a given set. Appendix H contains output file Costcalc for Project 2.

5.5.2 Output file Costmatrix

In this file, PWC and B/C ratio (calculated at the project-specific risk-adjusted discount rate) for each alternative in a given set are calculated. Appendix G contains the Costmatrix output files for the five projects used in the application of program RISKAN.

5.5.3 Output file Monte Carlo

This file contains the results of the simulation analysis. Appendix I contains part of this file for Project 2. In the first four columns (one column for each of the four alternatives in this set) the values obtained for PWC for one iteration are given. The next three columns contain corresponding values for the B/C ratio. In the next four columns $(x_i-\mu)^2$ for PWC values is calculated; corresponding values for the B/C ratio are calculated in the following three columns. The big variation in values in the first seven columns is the result of the project having been specified as rather risky; this is evident from the probability distributions for the key inputs in Appendix F.

The number of iterations used in the application of the program for calculating the standard deviation is 250. This number is user-supplied in the sense that the user can specify any number in the macro to a maximum of 250.

5.5.4 Output file Sensitivity

In this output file the results of the sensitivity analyses are presented in both tabular and graphic format. The values for PWC and B/C used in the analysis are based on the risk-free discount rate.

5.5.5 Output file Results

This file summarises the results of the simulation analysis. Appendix G contains examples of this file for the test data. The information in this file enables the selection of the best alternative from a given set on the basis of PWC calculated by using the risk-adjusted discount rate. It also enables the ranking of independent projects in terms of B/C ratio based on the risk-adjusted discount rate.

6 APPLICATION OF SOFTWARE

6.1 DESCRIPTION OF HYPOTHETICAL SET OF PROJECTS

Program RISKAN was used for the economic evaluation of five hypothetical rural road projects. Projects were specified in such a way as to reveal different risk profiles. This was done by specifying different probability distributions and confidence bands.

Details of the input data used for the analyses are given in Appendix F. A short description of each project is given below.

Project 1 (low risk)

- Null alternative: The existing road is a two-lane paved road in mountainous terrain, covering a distance of 5,5 km and carrying an ADT of 3 000. Three options for improving the road were considered.
- Alternative 1 involves the improvement of the vertical and horizontal alignment of the existing road.
- Alternative 2 involves the construction of a new road shortening the route distance to 4,8 km.
- Alternative 3 involves the further improvement of the vertical alignment of the road described under Alternative 2.

Project 2 (high risk)

- Null alternative: The existing road is a two-lane paved road with terrain type "tangent and rolling", covering a distance of 15,5 km and carrying an ADT of 8 000. Three options for improving this road were considered.
- Alternative 1 involves the widening of the road as well as the improvement of the horizontal and vertical alignment.
- Alternative 2 involves the construction of a freeway to replace the old road, shortening route distance to 14,2 km.
- Alternative 3 involves the further improvement of the geometric characteristics of the road described under Alternative 2.

Project 3 (high risk)

- Null alternative: The existing road is a two-lane paved in mountainous terrain, covering a distance of 6,0 km and carrying an ADT of 3200. Three options for improving this road were considered.
- Alternative 1 involves the improvement of the vertical and horizontal alignment of the existing road.
- Alternative 2 involves the construction of a new two-lane paved road on a new alignment, shortening route distance to 4,9 km.
- Alternative 3 involves the further improvement of the vertical and horizontal alignment of the road described under Alternative 2 .

Project 4 (medium risk)

- Null alternative: The existing road is a gravel road in mountainous terrain. This road covers a distance of 25,0 km and carries an ADT of 50. Two options for improving this road were considered.
- Alternative 1 involves the improvement of the geometric characteristics of the existing road.
- Alternative 2 involves the construction of a new gravel road with an improved alignment, shortening the route distance to 22,5 km.

Project 5 (medium risk)

- Null alternative: The existing road is a two-lane paved road with terrain type "flat and winding". It covers a distance of 33,0 km and carries an ADT of 4 500. Two options for improving this road were considered.
- Alternative 1 involves improving the geometric characteristics of the existing road.
- Alternative 2 involves the construction of a new two-lane paved road, shortening the route distance to 29,5 km.

6.2 DISCUSSION OF RESULTS OBTAINED

Details of the results of the analyses are given in Appendix G. The most important aspects are discussed below.

6.2.1 Project selection and ranking

The incorporation of risk in the evaluation process, at least in the manner suggested in Section 4, does not affect project selection (ie the selection of the best alternative from a set of mutually exclusive alternatives). This is illustrated in Table 6.1. This is not surprising, given the fact that total transport cost consists mainly of "future" costs (ie costs incurred over the analysis period) and that "present" cost (ie facility construction cost) contributes relatively insignificantly to this cost. Therefore, whatever discount rate is used, the relative attractiveness of alternatives would not be affected. The incorporation of risk would however make a difference to project selection in a borderline case, in other words where an alternative, without taking risk into account, is "just" viable, and in addition has a high risk profile. In such as case a higher discount rate may result in the project not being economically viable. A case in point is Project 4: without considering risk, Alternative 1 with a B/C ratio of 1,82 is economically justified; when risk is taken into account by using a risk-adjusted discount rate, neither Alternative 1 nor Alternative 2 is justified. In this case, the inclusion of an additional parameter in decision-making would preclude an investment decision which in fact is unwise.

The incorporation of risk does however affect project ranking. This is shown in Table 6.1, where the first three projects change places when risk is considered. This is particularly true where "similar" projects (Project 1 and Project 3) have differential risk profiles; Project 3 with a high risk profile falls to third place when risk in introduced.

TABLE 6.1: RANKING OF INDEPENDENT PROJECTS

WITHOUT RISK			WITH RISK			
RANKING		B/C RATIO	RANKING		B/C RATIO	RADR (%)
1	Project 3: Alt 2	12,4	1	Project 1: Alt 2	7,9	10,8
2	Project 1: Alt 2	9,8	2	Project 5: Alt 2	4,6	17,7
3	Project 5: Alt 2	8,8	3	Project 3: Alt 2	3,7	30,1
4	Project 2: Alt 2	4,0	4	Project 2: Alt 2	1,6	22,2
5	Project 4: Alt 1	1,8	5	Project 4: Alt 0	NA	18,7

6.2.2 Sensitivity analysis

The results of the sensitivity analyses indicate that all "sensitivity functions" have negative slopes; that is, as the value for a key input decreases, so does PWC. The exception, and for logical reasons, is travel speed: as speed decreases, PWC increases as travel time cost increases. Further, in all cases, again with the exception of travel speed, the PWC-percentage change relationship is linear.

In Table 6.2 the proportional change in PWC for a 1,1 change in the value of a given key input is indicated. This table reveals that the criticality of individual key inputs between different projects is relatively constant. In Table 6.3 key inputs are ranked in terms of their criticality. This ranking is relatively constant between projects. As could be expected, ADT is the most critical. Surprisingly, construction cost is the least critical. This table also highlights the importance of unit prices used in the analysis. Again, Project 4 is the exception, and construction cost moves up to fourth place. This is the result of the low value used for ADT in the analysis.

TABLE 6.2: VARIATION IN CRITICALITY OF KEY INPUTS BETWEEN PROJECTS

KEY INPUT	PROJECT				
	1	2	3	4	5
Unit price (excluding travel time and accident cost)	1,073	1,073	1,077	1,058	1,065
Unit price: travel time	1,017	1,019	1,014	1,011	1,028
Unit price: accidents	1,006	1,005	1,006	1,004	1,004
Construction cost	1,003	1,003	1,003	1,013	1,002
Annual daily traffic	1,096	1,096	1,096	1,076	1,097
Traffic growth rate	1,026	1,035	1,026	1,015	1,026
Vehicle occupancy rate	1,017	1,019	1,014	1,011	1,028
Vehicle speed	0,984	0,983	0,988	0,990	0,975

TABLE 6.3: RANKING OF KEY INPUTS IN TERMS OF CRITICALITY

RANKING	PROJECT				
	1	2	3	4	5
1	ADT	ADT	ADT	ADT	ADT
2	UP	UP	UP	UP	UP
3	TGR	TGR	TGR	TGR	Speed
4	Speed	Speed	Speed	Constr	UP:time
5	UP:time	UP:time	UP:time	Speed	VOR
6	VOR	VOR	VOR	UP:time	TGR
7	UP:acc	UP:acc	UP:acc	VOR	UP:acc
8	Constr	Constr	Constr	UP:acc	Constr

Note:
ADT = annual daily traffic
UP = unit price (excluding unit price of accidents and travel time)
TGR = traffic growth rate
UP:time = unit price of travel time
VOR = vehicle occupancy rate
UP:acc = unit price of accidents
Constr = facility construction cost.

6.2.3 Effect of risk for given project

To illustrate the implications of risk for project selection and ranking, the risk profile for Project 1 was changed as indicated below.

Data item	Unit price: w/o time & accident	Unit price: travel time	Unit price: accidents	Analysis period	A D T	Traffic growth rate	Vehicle occupancy rate	Vehicle classi-fication	Construction costs	Vehicle speed	Confidence bands
Percent Probability	5 10 20 60 5	5 10 20 60 5	5 10 20 60 5	0 0 100 0 0	5 15 60 15 5	5 15 60 15 5	5 15 60 15 5	0 0 100 0 0	5 15 60 15 5	5 15 60 15 5	-30 -15 0 15 30

This means that in effect two projects were considered:

- Project 1 with key inputs as indicated in Appendix F and results as indicated in Appendix G.1
- Project 6 which is the same as Project 1 but with a higher risk profile.

The results of the simulation analysis are given in Table 6.4 below.

TABLE 6.4: RESULTS OF SIMULATION ANALYSIS FOR PROJECT 6

PROJECT: Proj 6	SIMULATION ANALYSIS: SUMMARY OF RESULTS			
RADR 28.74%	Alt 0	Alt 1	Alt 2	Alt 3
PWOC at RFDR PWOC at RADR	90,082,209 28,235,223	80,918,483 25,929,372	68,865,274 23,232,769	70,604,417 24,107,432
B/C ratio at RFDR B/C ratio at RADR		12.1075 3.7950	9.8404 3.0844	7.7631 2.4333
Standard deviation Mean Coefficient of variation	17,122,921 96,269,220 0.177865	15,212,788 86,410,158 0.176053	12,692,948 73,427,696 0.172863	13,038,087 75,270,286 0.173217
Number of iterations	250	250	250	250

Table 6.4 illustrates the importance of considering risk in project evaluation. As project risk increases, the risk-adjusted discount rate increases from 10,8 percent for Project 1 to 28,7 percent for Project 6, and the risk-adjusted B/C ratio for the best alternative decreases from 7,9 to 3,1. The implications of this for project ranking is obvious.

7 CONCLUSIONS

7.1 NEED TO CONSIDER RISK

It is important that risk should be considered in the economic evaluation of road infrastructure projects in South Africa. As indicated, risk does affect project selection and ranking. If risk is not considered, it means that an important parameter in project selection and ranking is not available. This means that management information is incomplete, and that incorrect investment decisions could be made.

7.2 THE FORMAL APPLICATION OF RISK ANALYSIS

It is recommended that risk analysis should be applied formally to the economic evaluation of road projects in South Africa. This could be done by adding a risk module to program CB-Roads. An integrated approach to risk analysis should be adopted, such as suggested in this report.

7.3 AREAS FOR FURTHER RESEARCH

The following aspects need to be researched further:

- the implications of dependency with reference to cost flows for the procedure suggested
- the need to consider unique risk profiles for each of the alternatives in a set of mutually exclusive alternatives
- the implications of capital rationing for the procedure suggested
- the risk-return relationship. In this study this relationship was obtained by specifying a function that differentiates between projects regarded as having low risk, medium risk and high risk. This function can however be regarded as user-supplied as the user can change this function in the macro. The sensitivity of project outcome for different risk-return functions can be investigated in this way. However, it is recommended that the potential of using the portfolio approach (outlined in Section 3) for specifying this function should be investigated
- statistical distributions for input variables
- the number of iterations required in the Monte Carlo simulation.

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APPENDIX A:

RELATIONSHIPS FOR FACILITY MAINTENANCE COST

$MAI = (A + B * ADT * (1+j)) * RL_{Alt\ n}$

where:

MAI = facility construction cost at the end of the first year of the analysis period.

TABLE A.1: FACILITY MAINTENANCE COST: VALUE OF A AND B FOR GIVEN RT

	RT		
	1	2	3
A	14 652	7 194	2 973
B	0	0	17,2

APPENDIX B:

RELATIONSHIPS FOR VEHICLE OPERATING COST

FUEL COST

$F_C = A * RL_{Alt\,n} * ADT * (1+j) * \%C * UP_{petrol} * 365$

$F_D = A * RL_{Alt\,n} * ADT * (1+j) * \%D * UP_{petrol} * 365$

$F_L = A * RL_{Alt\,n} * ADT * (1+j) * \%L * UP_{diesel} * 365$

$F_H = A * RL_{Alt\,n} * ADT * (1+j) * \%H * UP_{diesel} * 365$

$F_B = A * RL_{Alt\,n} * ADT * (1+j) * \%B * UP_{diesel} * 365$

where:

F = fuel cost at the end of the first year of the analysis period.

TABLE B.1: FUEL COST: VALUE OF A FOR GIVEN RT, VT AND TT

RT	VT	TT				
		1	2	3	4	5
1	C	0,1088	0,1111	0,1009	0,0922	0,1113
	D	0,1250	0,1322	0,1128	0,1080	0,1346
	L	0,2787	0,3333	0,3005	0,3137	0,4016
	H	0,5251	0,6604	0,6450	0,7649	1,2018
	B	0,4270	0,4409	0,4230	0,4185	0,5975
2	C	0,0945	0,0968	0,0857	0,0812	0,1075
	D	0,1124	0,1196	0,0960	0,0968	0,1336
	L	0,2960	0,3339	0,2880	0,3207	0,4217
	H	0,5072	0,6425	0,6257	0,7523	1,2201
	B	0,4150	0,4952	0,3938	0,4578	0,6520
3	C	0,0854	0,0878	0,0850	0,0848	0,1478
	D	0,9590	0,1046	0,0947	0,1054	0,1744
	L	0,3170	0,3627	0,3230	0,3817	0,5287
	H	0,5200	0,6783	0,6820	0,8603	1,4473
	B	0,4170	0,5200	0,4030	0,4950	0,7810

TYRE COST

$$T_C = A * RL_{Alt\,n} * ADT * (1+j) * \%C * UP_{C:tyres} * 365$$

$$T_D = A * RL_{Alt\,n} * ADT * (1+j) * \%D * UP_{D:tyres} * 365$$

$$T_L = A * RL_{Alt\,n} * ADT * (1+j) * \%L * UP_{L:tyres} * 365$$

$$T_H = A * RL_{Alt\,n} * ADT * (1+j) * \%H * UP_{H:tyres} * 365$$

$$T_B = A * RL_{Alt\,n} * ADT * (1+j) * \%B * UP_{B:tyres} * 365$$

where:

T = tyre cost at the end of the first year of the analysis period.

TABLE B.2: TYRE COST: VALUE OF A FOR GIVEN RT, VT AND TT

RT	VT	TT				
		1	2	3	4	5
1	C	0,0000161	0,0000168	0,0000339	0,0000346	0,0000417
	D	0,0000161	0,0000168	0,0000339	0,0000346	0,0000417
	L	0,0000165	0,0000172	0,0000346	0,0000353	0,0000427
	H	0,0000153	0,0000159	0,0000322	0,0000328	0,0000397
	B	0,0000165	0,0000172	0,0000346	0,0000353	0,0000427
2	C	0,0000170	0,0000177	0,0000320	0,0000327	0,0000363
	D	0,0000170	0,0000177	0,0000320	0,0000327	0,0000363
	L	0,0000154	0,0000160	0,0000288	0,0000295	0,0000328
	H	0,0000136	0,0000142	0,0000256	0,0000262	0,0000290
	B	0,0000154	0,0000160	0,0000288	0,0000295	0,0000328
3	C	0,0000238	0,0000248	0,0000448	0,0000458	0,0000508
	D	0,0000238	0,0000248	0,0000448	0,0000458	0,0000508
	L	0,0000216	0,0000225	0,0000403	0,0000412	0,0000459
	H	0,0000190	0,0000198	0,0000358	0,0000366	0,0000406
	B	0,0000216	0,0000225	0,0000403	0,0000412	0,0000459

OIL COST

$O_C = A * RL_{Alt\,n} * ADT * (1+j) * \%C * UP_{C:oil} * 365$

$O_D = A * RL_{Alt\,n} * ADT * (1+j) * \%D * UP_{D:oil} * 365$

$O_L = A * RL_{Alt\,n} * ADT * (1+j) * \%L * UP_{L:oil} * 365$

$O_H = A * RL_{Alt\,n} * ADT * (1+j) * \%H * UP_{H:oil} * 365$

$O_B = A * RL_{Alt\,n} * ADT * (1+j) * \%B * UP_{B:oil} * 365$

where:

O = oil cost at the end of the first year of the analysis period.

TABLE B.3: OIL COST: VALUE OF A FOR GIVEN RT, VT AND TT

RT	VT	TT				
		1	2	3	4	5
1	C	0,000745	0,000751	0,000723	0,000698	0,000752
	D	0,001020	0,001040	0,000986	0,000972	0,001047
	L	0,002315	0,002430	0,002361	0,002389	0,002573
	H	0,004163	0,004447	0,004415	0,004666	0,005584
	B	0,003347	0,003376	0,003338	0,003329	0,003705
2	C	0,000705	0,000711	0,000680	0,000667	0,000741
	D	0,000985	0,001005	0,000939	0,000941	0,001044
	L	0,002356	0,002431	0,002335	0,002404	0,002616
	H	0,004125	0,003490	0,004374	0,004640	0,005622
	B	0,003322	0,003490	0,003277	0,003411	0,003819
3	C	0,000679	0,000686	0,000678	0,000677	0,000854
	D	0,000939	0,000963	0,000935	0,000965	0,000158
	L	0,002396	0,002492	0,002408	0,002532	0,002840
	H	0,004152	0,004484	0,004492	0,004867	0,006099
	B	0,003326	0,003542	0,003296	0,003490	0,004090

DEPRECIATION COST

$D_C = A * RL_{Alt\,n} * ADT * (1+j) * \%C * UP_{C:new\,vehicle} * 365$

$D_D = A * RL_{Alt\,n} * ADT * (1+j) * \%D * UP_{D:new\,vehicle} * 365$

$D_L = A * RL_{Alt\,n} * ADT * (1+j) * \%L * UP_{L:new\,vehicle} * 365$

$D_H = A * RL_{Alt\,n} * ADT * (1+j) * \%H * UP_{H:new\,vehicle} * 365$

$D_B = A * RL_{Alt\,n} * ADT * (1+j) * \%B * UP_{B:new\,vehicle} * 365$

where:

D = depreciation cost at the end of the first year of the analysis period.

TABLE B.4: DEPRECIATION COST: VALUE OF A FOR GIVEN RT, VT AND TT

RT	VT	TT				
		1	2	3	4	5
1	C	0,00000572	0,00000575	0,00000590	0,00000607	0,00000648
	D	0,00000721	0,00000733	0,00000741	0,00000766	0,00000830
	L	0,00000380	0,00000389	0,00000391	0,00000404	0,00000440
	H	0,00000159	0,00000163	0,00000164	0,00000170	0,00000190
	B	0,00000217	0,00000221	0,00000225	0,00000230	0,00000250
2	C	0,00000600	0,00000607	0,00000620	0,00000642	0,00000703
	D	0,00000754	0,00000760	0,00000775	0,00000803	0,00000879
	L	0,00000400	0,00000409	0,00000411	0,00000424	0,00000457
	H	0,00000167	0,00000172	0,00000174	0,00000181	0,00000205
	B	0,00000227	0,00000230	0,00000235	0,00000243	0,00000266
3	C	0,00000664	0,00000672	0,00000682	0,00000726	0,00000859
	D	0,00000830	0,00000839	0,00000863	0,00000908	0,00001050
	L	0,00000440	0,00000457	0,00000465	0,00000488	0,00000573
	H	0,00000190	0,00000194	0,00000198	0,00000211	0,00000265
	B	0,00000250	0,00000254	0,00000262	0,00000272	0,00000332

MAINTENANCE COST

M_C = $A * RL_{Alt\ n} * ADT * (1+j) * \%C * UP_{C:new\ vehicle} * 365$

M_D = $A * RL_{Alt\ n} * ADT * (1+j) * \%D * UP_{D:new\ vehicle} * 365$

M_L = $A * RL_{Alt\ n} * ADT * (1+j) * \%L * UP_{L:new\ vehicle} * 365$

M_H = $A * RL_{Alt\ n} * ADT * (1+j) * \%H * UP_{H:new\ vehicle} * 365$

M_B = $A * RL_{Alt\ n} * ADT * (1+j) * \%B * UP_{B:new\ vehicle} * 365$

where:

M = maintenance cost at the end of the first year of the analysis period.

TABLE B.5: MAINTENANCE COST: VALUE OF A FOR GIVEN RT, VT AND TT

RT	VT	TT				
		1	2	3	4	5
1	C	0,00000235	0,00000233	0,00000222	0,00000215	0,00000204
	D	0,00000483	0,00000466	0,00000452	0,00000426	0,00000383
	L	0,00000170	0,00000167	0,00000166	0,00000164	0,00000162
	H	0,00000141	0,00000138	0,00000138	0,00000137	0,00000137
	B	0,00000099	0,00000096	0,00000092	0,00000089	0,00000079
2	C	0,00000216	0,00000215	0,00000210	0,00000204	0,00000200
	D	0,00000437	0,00000435	0,00000423	0,00000398	0,00000369
	L	0,00000165	0,00000163	0,00000163	0,00000162	0,00000163
	H	0,00000137	0,00000136	0,00000136	0,00000136	0,00000141
	B	0,00000091	0,00000089	0,00000087	0,00000083	0,00000076
3	C	0,00000239	0,00000238	0,00000236	0,00000236	0,00000265
	D	0,00000452	0,00000451	0,00000442	0,00000431	0,00000438
	L	0,00000185	0,00000185	0,00000185	0,00000189	0,00000205
	H	0,00000155	0,00000154	0,00000156	0,00000159	0,00000184
	B	0,00000097	0,00000095	0,00000092	0,00000089	0,00000087

APPENDIX C:

RELATIONSHIPS FOR ACCIDENT COST

$$ACC_{fatal} = (RL_{Alt\ n)} * ADT * (1+j) * 365) / 10^8 * A * (UP_{fatal} + OC_{fatal})$$

$$ACC_{serious} = (RL_{Alt\ n)} * ADT * (1+j) * 365) / 10^8 * B * (UP_{serious} + OC_{serious})$$

$$ACC_{slight} = (RL_{Alt\ n)} * ADT * (1+j) * 365) / 10^8 * C * (UP_{slight} + OC_{slight})$$

$$ACC_{damage} = (RL_{Alt\ n)} * ADT * (1+j) * 365) / 10^8 * D * OC_{damage}$$

where:

ACC = accident cost at the end of the first year of the analysis period.

TABLE C.1: ACCIDENT COST: VALUE OF A, B, C AND D FOR GIVEN RT

	RT		
	1	2	3
A	4,5228937	10,828424	12,160669
B	3,0720640	10,011669	12,621143
C	5,4286976	16,410015	27,494419
D	10,963312	32,748711	47,738736

The number of collisions per 10^8 vehicle kilometres by category and severity is given as relative percentages in Table SD12 of program CB-Roads version 4.1 (1). In Table C.2 below, these percentages are reworked to actual numbers. In preparing Table C.2, the following personal injury accident (PIA) rates (from Table SD11 of CB-Roads) were used:

- freeways: $24/10^8$ vehicle kilometres
- paved single-carriageways: $70/10^8$ vehicle kilometres
- gravel roads: $100/10^8$ vehicle kilometres

TABLE C.2: NUMBER OF COLLISIONS PER 10^8 VEHICLE KILOMETRES BY CATEGORY AND SEVERITY

FREEWAYS

CATEGORY	FATAL	SERIOUS	SLIGHT	FDAM	TOTAL
1	0.2535090	0.3259401	0.6277365	2.8248144	4.0320000
2	0.0425987	0.0650191	0.1165860	0.8317962	1.0560000
3	0.0023780	0.0011890	0.0096440	0.0587890	0.0720000
4	0.0146341	0.0111220	0.0327805	0.1574634	0.2160000
5	0.2732308	0.1676643	0.1800839	0.2670210	0.8880000
6	0.0794182	0.0916364	0.1344000	0.5345455	0.8400000
7	0.0110164	0.0206557	0.0302951	0.0930000	0.1549672
8	0.0250345	0.0250345	0.0637241	0.1502069	0.2640000
9	0.0088662	0.0042803	0.0174268	0.0654268	0.0960000
10	0.0000000	0.0014118	0.0004706	0.0221176	0.0240000
11	0.8422295	0.9308852	2.6596721	3.6792131	8.1120000
12	0.0000000	0.0037895	0.0025263	0.0176842	0.0240000
13	0.0189383	0.0871162	0.2727116	2.2612339	2.6400000
14	2.9510400	1.3363200	1.2806400	0.0000000	5.5680000
TOTAL	4.5228937	3.0720640	5.4286976	10.9633119	23.9869672

TWO-LANE PAVED ROADS

CATEGORY	FATAL	SERIOUS	SLIGHT	FDAM	TOTAL
1	0.2299561	0.4270614	0.9855263	5.8474561	7.4900000
2	0.1242459	0.1754060	0.4312065	2.4191415	3.1500000
3	0.0065479	0.0126281	0.0275947	0.1632294	0.2100000
4	0.0165301	0.0330602	0.0673012	0.3719277	0.4888193
5	0.3741243	0.2436158	0.2523164	2.2099435	3.0800000
6	0.1486726	0.2312684	0.4460177	1.9740413	2.8000000
7	0.0690749	0.1424670	0.2201762	0.5482819	0.9800000
8	0.0480144	0.0909747	0.1137184	0.4472924	0.7000000
9	0.0066038	0.0224528	0.0369811	0.2139623	0.2800000
10	0.0003471	0.0018512	0.0093719	0.1284298	0.1400000
11	2.2909424	2.8938220	6.8728272	10.9724084	23.0300000
12	0.0091971	0.0122628	0.0296350	0.0889051	0.1400000
13	0.1058678	0.2234986	0.8469421	7.3636915	8.5400000
14	7.3983000	5.5013000	6.0704000	0.0000000	18.9700000
TOTAL	10.8284244	10.0116691	16.4100148	32.7487109	69.9988193

GRAVEL ROADS

CATEGORY	FATAL	SERIOUS	SLIGHT	FDAM	TOTAL
1	0.0794702	0.1788079	0.4039735	2.3377483	3.0000000
2	0.0510204	0.0448980	0.1081633	1.0959184	1.3000000
3	0.0116402	0.0116402	0.0296296	0.1470899	0.2000000
4	0.0123596	0.0556627	0.0944578	0.2876404	0.4501205
5	0.3079812	0.3604520	0.6836158	2.1751174	3.5271664
6	0.0605405	0.2713864	0.7197640	1.7216216	2.7733126
7	0.0513761	0.0513761	0.0513761	0.4165138	0.5706422
8	0.0006083	0.0328467	0.0827251	0.3783455	0.4945255
9	0.0160377	0.0103774	0.0679245	0.3056604	0.4000000
10	0.0000000	0.0014925	0.0022388	0.0962687	0.1000000
11	5.9304348	5.6608696	15.3652174	28.8434783	55.8000000
12	0.0000000	0.0193333	0.0473333	0.1333333	0.2000000
13	0.0112000	0.2940000	0.9940000	9.8000000	11.0992000
14	5.6280000	5.6280000	8.8440000	0.0000000	20.1000000
TOTAL	12.1606691	12.6211428	27.4944193	47.7387360	100.0149672

APPENDIX D:

RELATIONSHIPS FOR TRAVEL TIME COST

$$TIM_C = RL_{Alt\ n} / Speed_{C:Alt\ n} * VOR_C * ADT * (1+j) * 365 * \%C * UP_t$$

$$TIM_D = RL_{Alt\ n} / Speed_{D:Alt\ n} * VOR_D * ADT * (1+j) * 365 * \%D * UP_t$$

$$TIM_L = RL_{Alt\ n} / Speed_{L:Alt\ n} * VOR_L * ADT * (1+j) * 365 * \%L * UP_t$$

$$TIM_H = RL_{Alt\ n} / Speed_{H:Alt\ n} * VOR_H * ADT * (1+j) * 365 * \%H * UP_t$$

$$TIM_B = RL_{Alt\ n} / Speed_{B:Alt\ n} * VOR_B * ADT * (1+j) * 365 * \%B * UP_t$$

where:

TIM = travel time cost at the end of the first year of the analysis period.

APPENDIX E:

UNIT PRICES

TABLE E.1: UNIT PRICES

ITEM	NOTATION	PRICE PER UNIT (1993 RANDS)	UNIT	SOURCE
Petrol	UP_{petrol}	1,05	litres	Costdata (1)
Diesel	UP_{diesel}	1,00	litres	Costdata (1)
Tyres: cars	$UP_{C:tyres}$	686	set of tyres	Costdata (1)
Tyres: LDVs	$UP_{D:tyres}$	742	set of tyres	Costdata (1)
Tyres: LGVs	$UP_{L:tyres}$	5 178	set of tyres	Costdata (1)
Tyres: HGVs	$UP_{H:tyres}$	16 374	set of tyres	Costdata (1)
Tyres: Buses	$UP_{B:tyres}$	5 178	set of tyres	Costdata (1)
Oil: cars	$UP_{C:oil}$	5,17	litres	Costdata (1)
Oil: LDVs	$UP_{D:oil}$	5,17	litres	Costdata (1)
Oil: LGVs	$UP_{L:oil}$	3,61	litres	Costdata (1)
Oil: HGVs	$UP_{H:oil}$	3,61	litres	Costdata (1)
Oil: Buses	$UP_{B:oil}$	3,61	litres	Costdata (1)
New vehicle: cars	$UP_{C:new\ vehicle}$	55 299	new vehicle	Costdata (1)
New vehicle: LDVs	$UP_{D:new\ vehicle}$	42 938	new vehicle	Costdata (1)
New vehicle: LGVs	$UP_{L:new\ vehicle}$	179 471	new vehicle	Costdata (1)
New vehicle: HGVs	$UP_{H:new\ vehicle}$	298 920	new vehicle	Costdata (1)
New vehicle: Buses	$UP_{B:new\ vehicle}$	346 858	new vehicle	Costdata (1)
Accidents: loss of output only				
Fatal	UP_{fatal}	476 063	accident	See below
Serious	$UP_{serious}$	61 862	accident	See below
Slight	UP_{slight}	355	accident	See below
Accident property cost				
Fatal	OC_{fatal}	82 243	accident	See below
Serious	$OC_{serious}$	55 328	accident	See below
Slight	OC_{slight}	28 065	accident	See below
Damage-only	OC_{damage}	8 542	accident	See below
Travel time	UP_t	6,85	person hour	See below

Source of information:

1 Accident costs

Accident costs in 1987 Rands are given in program CB-Roads: Description of methodologies: Appendix B (1). These costs were inflated to 1993 prices as follows:

$$\text{Accident cost}_{1993} = \text{Accident cost}_{1987} * 1{,}15^5 * 1{,}1$$

Further, a worker/anyone split of 0,3/0,7 and an income distribution split (low, medium and high income) of 0,58/0,154/0,266 were assumed for calculating the loss of output component. Accident costs resulting from other worker/anyone splits and income distribution are given in Table E.2.

2 Travel time cost

Travel time cost in 1987 Rands are given in Table 6.9 of the CEAS manual (1). The values given in Table E.1 are weighted national averages. The same index as for accident cost was used to express these costs in 1993 Rands. Also, the same worker/anyone split and income distribution as for accident costs were assumed. The effect of other worker/anyone splits and income distributions are given in Table E.3.

TABLE E.2: UNIT PRICE OF ACCIDENTS: LOSS OF OUTPUT ONLY: EFFECT OF WORKER/ANYONE SPLIT AND INCOME DISTRIBUTION (1993 RANDS)

INCOME DISTRIBUTION (L/M/H %)	WORKER/ANYONE SPLIT (%)						
FATAL	15/85	20/80	25/75	30/70	35/65	40/60	45/55
43/154/416	514508	571706	628904	686103	743301	800499	857697
48/154/366	461550	513063	564576	616089	667603	719116	770629
53/154/316	408592	454420	500248	546076	591904	637733	683561
58/154/266	355634	395777	435920	476063	516206	556349	596492
63/154/216	302676	337134	371592	406050	440508	474966	509424
68/154/166	249718	278491	307264	336037	364810	393583	422356
73/154/116	196760	219848	242936	266024	289112	312199	335287
SERIOUS							
43/154/416	67019	74378	81736	89095	96453	103812	111170
48/154/366	60127	66757	73387	80017	86647	93277	99907
53/154/316	53236	59137	65038	70940	76841	82742	88644
58/154/266	46344	51517	56689	61862	67035	72208	77380
63/154/216	39452	43896	48341	52785	57229	61673	66117
68/154/166	32560	36276	39992	43707	47423	51138	54854
73/154/116	25669	28656	31643	34630	37617	40604	43591
SLIGHT							
43/154/416	384	427	470	512	555	598	641
48/154/366	344	383	421	460	498	537	575
53/154/316	305	339	373	407	442	476	510
58/154/266	265	295	325	355	385	415	445
63/154/216	225	251	277	303	328	354	380
68/154/166	186	207	229	250	272	293	315
73/154/116	146	163	181	198	215	232	250

TABLE E.3: UNIT PRICE OF TRAVEL TIME: EFFECT OF WORKER/ANYONE SPLIT AND INCOME DISTRIBUTION (1993 RANDS)

INCOME DISTRIBUTION (L/M/H %)	WORKER/ANYONE SPLIT (%)						
	15/85	20/80	25/75	30/70	35/65	40/60	45/55
43/154/416	6.18	7.41	8.63	9.85	11.08	12.30	13.52
48/154/366	5.55	6.65	7.75	8.85	9.95	11.05	12.15
53/154/316	4.92	5.90	6.87	7.85	8.83	9.81	10.78
58/154/266	4.29	5.14	5.86	6.85	7.71	8.56	9.42
63/154/216	3.66	4.39	5.12	5.85	6.58	7.32	8.05
68/154/166	3.02	3.63	4.24	4.85	5.46	6.07	6.68
73/154/116	2.39	2.88	3.36	3.85	4.34	4.82	5.31

APPENDIX F:

DETAILS OF INPUT DATA USED IN ANALYSES

PROJECT 1

INPUT SCREEN 1

DATA ITEM	UNITS	NOTATION	VALUE **(user entered)**
Project Name			Proj 1
Number of mutually exclusive alternative:	-	n	4
Analysis period	years	AP	20
Discount rate	decimal pa	i	0.08
A D T	vehicles pa	ADT	3000
Traffic Growth rate	decimal pa	j	0.03
Vehicle occupancy rate			
cars	persons/vehicle	VOR(c)	1.2
L D Vs	persons/vehicle	VOR(d)	1.2
L G Vs	persons/vehicle	VOR(l)	1.1
H G Vs	persons/vehicle	VOR(h)	1.1
Buses	persons/vehicle	VOR(b)	23
Vehicle classification			
cars	% of A D T	%C	0.8
L D Vs	% of A D T	%D	0.05
L G Vs	% of A D T	%L	0.05
H G Vs	% of A D T	%H	0.05
Buses	% of A D T	%B	0.05

INPUT SCREEN 2

Data item	Notation	Units	Alt 0	Alt 1	Alt2	Alt3
Construction costs		R	-	825,000	2,400,000	2,880,000
Route length	RL(Altn)	km	5.5	5.5	4.8	4.8
Vehicle speed						
cars	Speed(c)	km/h	80	90	100	105
L D Vs	Speed(d)	km/h	70	80	90	95
L G Vs	Speed(l)	km/h	70	80	90	95
H G Vs	Speed(h)	km/h	60	70	80	85
buses	Speed(b)	km/h	60	70	80	85
Road type	RT(Altn)		2	2	2	2
Terrain type	TT(Altn)		5	4	2	4

PROBABILITIES

Data item	Unit price: w/o time & accident	Unit price: travel time	Unit price: accidents	Analysis period	A D T	Traffic growth rate	Vehicle occupancy rate	Vehicle classi-fication	Construction costs	Vehicle speed	Confidence bands
	0	0	0	0	0	0	0	0	0	0	-15
Percent	3	5	5	0	1	5	5	0	5	2	-7.5
	95	90	90	100	98	90	90	100	90	95	0
Probability	2	5	5	0	1	5	5	0	5	3	7.5
	0	0	0	0	0	0	0	0	0	0	15

PROJECT 2

INPUT SCREEN 1

DATA ITEM	UNITS	NOTATION	VALUE (user entered)
Project Name			Proj 2
Number of mutually exclusive alternatives	-	n	4
Analysis period	years	AP	20
Discount rate	decimal pa	i	0.08
A D T	vehicles pa	ADT	8000
Traffic Growth rate	decimal pa	j	0.04
Vehicle occupancy rate			
cars	persons/vehicle	VOR(c)	1.4
L D Vs	persons/vehicle	VOR(d)	1.3
L G Vs	persons/vehicle	VOR(l)	1.2
H G Vs	persons/vehicle	VOR(h)	1.3
Buses	persons/vehicle	VOR(b)	40
Vehicle classification			
cars	% of A D T	%C	0.7
L D Vs	% of A D T	%D	0.05
L G Vs	% of A D T	%L	0.05
H G Vs	% of A D T	%H	0.15
Buses	% of A D T	%B	0.05

INPUT SCREEN 2

Data item	Notation	Units	Alt 0	Alt 1	Alt2	Alt3
Construction costs		R	-	3,100,000	21,300,000	25,560,000
Route length	RL(Altn)	km	15.5	15.5	14.2	14.2
Vehicle speed						
cars	Speed(c)	km/h	100	105	110	115
L D Vs	Speed(d)	km/h	95	100	105	110
L G Vs	Speed(l)	km/h	95	100	105	110
H G Vs	Speed(h)	km/h	85	90	95	100
buses	Speed(b)	km/h	85	90	95	100
Road type	RT(Altn)		2	2	1	1
Terrain type	TT(Altn)		2	3	3	4

PROBABILITIES

Data item	Unit price: w/o time & accident	Unit price: travel time	Unit price: accidents	Analysis period	A D T	Traffic growth rate	Vehicle occupancy rate	Vehicle classi-fication	Construction costs	Vehicle speed	Confidence bands
Percent Probability	5 10 70 10 5	5 10 70 10 5	5 10 70 10 5	0 0 100 0 0	5 10 70 10 5	5 10 70 10 5	5 10 70 10 5	0 0 100 0 0	5 10 70 10 5	5 10 70 10 5	-20 -10 0 10 20

PROJECT 3

INPUT SCREEN 1

DATA ITEM	UNITS	NOTATION	VALUE (user entered)
Project Name			Proj 3
Number of mutually exclusive alternative:	-	n	4
Analysis period	years	AP	20
Discount rate	decimal pa	i	0.08
A D T	vehicles pa	ADT	3200
Traffic Growth rate	decimal pa	j	0.03
Vehicle occupancy rate			
cars	persons/vehicle	VOR(c)	1.2
L D Vs	persons/vehicle	VOR(d)	1.2
L G Vs	persons/vehicle	VOR(l)	1.1
H G Vs	persons/vehicle	VOR(h)	1.1
Buses	persons/vehicle	VOR(b)	20
Vehicle classification			
cars	% of A D T	%C	0.7
L D Vs	% of A D T	%D	0.15
L G Vs	% of A D T	%L	0.05
H G Vs	% of A D T	%H	0.07
Buses	% of A D T	%B	0.03

INPUT SCREEN 2

Data item	Notation	Units	Alt 0	Alt 1	Alt2	Alt3
Construction costs		R	-	900,000	2,450,000	2,940,000
Route length	RL(Altn)	km	6	6	4.9	4.9
Vehicle speed						
cars	Speed(c)	km/h	80	85	95	105
L D Vs	Speed(d)	km/h	80	85	95	105
L G Vs	Speed(l)	km/h	75	80	90	100
H G Vs	Speed(h)	km/h	65	70	80	90
buses	Speed(b)	km/h	65	70	80	90
Road type	RT(Altn)		2	2	2	2
Terrain type	TT(Altn)		5	4	2	4

PROBABILITIES

Data item	Unit price: w/o time & accident	Unit price: travel time	Unit price: accidents	Analysis period	A D T	Traffic growth rate	Vehicle occupancy rate	Vehicle classi-fication	Construction costs	Vehicle speed	Confidence bands
Percent	5	5	5	0	5	5	5	0	5	5	-30
	15	10	10	0	15	10	10	0	10	10	-15
	60	70	70	100	60	70	70	100	70	70	0
Probability	15	10	10	0	15	10	10	0	10	10	15
	5	5	5	0	5	5	5	0	5	5	30

PROJECT 4

INPUT SCREEN 1

DATA ITEM	UNITS	NOTATION	VALUE (user entered)
Project Name			Proj 4
Number of mutually exclusive alternatives	-	n	3
Analysis period	years	AP	20
Discount rate	decimal pa	i	0.08
A D T	vehicles pa	ADT	50
Traffic Growth rate	decimal pa	j	0.02
Vehicle occupancy rate			
cars	persons/vehicle	VOR(c)	1.2
L D Vs	persons/vehicle	VOR(d)	1.4
L G Vs	persons/vehicle	VOR(l)	1.2
H G Vs	persons/vehicle	VOR(h)	1.4
Buses	persons/vehicle	VOR(b)	15
Vehicle classification			
cars	% of A D T	%C	0.8
L D Vs	% of A D T	%D	0.05
L G Vs	% of A D T	%L	0.03
H G Vs	% of A D T	%H	0.1
Buses	% of A D T	%B	0.02

INPUT SCREEN 2

Data item	Notation	Units	Alt 0	Alt 1	Alt2	Alt3
Construction costs		R	-	1,000,000	2,250,000	
Route length	RL(Altn)	km	25	25	22.5	
Vehicle speed						
cars	Speed(c)	km/h	65	67	70	
L D Vs	Speed(d)	km/h	65	67	70	
L G Vs	Speed(l)	km/h	65	67	70	
H G Vs	Speed(h)	km/h	60	62	65	
buses	Speed(b)	km/h	55	57	60	
Road type	RT(Altn)		3	3	3	
Terrain type	TT(Altn)		5	2	4	

PROBABILITIES

Data item	Unit price: w/o time & accident	Unit price: travel time	Unit price: accidents	Analysis period	A D T	Traffic growth rate	Vehicle occupancy rate	Vehicle classification	Construction costs	Vehicle speed	Confidence bands
	3	3	3	0	3	3	3	0	3	3	-20
Percent	7	7	7	0	7	7	7	0	7	7	-10
	80	80	80	100	80	80	80	100	80	80	0
Probability	7	7	7	0	7	7	7	0	7	7	10
	3	3	3	0	3	3	3	0	3	3	20

PROJECT 5

INPUT SCREEN 1

DATA ITEM	UNITS	NOTATION	VALUE (user entered)
Project Name			Proj 5
Number of mutually exclusive alternatives	-	n	3
Analysis period	years	AP	20
Discount rate	decimal pa	i	0.08
A D T	vehicles pa	ADT	4500
Traffic Growth rate	decimal pa	j	0.03
Vehicle occupancy rate			
cars	persons/vehicle	VOR(c)	1.5
L D Vs	persons/vehicle	VOR(d)	1.4
L G Vs	persons/vehicle	VOR(l)	1.2
H G Vs	persons/vehicle	VOR(h)	1.2
Buses	persons/vehicle	VOR(b)	20
Vehicle classification			
cars	% of A D T	%C	0.7
L D Vs	% of A D T	%D	0.05
L G Vs	% of A D T	%L	0.03
H G Vs	% of A D T	%H	0.02
Buses	% of A D T	%B	0.2

INPUT SCREEN 2

Data item	Notation	Units	Alt 0	Alt 1	Alt2	Alt3
Construction costs		R	-	8,250,000	17,700,000	
Route length	RL(Altn)	km	33	33	29.5	
Vehicle speed						
cars	Speed(c)	km/h	95	100	110	
L D Vs	Speed(d)	km/h	90	95	105	
L G Vs	Speed(l)	km/h	80	85	95	
H G Vs	Speed(h)	km/h	70	75	85	
buses	Speed(b)	km/h	80	85	95	
Road type	RT(Altn)		2	2	2	
Terrain type	TT(Altn)		3	1	1	

PROBABILITIES

Data item	Unit price: w/o time & accident	Unit price: travel time	Unit price: accidents	Analysis period	A D T	Traffic growth rate	Vehicle occupancy rate	Vehicle classi-fication	Construction costs	Vehicle speed	Confidence bands
Percent Probability	3 7 80 7 3	3 7 80 7 3	3 7 80 7 3	0 0 100 0 0	3 7 80 7 3	3 7 80 7 3	3 7 80 7 3	0 0 100 0 0	3 7 80 7 3	3 7 80 7 3	-20 -10 0 10 20

APPENDIX G:

RESULTS OF ANALYSES

APPENDIX G.1

PROJECT 1

COST FLOW MATRIX

A0

Year	Costs Constr	Maint	VOC	Accident	Time	Total
0	0	0	0	0	0	0
1	0	39,567	5,386,893	494,080	1,433,085	7,353,625
		389,821	53,072,627	4,867,764	14,119,006	72,449,218
						72,449,218

A1

Year	Costs Constr	Maint	VOC	Accident	Time	Total
0	825,000	0	0	0	0	825,000
1	0	39,567	4,758,782	494,080	1,245,792	6,538,221
		389,821	46,884,366	4,867,764	12,273,767	65,240,718
						65,240,718

A2

Year	Costs Constr	Maint	VOC	Accident	Time	Total
0	2,400,000	0	0	0	0	2,400,000
1	0	34,531	3,998,028	431,197	961,962	5,425,718
		340,208	39,389,285	4,248,230	9,477,417	55,855,141
						55,855,141

A3

Year	Costs Constr	Maint	VOC	Accident	Time	Total
0	2,880,000	0	0	0	0	2,880,000
1	0	34,531	4,153,119	431,197	909,658	5,528,505
		340,208	40,917,265	4,248,230	8,962,112	57,347,814
						57,347,814

A1-A0

Year	Costs Constr	Maint	VRC	Accident	Time	Total
0	(825,000)	0	0	0	0	0
1	0	0	628,111	0	187,292	815,403
						8,033,500
						9.7376

A2-A0

Year	Costs Constr	Maint	VRC	Accident	Time	Total
0	(2,400,000)	0	0	0	0	0
1	0	5,036	1,388,865	62,883	471,123	1,927,907
						18,994,077
						7.9142

A3-A0

Year	Costs Constr	Maint	VRC	Accident	Time	Total
0	(2,880,000)	0	0	0	0	0
1	0	5,036	1,233,774	62,883	523,427	1,825,120
						17,981,404
						6.2435

RESULTS OF SIMULATION ANALYSIS

PROJECT: Proj 1	SIMULATION ANALYSIS: SUMMARY OF RESULTS			
RADR 10.79%	Alt 0	Alt 1	Alt 2	Alt 3
PWOC at RFDR PWOC at RADR	90,082,209 72,449,218	80,918,483 65,240,718	68,865,274 55,855,141	70,604,417 57,347,814
B/C ratio at RFDR B/C ratio at RADR		12.1075 9.7376	9.8404 7.9142	7.7631 6.2435
Standard deviation Mean Coefficient of variation	2,164,977 90,116,077 0.024024	1,921,709 80,949,299 0.023740	1,600,201 68,891,738 0.023228	1,641,482 70,631,342 0.023240
Number of iterations	250	250	250	250

RESULTS OF SENSITIVITY ANALYSIS

Unit prices	Present values of costs				B/C ratios		
	A0	A1	A2	A3	A0 - A1	A0 - A2	A0 - A3
1.20	103,612,180	92,909,577	78,950,256	81,069,372	13.9729	11.2758	8.8274
1.10	96,847,195	86,914,030	73,907,765	75,836,894	13.0402	10.5581	8.2952
1	90,082,209	80,918,483	68,865,274	70,604,417	12.1075	9.8404	7.7631
0.90	83,317,224	74,922,936	63,822,784	65,371,940	11.1749	9.1227	7.2310
0.80	76,552,238	68,927,389	58,780,293	60,139,462	10.2422	8.4050	6.6989

Unit Price: Travel time	Present values of costs				B/C ratios		
	A0	A1	A2	A3	A0 - A1	A0 - A2	A0 - A3
1.20	93,593,279	83,970,684	71,222,089	72,833,087	12.6638	10.3213	8.2084
1.10	91,837,744	82,444,584	70,043,681	71,718,752	12.3856	10.0809	7.9858
1	90,082,209	80,918,483	68,865,274	70,604,417	12.1075	9.8404	7.7631
0.90	88,326,674	79,392,382	67,686,867	69,490,082	11.8294	9.5999	7.5405
0.80	86,571,140	77,866,281	66,508,460	68,375,747	11.5513	9.3594	7.3178

Unit Price: Accidents	Present values of costs				B/C ratios		
	A0	A1	A2	A3	A0 - A1	A0 - A2	A0 - A3
1.20	90,960,671	81,796,945	69,631,932	71,371,075	12.1075	9.8870	7.8019
1.10	90,521,440	81,357,714	69,248,603	70,987,746	12.1075	9.8637	7.7825
1	90,082,209	80,918,483	68,865,274	70,604,417	12.1075	9.8404	7.7631
0.90	89,642,978	80,479,252	68,481,946	70,221,088	12.1075	9.8171	7.7437
0.80	89,203,747	80,040,021	68,098,617	69,837,759	12.1075	9.7938	7.7243

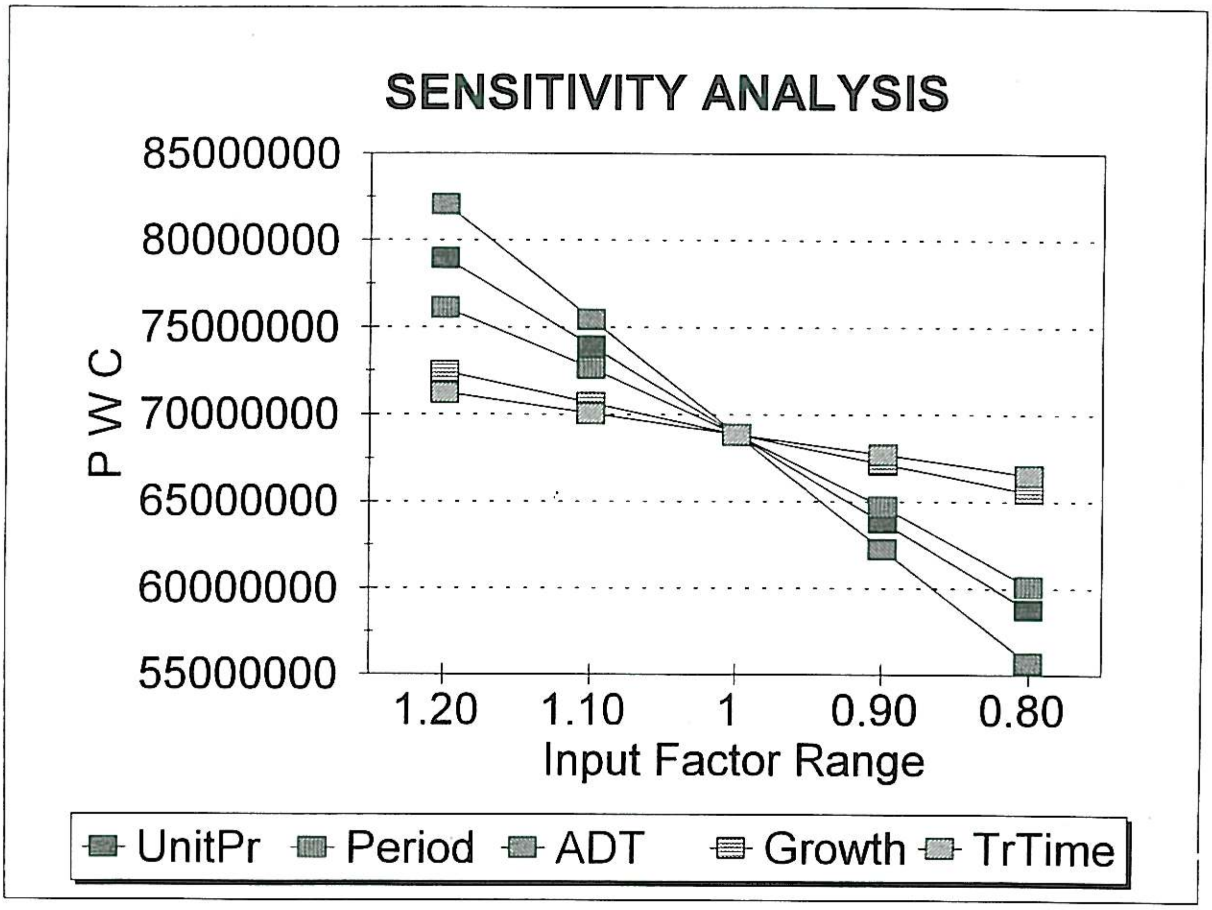
Construction costs	Present values of costs				B/C ratios		
	A0	A1	A2	A3	A0 - A1	A0 - A2	A0 - A3
1.20	90,082,209	81,083,483	69,345,274	71,180,417	10.0896	8.2003	6.4693
1.10	90,082,209	81,000,983	69,105,274	70,892,417	11.0069	8.9458	7.0574
1	90,082,209	80,918,483	68,865,274	70,604,417	12.1075	9.8404	7.7631
0.90	90,082,209	80,835,983	68,625,274	70,316,417	13.4528	10.9338	8.6257
0.80	90,082,209	80,753,483	68,385,274	70,028,417	15.1344	12.3005	9.7039

A D T	Present values of costs				B/C ratios		
	A0	A1	A2	A3	A0 - A1	A0 - A2	A0 - A3
1.20	108,001,712	96,840,240	82,073,728	84,064,699	14.5291	11.8033	9.3115
1.10	99,041,960	88,879,361	75,469,501	77,334,558	13.3183	10.8219	8.5373
1	90,082,209	80,918,483	68,865,274	70,604,417	12.1075	9.8404	7.7631
0.90	81,122,458	72,957,604	62,261,048	63,874,276	10.8968	8.8589	6.9890
0.80	72,162,707	64,996,726	55,656,821	57,144,135	9.6860	7.8775	6.2148

Traffic growth rate	Present values of costs				B/C ratios		
	A0	A1	A2	A3	A0 - A1	A0 - A2	A0 - A3
1.20	94,935,470	85,233,264	72,445,752	74,252,774	12.7602	10.3707	8.1815
1.10	92,468,061	83,039,621	70,625,430	72,397,942	12.4284	10.1011	7.9688
1	90,082,209	80,918,483	68,865,274	70,604,417	12.1075	9.8404	7.7631
0.90	87,774,942	78,867,209	67,163,092	68,869,965	11.7973	9.5883	7.5642
0.80	85,543,400	76,883,256	65,516,773	67,192,435	11.4971	9.3444	7.3719

Vehicle occupancy rate	Present values of costs				B/C ratios		
	A0	A1	A2	A3	A0 - A1	A0 - A2	A0 - A3
1.20	93,593,279	83,970,684	71,222,089	72,833,087	12.6638	10.3213	8.2084
1.10	91,837,744	82,444,584	70,043,681	71,718,752	12.3856	10.0809	7.9858
1	90,082,209	80,918,483	68,865,274	70,604,417	12.1075	9.8404	7.7631
0.90	88,326,674	79,392,382	67,686,867	69,490,082	11.8294	9.5999	7.5405
0.80	86,571,140	77,866,281	66,508,460	68,375,747	11.5513	9.3594	7.3178

Vehicle speed	Present values of costs				B/C ratios		
	A0	A1	A2	A3	A0 - A1	A0 - A2	A0 - A3
1.20	87,156,318	78,374,982	66,901,263	68,747,192	11.6440	9.4396	7.3921
1.10	88,486,268	79,531,119	67,793,995	69,591,385	11.8547	9.6218	7.5607
1	90,082,209	80,918,483	68,865,274	70,604,417	12.1075	9.8404	7.7631
0.90	92,032,804	82,614,150	70,174,616	71,842,567	12.4165	10.1076	8.0105
0.80	94,471,046	84,733,735	71,811,292	73,390,254	12.8028	10.4416	8.3197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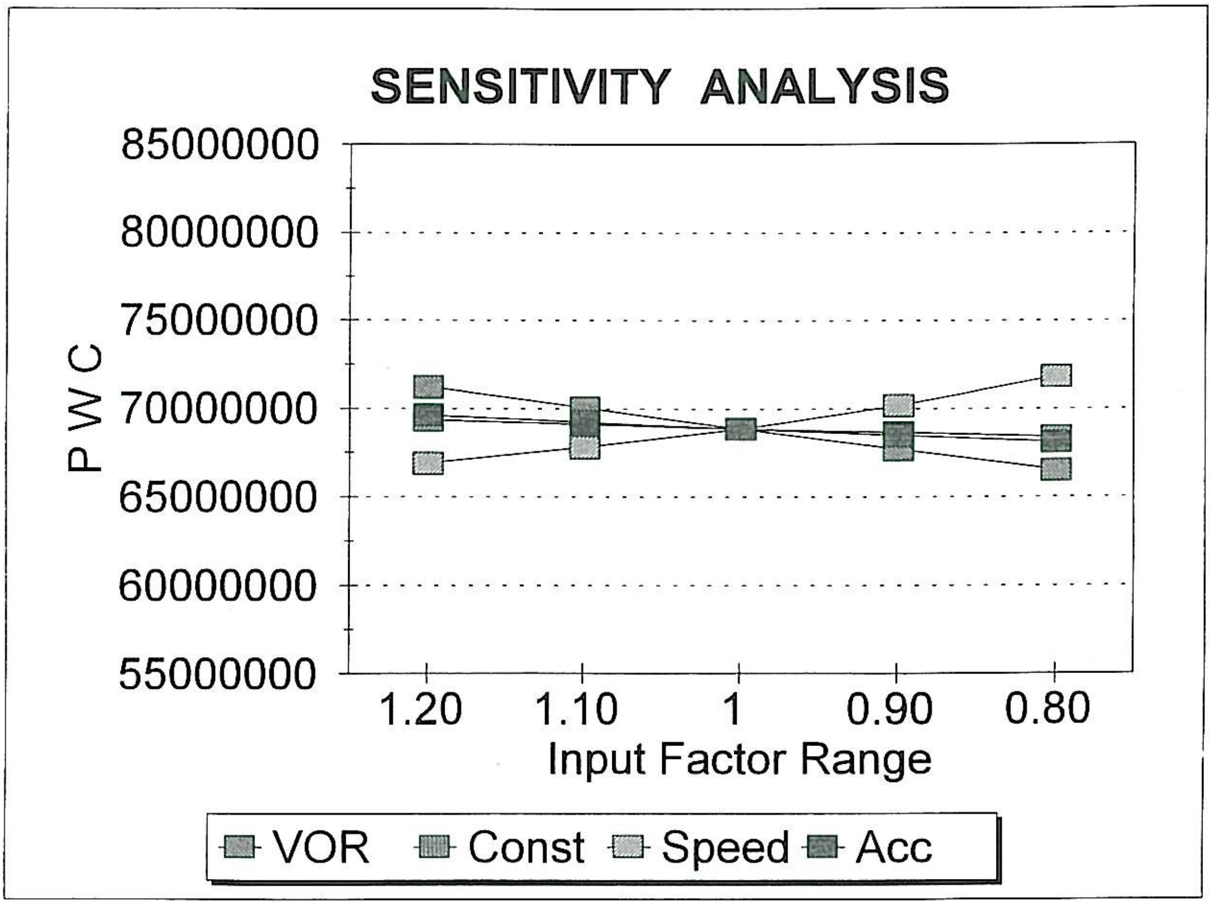
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P W C
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1.10
1
0.90
0.80
Input Factor Range
VOR
Const
Speed
Acc

APPENDIX G.2

PROJECT 2

COST FLOW MATRIX

A0

Year	Costs Constr	Maint	VOC	Accident	Time	Total
0	0	0	0	0	0	0
1	0	111,507	40,596,490	3,749,136	11,910,427	56,367,560
		588,775	214,355,912	19,796,031	62,888,947	297,629,665
						297,629,665

A1

Year	Costs Constr	Maint	VOC	Accident	Time	Total
0	3,100,000	0	0	0	0	3,100,000
1	0	111,507	41,881,322	3,749,136	11,276,172	57,018,136
		588,775	221,140,028	19,796,031	59,539,978	304,164,812
						304,164,812

A2

Year	Costs Constr	Maint	VOC	Accident	Time	Total
0	21,300,000	0	0	0	0	21,300,000
1	0	208,058	36,541,850	3,434,692	9,808,359	49,992,960
		1,098,581	192,946,769	18,135,719	51,789,695	285,270,764
						285,270,764

A3

Year	Costs Constr	Maint	VOC	Accident	Time	Total
0	25,560,000	0	0	0	0	25,560,000
1	0	208,058	40,344,727	3,434,692	9,336,703	53,324,180
		1,098,581	213,026,563	18,135,719	49,299,273	307,120,136
						307,120,136

A1-A0

Year	Costs Constr	Maint	VRC	Accident	Time	Total
0	(3,100,000)	0	0	0	0	0
1	0	0	(1,284,832)	0	634,255	(650,576)
						(3,435,147)
						-1.1081

A2-A0

Year	Costs Constr	Maint	VRC	Accident	Time	Total
0	(21,300,000)	0	0	0	0	0
1	0	(96,551)	4,054,640	314,444	2,102,068	6,374,600
						33,658,901
						1.5802

A3-A0

Year	Costs Constr	Maint	VRC	Accident	Time	Total
0	(25,560,000)	0	0	0	0	0
1	0	(96,551)	251,763	314,444	2,573,725	3,043,380
						16,069,529
						0.6287

RESULTS OF SIMULATION ANALYSIS

PROJECT: Proj 2	SIMULATION ANALYSIS: SUMMARY OF RESULTS			
RADR 22.18%	Alt 0	Alt 1	Alt 2	Alt 3
PWOC at RFDR PWOC at RADR	746,727,074 297,629,665	758,445,561 304,164,812	683,579,805 285,270,764	731,970,017 307,120,136
B/C ratio at RFDR B/C ratio at RADR		-2.7802 -1.1081	3.9647 1.5802	1.5773 0.6287
Standard deviation Mean Coefficient of variation	91,430,654 754,754,373 0.121140	93,159,410 766,658,889 0.121514	81,654,005 690,801,321 0.118202	88,184,541 739,811,736 0.119199
Number of iterations	250	250	250	250

RESULTS OF SENSITIVITY ANALYSIS

Unit prices

	Present values of costs				B/C ratios		
	A0	A1	A2	A3	A0 - A1	A0 - A2	A0 - A3
1.20	857,011,851	872,134,490	782,893,322	841,359,227	-3.8783	4.4797	1.6124
1.10	801,869,463	815,290,025	733,236,564	786,664,622	-3.3292	4.2222	1.5949
1	746,727,074	758,445,561	683,579,805	731,970,017	-2.7802	3.9647	1.5773
0.90	691,584,686	701,601,096	633,923,046	677,275,412	-2.2311	3.7071	1.5598
0.80	636,442,297	644,756,632	584,266,288	622,580,807	-1.6820	3.4496	1.5423

Unit Price: Travel time

	Present values of costs				B/C ratios		
	A0	A1	A2	A3	A0 - A1	A0 - A2	A0 - A3
1.20	778,283,659	788,321,691	709,566,978	756,707,539	-2.2381	4.2261	1.8441
1.10	762,505,367	773,383,626	696,573,391	744,338,778	-2.5091	4.0954	1.7107
1	746,727,074	758,445,561	683,579,805	731,970,017	-2.7802	3.9647	1.5773
0.90	730,948,781	743,507,495	670,586,219	719,601,256	-3.0512	3.8339	1.4440
0.80	715,170,489	728,569,430	657,592,632	707,232,495	-3.3222	3.7032	1.3106

Unit Price: Accidents

	Present values of costs				B/C ratios		
	A0	A1	A2	A3	A0 - A1	A0 - A2	A0 - A3
1.20	753,935,690	765,654,176	690,183,827	738,574,039	-2.7802	3.9930	1.6010
1.10	750,331,382	762,049,869	686,881,816	735,272,028	-2.7802	3.9789	1.5892
1	746,727,074	758,445,561	683,579,805	731,970,017	-2.7802	3.9647	1.5773
0.90	743,122,766	754,841,253	680,277,794	728,668,006	-2.7802	3.9505	1.5655
0.80	739,518,458	751,236,945	676,975,783	725,365,995	-2.7802	3.9363	1.5537

Construction costs

	Present values of costs				B/C ratios		
	A0	A1	A2	A3	A0 - A1	A0 - A2	A0 - A3
1.20	746,727,074	759,065,561	687,839,805	737,082,017	-2.3168	3.3039	1.3145
1.10	746,727,074	758,755,561	685,709,805	734,526,017	-2.5274	3.6042	1.4340
1	746,727,074	758,445,561	683,579,805	731,970,017	-2.7802	3.9647	1.5773
0.90	746,727,074	758,135,561	681,449,805	729,414,017	-3.0891	4.4052	1.7526
0.80	746,727,074	757,825,561	679,319,805	726,858,017	-3.4752	4.9558	1.9717

A D T

	Present values of costs				B/C ratios		
	A0	A1	A2	A3	A0 - A1	A0 - A2	A0 - A3
1.20	895,777,052	909,219,236	815,484,517	872,700,771	-3.3362	4.7696	1.9028
1.10	821,252,063	833,832,398	749,532,161	802,335,394	-3.0582	4.3671	1.7401
1	746,727,074	758,445,561	683,579,805	731,970,017	-2.7802	3.9647	1.5773
0.90	672,202,085	683,058,723	617,627,449	661,604,640	-2.5021	3.5622	1.4146
0.80	597,677,096	607,671,886	551,675,093	591,239,263	-2.2241	3.1597	1.2519

Traffic growth rate

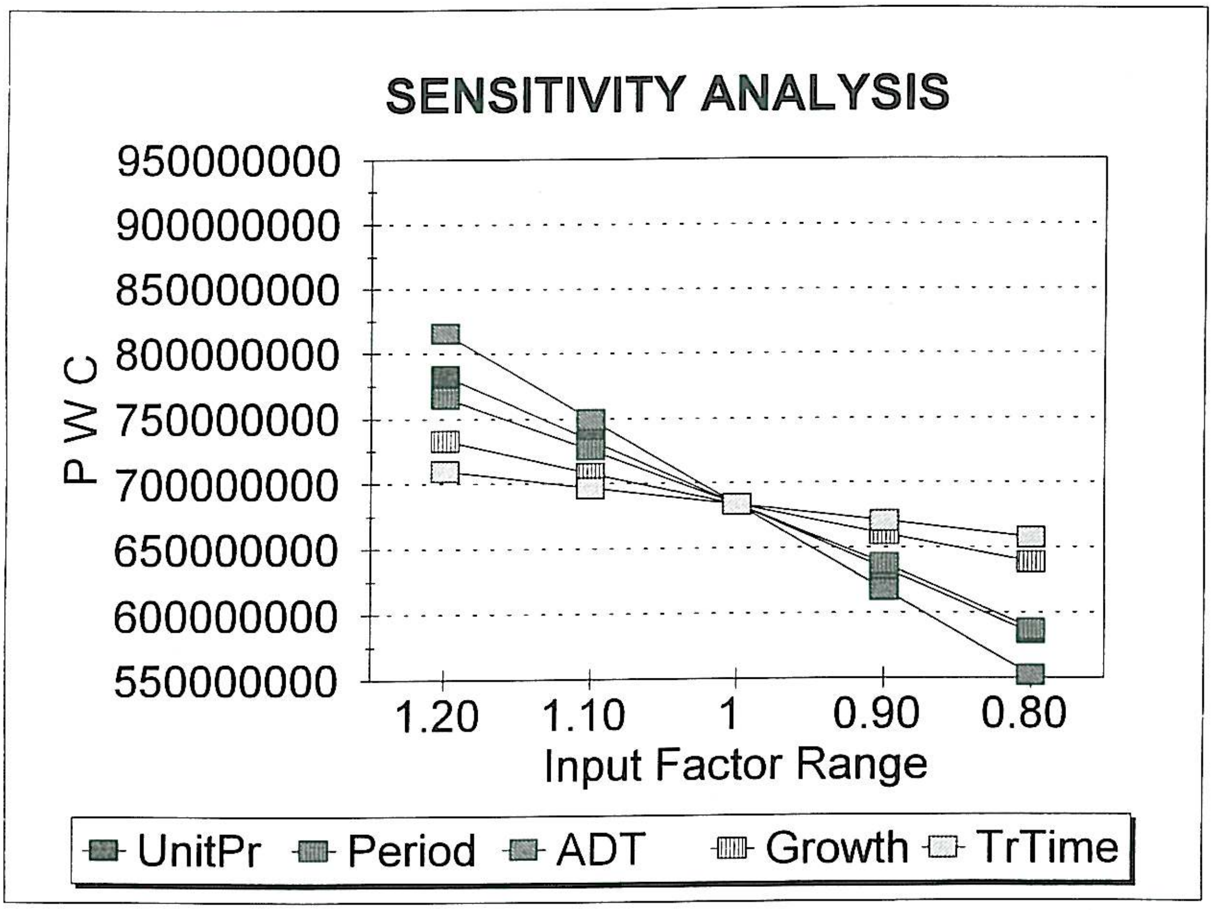
	Present values of costs				B/C ratios		
	A0	A1	A2	A3	A0 - A1	A0 - A2	A0 - A3
1.20	802,371,442	814,732,298	732,919,497	784,598,906	-2.9874	4.2607	1.6953
1.10	773,918,067	785,950,451	707,690,030	757,687,527	-2.8814	4.1093	1.6350
1	746,727,074	758,445,561	683,579,805	731,970,017	-2.7802	3.9647	1.5773
0.90	720,737,310	732,155,767	660,534,609	707,388,548	-2.6834	3.8264	1.5223
0.80	695,890,648	707,022,273	638,502,910	683,886,151	-2.5908	3.6943	1.4696

Vehicle occupancy rate

	Present values of costs				B/C ratios		
	A0	A1	A2	A3	A0 - A1	A0 - A2	A0 - A3
1.20	778,283,659	788,321,691	709,566,978	756,707,539	-2.2381	4.2261	1.8441
1.10	762,505,367	773,383,626	696,573,391	744,338,778	-2.5091	4.0954	1.7107
1	746,727,074	758,445,561	683,579,805	731,970,017	-2.7802	3.9647	1.5773
0.90	730,948,781	743,507,495	670,586,219	719,601,256	-3.0512	3.8339	1.4440
0.80	715,170,489	728,569,430	657,592,632	707,232,495	-3.3222	3.7032	1.3106

Vehicle speed

	Present values of costs				B/C ratios		
	A0	A1	A2	A3	A0 - A1	A0 - A2	A0 - A3
1.20	720,429,920	733,548,785	661,923,828	711,355,415	-3.2319	3.7468	1.3550
1.10	732,383,172	744,865,501	671,767,454	720,725,689	-3.0266	3.8458	1.4561
1	746,727,074	758,445,561	683,579,805	731,970,017	-2.7802	3.9647	1.5773
0.90	764,258,510	775,043,411	698,017,123	745,713,085	-2.4790	4.1099	1.7256
0.80	786,172,806	795,790,724	716,063,771	762,891,920	-2.1026	4.2915	1.9108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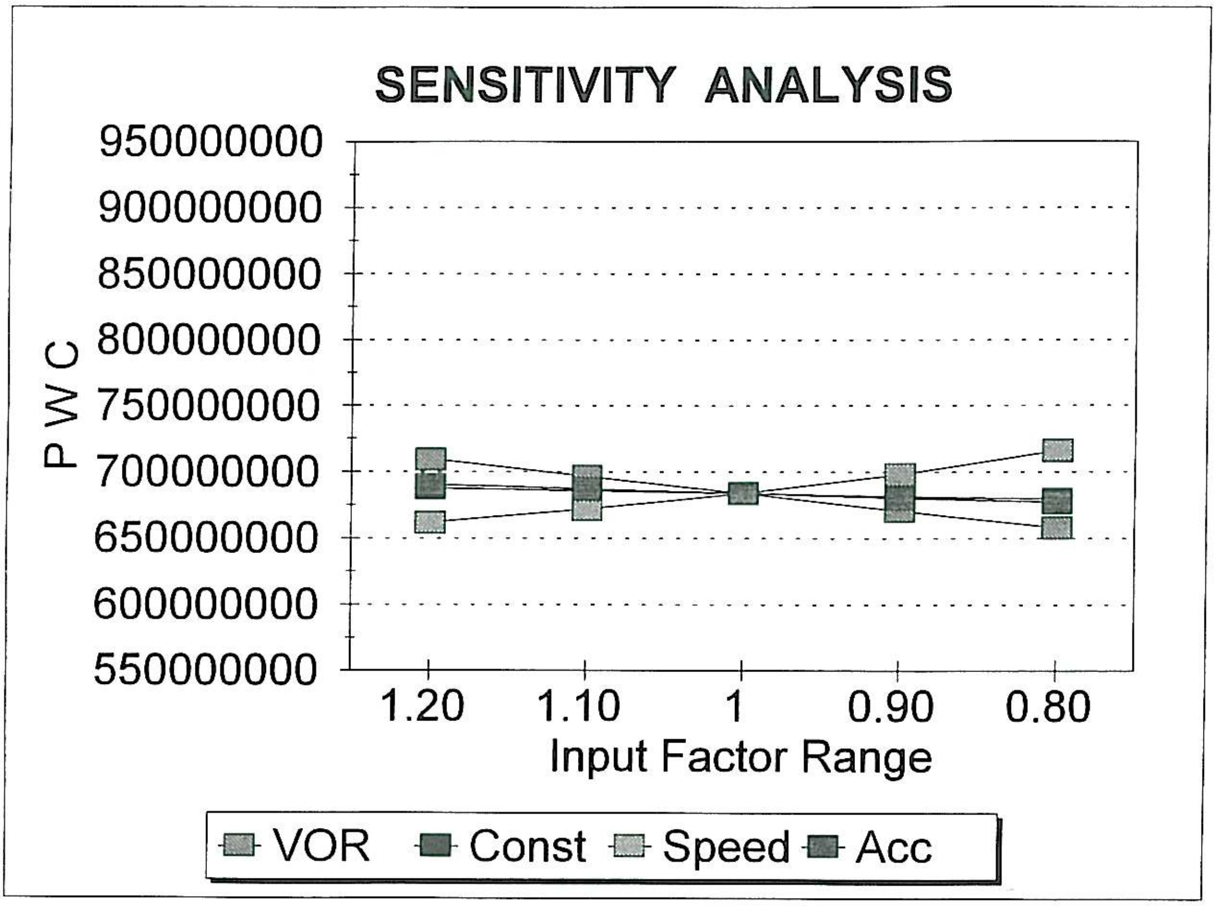
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Input Factor Range
VOR
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Speed
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APPENDIX G.3

PROJECT 3

COST FLOW MATRIX

A0	Costs					
Year	Constr	Maint	VOC	Accident	Time	Total
0	0	0	0	0	0	0
1	0	43,164	6,410,515	574,929	1,181,671	8,210,279
		157,715	23,423,109	2,100,711	4,317,657	29,999,192
						29,999,192

A1	Costs					
Year	Constr	Maint	VOC	Accident	Time	Total
0	900,000	0	0	0	0	900,000
1	0	43,164	5,642,795	574,929	1,105,536	7,366,424
		157,715	20,617,970	2,100,711	4,039,471	27,815,867
						27,815,867

A2	Costs					
Year	Constr	Maint	VOC	Accident	Time	Total
0	2,450,000	0	0	0	0	2,450,000
1	0	35,251	4,417,013	469,526	799,947	5,721,737
		128,801	16,139,139	1,715,580	2,922,892	23,356,412
						23,356,412

A3	Costs					
Year	Constr	Maint	VOC	Accident	Time	Total
0	2,940,000	0	0	0	0	2,940,000
1	0	35,251	4,608,282	469,526	718,220	5,831,279
		128,801	16,838,009	1,715,580	2,624,273	24,246,663
						24,246,663

A1-A0	Costs					
Year	Constr	Maint	VRC	Accident	Time	Total
0	(900,000)	0	0	0	0	0
1	0	0	767,720	0	76,135	843,855
						3,083,325
						3.4259

A2-A0	Costs					
Year	Constr	Maint	VRC	Accident	Time	Total
0	(2,450,000)	0	0	0	0	0
1	0	7,913	1,993,501	105,404	381,724	2,488,542
						9,092,780
						3.7113

A3-A0	Costs					
Year	Constr	Maint	VRC	Accident	Time	Total
0	(2,940,000)	0	0	0	0	0
1	0	7,913	1,802,232	105,404	463,451	2,379,000
						8,692,529
						2.9566

RESULTS OF SIMULATION ANALYSIS

PROJECT: Proj 3	SIMULATION ANALYSIS: SUMMARY OF RESULTS			
RADR 30.11%	Alt 0	Alt 1	Alt 2	Alt 3
PWOC at RFDR	100,576,256	91,139,001	72,541,509	74,373,404
PWOC at RADR	29,999,192	27,815,867	23,356,412	24,246,663
B/C ratio at RFDR		11.4858	12.4428	9.9125
B/C ratio at RADR		3.4259	3.7113	2.9566
Standard deviation	19,150,550	17,087,652	13,327,548	13,704,639
Mean	100,254,122	90,861,595	72,325,175	74,142,877
Coefficient of variation	0.191020	0.188062	0.184273	0.184841
Number of iterations	250	250	250	250

RESULTS OF SENSITIVITY ANALYSIS

Unit prices	Present values of costs				B/C ratios		
	A0	A1	A2	A3	A0 - A1	A0 - A2	A0 - A3
1.20	116,668,442	105,350,267	83,678,766	85,979,271	13.5758	14.4652	11.4385
1.10	108,622,349	98,244,634	78,110,137	80,176,337	12.5308	13.4540	10.6755
1	100,576,256	91,139,001	72,541,509	74,373,404	11.4858	12.4428	9.9125
0.90	92,530,163	84,033,368	66,972,881	68,570,470	10.4409	11.4315	9.1496
0.80	84,484,071	76,927,735	61,404,253	62,767,537	9.3959	10.4203	8.3866

Unit Price: Travel time	Present values of costs				B/C ratios		
	A0	A1	A2	A3	A0 - A1	A0 - A2	A0 - A3
1.20	103,471,359	93,847,573	74,501,386	76,133,048	11.6931	12.8245	10.2987
1.10	102,023,808	92,493,287	73,521,448	75,253,226	11.5895	12.6336	10.1056
1	100,576,256	91,139,001	72,541,509	74,373,404	11.4858	12.4428	9.9125
0.90	99,128,705	89,784,715	71,561,571	73,493,581	11.3822	12.2519	9.7194
0.80	97,681,153	88,430,429	70,581,633	72,613,759	11.2786	12.0610	9.5263

Unit Price: Accidents	Present values of costs				B/C ratios		
	A0	A1	A2	A3	A0 - A1	A0 - A2	A0 - A3
1.20	101,598,466	92,161,211	73,376,314	75,208,209	11.4858	12.5192	9.9763
1.10	101,087,361	91,650,106	72,958,912	74,790,806	11.4858	12.4810	9.9444
1	100,576,256	91,139,001	72,541,509	74,373,404	11.4858	12.4428	9.9125
0.90	100,065,151	90,627,896	72,124,107	73,956,001	11.4858	12.4045	9.8807
0.80	99,554,046	90,116,791	71,706,704	73,538,599	11.4858	12.3663	9.8488

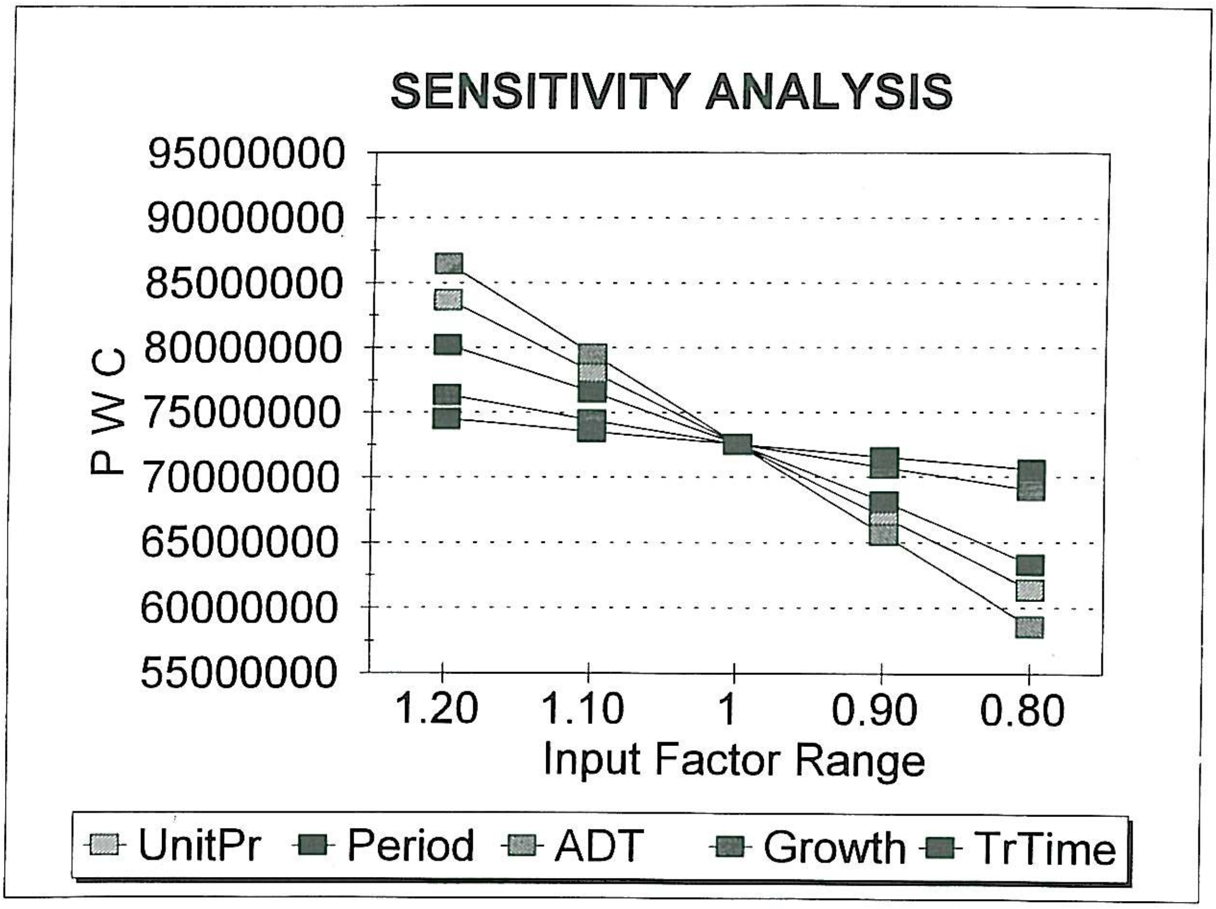
Construction costs	Present values of costs				B/C ratios		
	A0	A1	A2	A3	A0 - A1	A0 - A2	A0 - A3
1.20	100,576,256	91,319,001	73,031,509	74,961,404	9.5715	10.3690	8.2604
1.10	100,576,256	91,229,001	72,786,509	74,667,404	10.4417	11.3116	9.0114
1	100,576,256	91,139,001	72,541,509	74,373,404	11.4858	12.4428	9.9125
0.90	100,576,256	91,049,001	72,296,509	74,079,404	12.7620	13.8253	11.0139
0.80	100,576,256	90,959,001	72,051,509	73,785,404	14.3573	15.5534	12.3907

A D T	Present values of costs				B/C ratios		
	A0	A1	A2	A3	A0 - A1	A0 - A2	A0 - A3
1.20	120,585,755	109,081,049	86,473,447	88,573,720	13.7830	14.9234	11.8884
1.10	110,581,006	100,110,025	79,507,478	81,473,562	12.6344	13.6831	10.9005
1	100,576,256	91,139,001	72,541,509	74,373,404	11.4858	12.4428	9.9125
0.90	90,571,507	82,167,977	65,575,541	67,273,245	10.3373	11.2024	8.9246
0.80	80,566,757	73,196,953	58,609,572	60,173,087	9.1887	9.9621	7.9366

Traffic growth rate	Present values of costs				B/C ratios		
	A0	A1	A2	A3	A0 - A1	A0 - A2	A0 - A3
1.20	105,994,969	96,000,445	76,317,419	78,221,653	12.1050	13.1133	10.4467
1.10	103,240,083	93,528,877	74,397,739	76,265,195	11.7902	12.7724	10.1751
1	100,576,256	91,139,001	72,541,509	74,373,404	11.4858	12.4428	9.9125
0.90	98,000,171	88,827,841	70,746,418	72,543,922	11.1915	12.1240	9.6586
0.80	95,508,633	86,592,532	69,010,239	70,774,482	10.9068	11.8157	9.4130

Vehicle occu-pancy rate	Present values of costs				B/C ratios		
	A0	A1	A2	A3	A0 - A1	A0 - A2	A0 - A3
1.20	103,471,359	93,847,573	74,501,386	76,133,048	11.6931	12.8245	10.2987
1.10	102,023,808	92,493,287	73,521,448	75,253,226	11.5895	12.6336	10.1056
1	100,576,256	91,139,001	72,541,509	74,373,404	11.4858	12.4428	9.9125
0.90	99,128,705	89,784,715	71,561,571	73,493,581	11.3822	12.2519	9.7194
0.80	97,681,153	88,430,429	70,581,633	72,613,759	11.2786	12.0610	9.5263

Vehicle speed	Present values of costs				B/C ratios		
	A0	A1	A2	A3	A0 - A1	A0 - A2	A0 - A3
1.20	98,163,670	88,881,857	70,908,279	72,907,033	11.3131	12.1246	9.5907
1.10	99,260,300	89,907,832	71,650,656	73,573,565	11.3916	12.2692	9.7370
1	100,576,256	91,139,001	72,541,509	74,373,404	11.4858	12.4428	9.9125
0.90	102,184,647	92,643,763	73,630,330	75,350,984	11.6010	12.6548	10.1271
0.80	104,195,135	94,524,716	74,991,355	76,572,959	11.7449	12.9199	10.3953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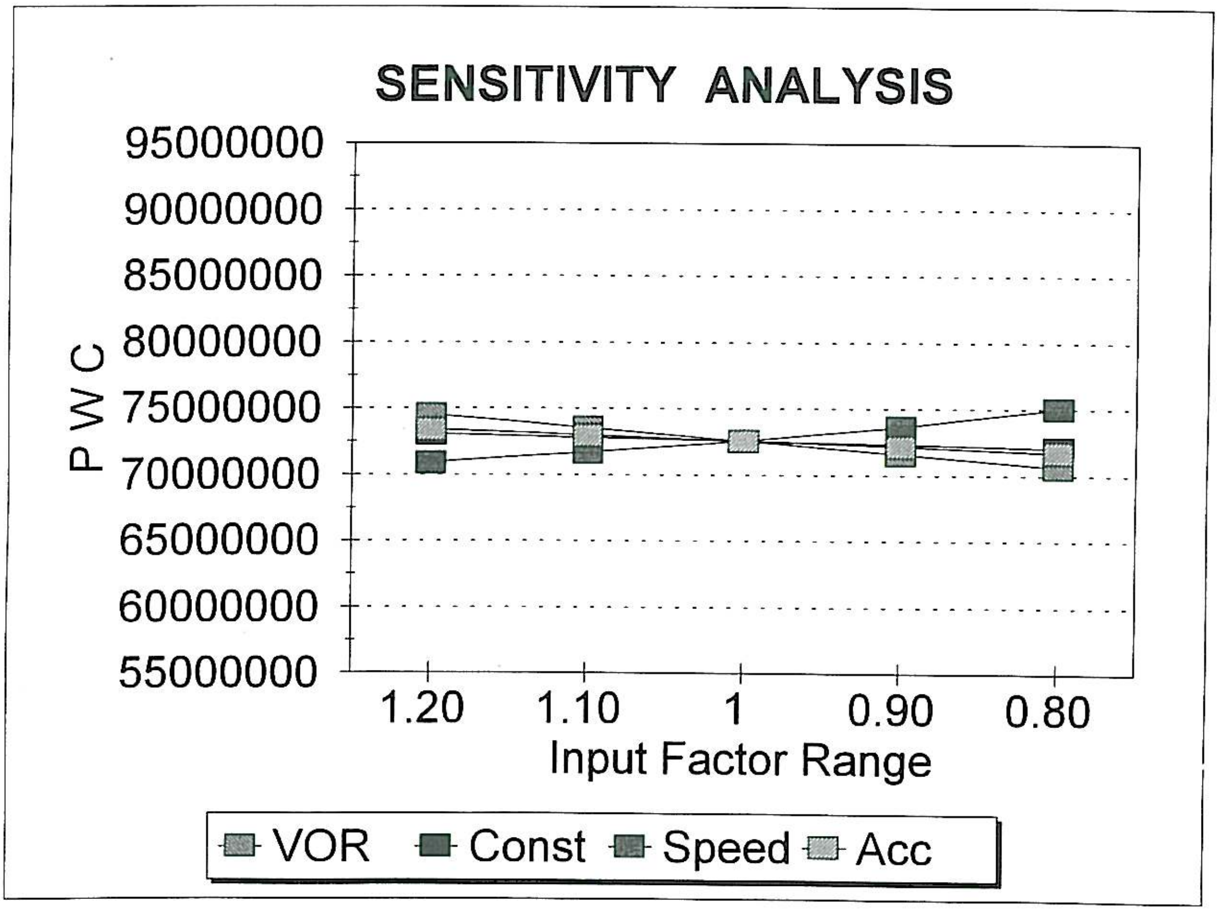
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Input Factor Range
VOR
Const
Speed
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APPENDIX G.4

PROJECT 4

COST FLOW MATRIX

A0	Costs					
Year	Constr	Maint	VOC	Accident	Time	Total
0	0	0	0	0	0	0
1	0	96,255	539,084	44,013	77,107	756,459
		549,288	3,076,335	251,167	440,016	4,316,806
						4,316,806

A1	Costs					
Year	Constr	Maint	VOC	Accident	Time	Total
0	1,000,000	0	0	0	0	1,000,000
1	0	96,255	381,344	44,013	74,696	596,308
		549,288	2,176,175	251,167	426,259	4,402,889
						4,402,889

A2	Costs					
Year	Constr	Maint	VOC	Accident	Time	Total
0	2,250,000	0	0	0	0	2,250,000
1	0	86,630	382,537	39,612	64,216	572,995
		494,359	2,182,985	226,050	366,455	5,519,849
						5,519,849

A1-A0	Costs					
Year	Constr	Maint	VRC	Accident	Time	Total
0	(1,000,000)	0	0	0	0	0
1	0	0	157,740	0	2,411	160,151
						913,917
						0.9139

A2-A0	Costs					
Year	Constr	Maint	VRC	Accident	Time	Total
0	(2,250,000)	0	0	0	0	0
1	0	9,626	156,547	4,401	12,891	183,464
						1,046,957
						0.4653

RESULTS OF SIMULATION ANALYSIS

PROJECT: Proj 4	SIMULATION ANALYSIS: SUMMARY OF RESULTS			
RADR 18.68%	Alt 0	Alt 1	Alt 2	Alt 3
PWOC at RFDR PWOC at RADR	8,588,243 4,316,806	7,770,014 4,402,889	8,755,332 5,519,849	ERR ERR
B/C ratio at RFDR B/C ratio at RADR		1.8182 0.9139	0.9257 0.4653	ERR ERR
Standard deviation Mean Coefficient of variation	767,951 8,632,238 0.088963	580,777 7,798,737 0.074471	572,918 8,776,968 0.065275	ERR ERR ERR
Number of iterations	250	250	250	250

RESULTS OF SENSITIVITY ANALYSIS

Unit prices	Present values of costs				B/C ratios		
	A0	A1	A2	A3	A0 - A1	A0 - A2	A0 - A3
1.20	9,842,721	8,666,321	9,651,306	ERR	2.1764	1.0851	ERR
1.10	9,215,482	8,218,168	9,203,319	ERR	1.9973	1.0054	ERR
1	8,588,243	7,770,014	8,755,332	ERR	1.8182	0.9257	ERR
0.90	7,961,004	7,321,861	8,307,344	ERR	1.6391	0.8461	ERR
0.80	7,333,765	6,873,708	7,859,357	ERR	1.4601	0.7664	ERR

Unit Price: Travel time	Present values of costs				B/C ratios		
	A0	A1	A2	A3	A0 - A1	A0 - A2	A0 - A3
1.20	8,763,324	7,939,622	8,901,143	ERR	1.8237	0.9387	ERR
1.10	8,675,783	7,854,818	8,828,237	ERR	1.8210	0.9322	ERR
1	8,588,243	7,770,014	8,755,332	ERR	1.8182	0.9257	ERR
0.90	8,500,702	7,685,211	8,682,426	ERR	1.8155	0.9192	ERR
0.80	8,413,161	7,600,407	8,609,520	ERR	1.8128	0.9127	ERR

Unit Price: Accidents	Present values of costs				B/C ratios		
	A0	A1	A2	A3	A0 - A1	A0 - A2	A0 - A3
1.20	8,657,771	7,839,543	8,817,907	ERR	1.8182	0.9288	ERR
1.10	8,623,007	7,804,779	8,786,620	ERR	1.8182	0.9273	ERR
1	8,588,243	7,770,014	8,755,332	ERR	1.8182	0.9257	ERR
0.90	8,553,478	7,735,250	8,724,044	ERR	1.8182	0.9242	ERR
0.80	8,518,714	7,700,486	8,692,756	ERR	1.8182	0.9226	ERR

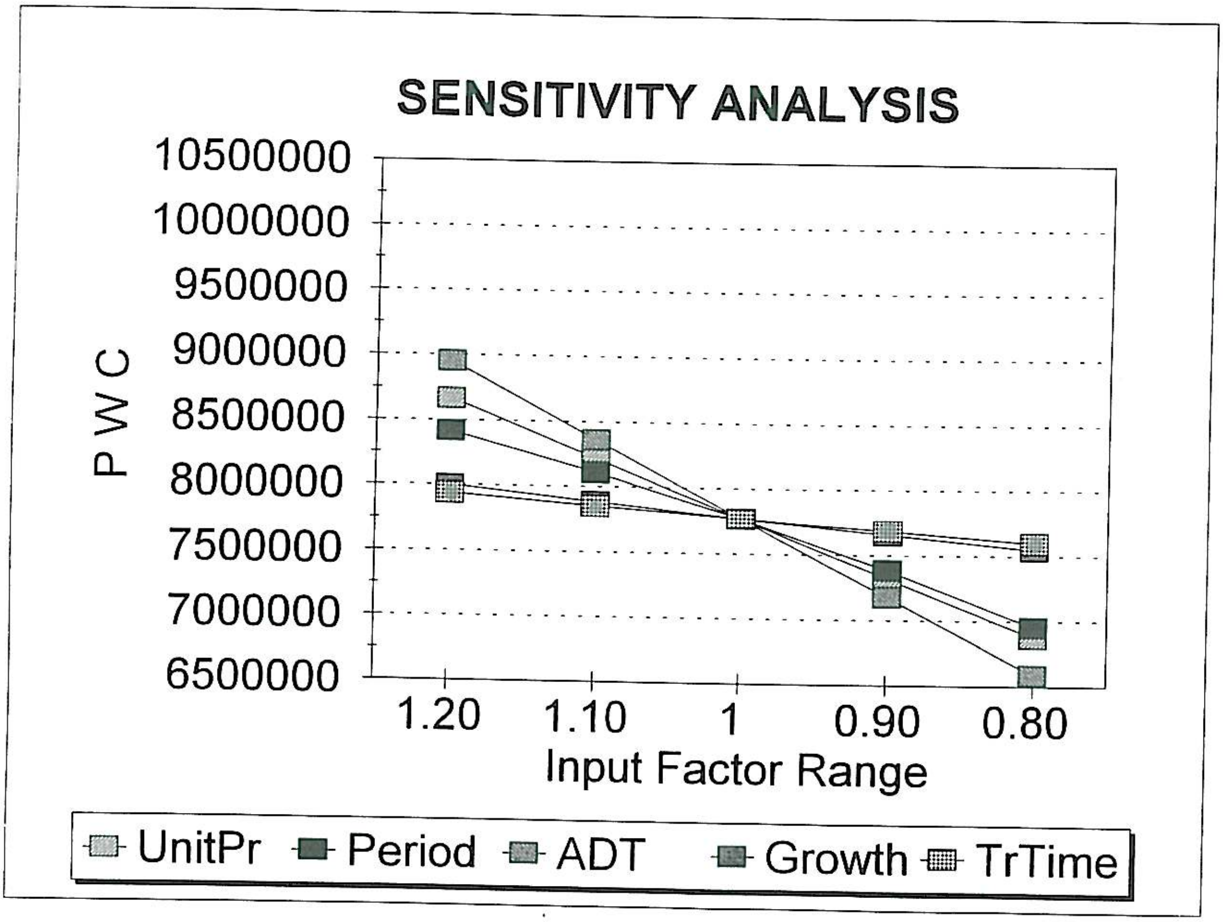
Construction costs	Present values of costs				B/C ratios		
	A0	A1	A2	A3	A0 - A1	A0 - A2	A0 - A3
1.20	8,588,243	7,970,014	9,205,332	ERR	1.5152	0.7714	ERR
1.10	8,588,243	7,870,014	8,980,332	ERR	1.6529	0.8416	ERR
1	8,588,243	7,770,014	8,755,332	ERR	1.8182	0.9257	ERR
0.90	8,588,243	7,670,014	8,530,332	ERR	2.0203	1.0286	ERR
0.80	8,588,243	7,570,014	8,305,332	ERR	2.2728	1.1572	ERR

A D T	Present values of costs				B/C ratios		
	A0	A1	A2	A3	A0 - A1	A0 - A2	A0 - A3
1.20	10,137,126	8,955,252	9,904,509	ERR	2.1819	1.1034	ERR
1.10	9,362,684	8,362,633	9,329,920	ERR	2.0001	1.0146	ERR
1	8,588,243	7,770,014	8,755,332	ERR	1.8182	0.9257	ERR
0.90	7,813,801	7,177,396	8,180,743	ERR	1.6364	0.8369	ERR
0.80	7,039,360	6,584,777	7,606,154	ERR	1.4546	0.7481	ERR

Traffic growth rate	Present values of costs				B/C ratios		
	A0	A1	A2	A3	A0 - A1	A0 - A2	A0 - A3
1.20	8,882,338	8,001,124	8,977,614	ERR	1.8812	0.9577	ERR
1.10	8,733,671	7,884,299	8,865,250	ERR	1.8494	0.9415	ERR
1	8,588,243	7,770,014	8,755,332	ERR	1.8182	0.9257	ERR
0.90	8,445,974	7,658,211	8,647,800	ERR	1.7878	0.9103	ERR
0.80	8,306,788	7,548,827	8,542,596	ERR	1.7580	0.8952	ERR

Vehicle occu-pancy rate	Present values of costs				B/C ratios		
	A0	A1	A2	A3	A0 - A1	A0 - A2	A0 - A3
1.20	8,763,324	7,939,622	8,901,143	ERR	1.8237	0.9387	ERR
1.10	8,675,783	7,854,818	8,828,237	ERR	1.8210	0.9322	ERR
1	8,588,243	7,770,014	8,755,332	ERR	1.8182	0.9257	ERR
0.90	8,500,702	7,685,211	8,682,426	ERR	1.8155	0.9192	ERR
0.80	8,413,161	7,600,407	8,609,520	ERR	1.8128	0.9127	ERR

Vehicle speed	Present values of costs				B/C ratios		
	A0	A1	A2	A3	A0 - A1	A0 - A2	A0 - A3
1.20	8,442,341	7,628,675	8,633,822	ERR	1.8137	0.9149	ERR
1.10	8,508,660	7,692,920	8,689,054	ERR	1.8157	0.9198	ERR
1	8,588,243	7,770,014	8,755,332	ERR	1.8182	0.9257	ERR
0.90	8,685,510	7,864,241	8,836,338	ERR	1.8213	0.9330	ERR
0.80	8,807,094	7,982,024	8,937,596	ERR	1.8251	0.9420	ERR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Growth
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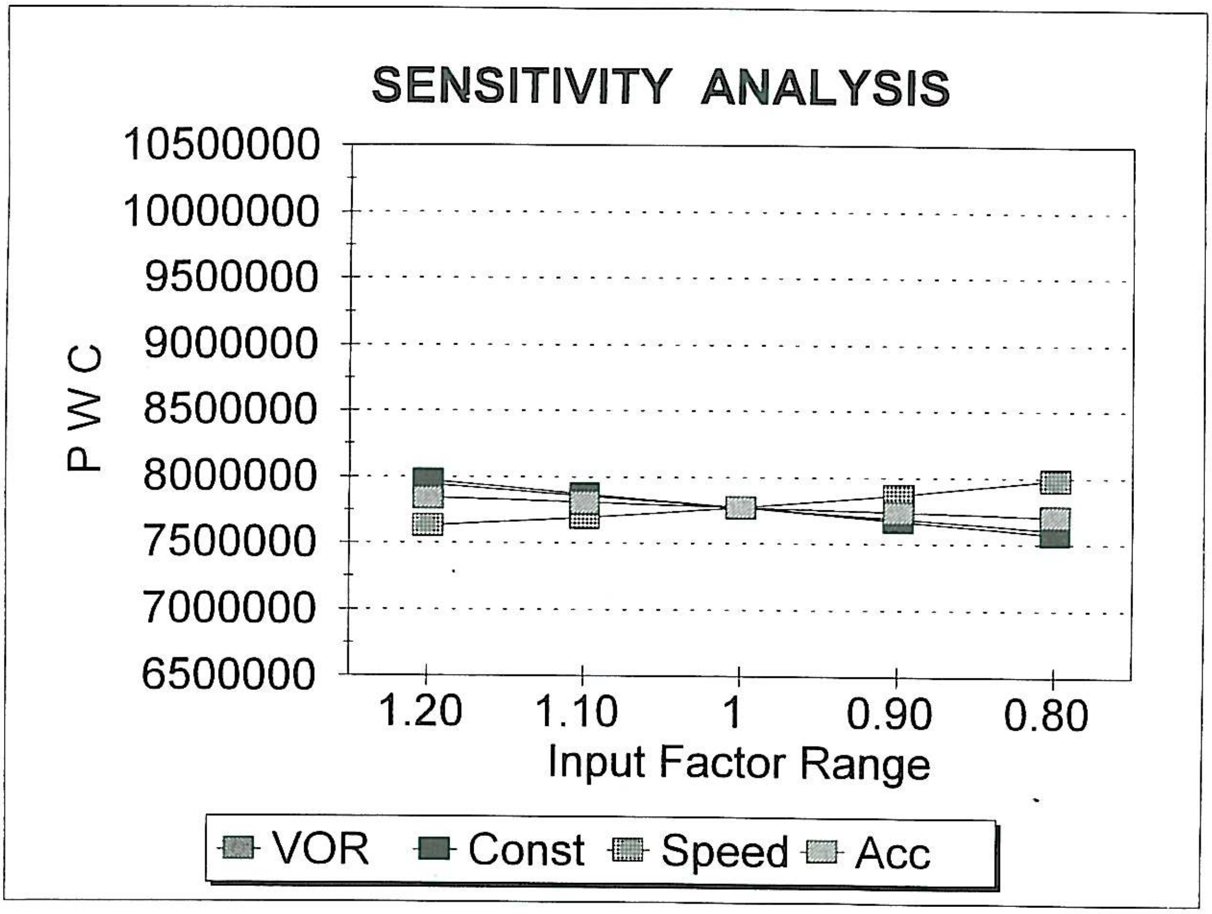
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Input Factor Range
VOR
Const
Speed
Acc

APPENDIX G.5

PROJECT 5

COST FLOW MATRIX

A0	Costs					
Year	Constr	Maint	VOC	Accident	Time	Total
0	0	0	0	0	0	0
1	0	237,402	47,601,650	4,446,720	23,948,749	76,234,522
		1,503,173	301,402,426	28,155,583	151,637,831	482,699,015
						482,699,015

A1	Costs					
Year	Constr	Maint	VOC	Accident	Time	Total
0	8,250,000	0	0	0	0	8,250,000
1	0	237,402	46,078,791	4,446,720	22,578,108	73,341,020
		1,503,173	291,760,036	28,155,583	142,959,255	472,628,048
						472,628,048

A2	Costs					
Year	Constr	Maint	VOC	Accident	Time	Total
0	17,700,000	0	0	0	0	17,700,000
1	0	212,223	41,191,646	3,975,098	18,111,581	63,490,548
		1,343,746	260,815,790	25,169,385	114,678,260	419,707,181
						419,707,181

A1-A0	Costs					
Year	Constr	Maint	VRC	Accident	Time	Total
0	(8,250,000)	0	0	0	0	0
1	0	0	1,522,860	0	1,370,641	2,893,501
						18,320,967
						2.2207

A2-A0	Costs					
Year	Constr	Maint	VRC	Accident	Time	Total
0	(17,700,000)	0	0	0	0	0
1	0	25,179	6,410,004	471,622	5,837,168	12,743,973
						80,691,833
						4.5589

RESULTS OF SIMULATION ANALYSIS

PROJECT: Proj 5	SIMULATION ANALYSIS: SUMMARY OF RESULTS			
RADR 17.70%	Alt 0	Alt 1	Alt 2	Alt 3
PWOC at RFDR	933,876,049	906,680,540	795,461,849	ERR
PWOC at RADR	482,699,015	472,628,048	419,707,181	ERR
B/C ratio at RFDR		4.2964	8.8200	ERR
B/C ratio at RADR		2.2207	4.5589	ERR
Standard deviation	76,393,959	73,551,841	64,043,582	ERR
Mean	930,109,720	903,111,682	792,523,716	ERR
Coefficient of variation	0.082134	0.081443	0.080810	ERR
Number of iterations	250	250	250	250

RESULTS OF SENSITIVITY ANALYSIS

Unit prices	Present values of costs				B/C ratios		
	A0	A1	A2	A3	A0 - A1	A0 - A2	A0 - A3
1.20	1,053,488,831	1,022,562,303	899,053,122	ERR	4.7487	9.7252	ERR
1.10	993,682,440	964,621,422	847,257,485	ERR	4.5225	9.2726	ERR
1	933,876,049	906,680,540	795,461,849	ERR	4.2964	8.8200	ERR
0.90	874,069,657	848,739,658	743,666,212	ERR	4.0703	8.3674	ERR
0.80	814,263,266	790,798,777	691,870,576	ERR	3.8442	7.9148	ERR

Unit Price: Travel time	Present values of costs				B/C ratios		
	A0	A1	A2	A3	A0 - A1	A0 - A2	A0 - A3
1.20	992,550,682	961,997,091	839,835,372	ERR	4.7035	9.6280	ERR
1.10	963,213,365	934,338,816	817,648,610	ERR	4.4999	9.2240	ERR
1	933,876,049	906,680,540	795,461,849	ERR	4.2964	8.8200	ERR
0.90	904,538,732	879,022,264	773,275,087	ERR	4.0929	8.4160	ERR
0.80	875,201,415	851,363,989	751,088,325	ERR	3.8694	8.0120	ERR

Unit Price: Accidents	Present values of costs				B/C ratios		
	A0	A1	A2	A3	A0 - A1	A0 - A2	A0 - A3
1.20	941,782,205	914,586,697	802,529,474	ERR	4.2964	8.8674	ERR
1.10	937,829,127	910,633,618	798,995,661	ERR	4.2964	8.8437	ERR
1	933,876,049	906,680,540	795,461,849	ERR	4.2964	8.8200	ERR
0.90	929,922,970	902,727,462	791,928,036	ERR	4.2964	8.7963	ERR
0.80	925,969,892	898,774,383	788,394,224	ERR	4.2964	8.7726	ERR

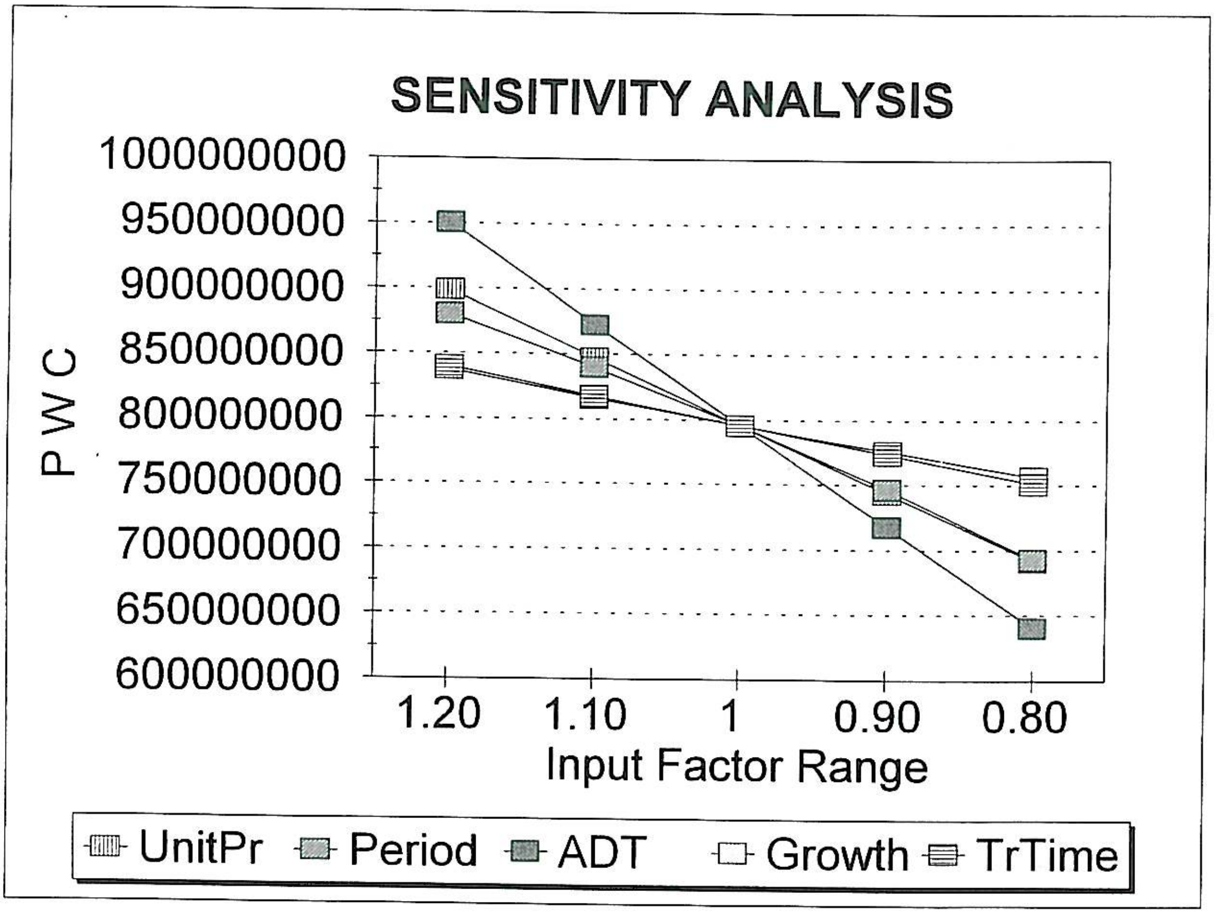
Construction costs	Present values of costs				B/C ratios		
	A0	A1	A2	A3	A0 - A1	A0 - A2	A0 - A3
1.20	933,876,049	908,330,540	799,001,849	ERR	3.5804	7.3500	ERR
1.10	933,876,049	907,505,540	797,231,849	ERR	3.9058	8.0182	ERR
1	933,876,049	906,680,540	795,461,849	ERR	4.2964	8.8200	ERR
0.90	933,876,049	905,855,540	793,691,849	ERR	4.7738	9.8000	ERR
0.80	933,876,049	905,030,540	791,921,849	ERR	5.3705	11.0250	ERR

A D T	Present values of costs				B/C ratios		
	A0	A1	A2	A3	A0 - A1	A0 - A2	A0 - A3
1.20	1,120,069,621	1,085,785,011	950,494,270	ERR	5.1557	10.5805	ERR
1.10	1,026,972,835	996,232,775	872,978,060	ERR	4.7261	9.7003	ERR
1	933,876,049	906,680,540	795,461,849	ERR	4.2964	8.8200	ERR
0.90	840,779,262	817,128,304	717,945,638	ERR	3.8668	7.9398	ERR
0.80	747,682,476	727,576,069	640,429,427	ERR	3.4371	7.0595	ERR

Traffic growth rate	Present values of costs				B/C ratios		
	A0	A1	A2	A3	A0 - A1	A0 - A2	A0 - A3
1.20	984,202,388	955,096,056	837,374,149	ERR	4.5280	9.2954	ERR
1.10	958,616,322	930,481,460	816,065,810	ERR	4.4103	9.0537	ERR
1	933,876,049	906,680,540	795,461,849	ERR	4.2964	8.8200	ERR
0.90	909,950,747	883,663,643	775,536,598	ERR	4.1863	8.5940	ERR
0.80	886,810,747	861,402,228	756,265,348	ERR	4.0798	8.3754	ERR

Vehicle occupancy rate	Present values of costs				B/C ratios		
	A0	A1	A2	A3	A0 - A1	A0 - A2	A0 - A3
1.20	992,550,682	961,997,091	839,835,372	ERR	4.7035	9.6280	ERR
1.10	963,213,365	934,338,816	817,648,610	ERR	4.4999	9.2240	ERR
1	933,876,049	906,680,540	795,461,849	ERR	4.2964	8.8200	ERR
0.90	904,538,732	879,022,264	773,275,087	ERR	4.0929	8.4160	ERR
0.80	875,201,415	851,363,989	751,088,325	ERR	3.8894	8.0120	ERR

Vehicle speed	Present values of costs				B/C ratios		
	A0	A1	A2	A3	A0 - A1	A0 - A2	A0 - A3
1.20	884,980,521	860,583,414	758,483,912	ERR	3.9572	8.1467	ERR
1.10	907,205,761	881,536,653	775,292,065	ERR	4.1114	8.4528	ERR
1	933,876,049	906,680,540	795,461,849	ERR	4.2964	8.8200	ERR
0.90	966,473,067	937,411,957	820,113,806	ERR	4.5226	9.2689	ERR
0.80	1,007,219,340	975,826,229	850,928,753	ERR	4.8052	9.8300	ERR



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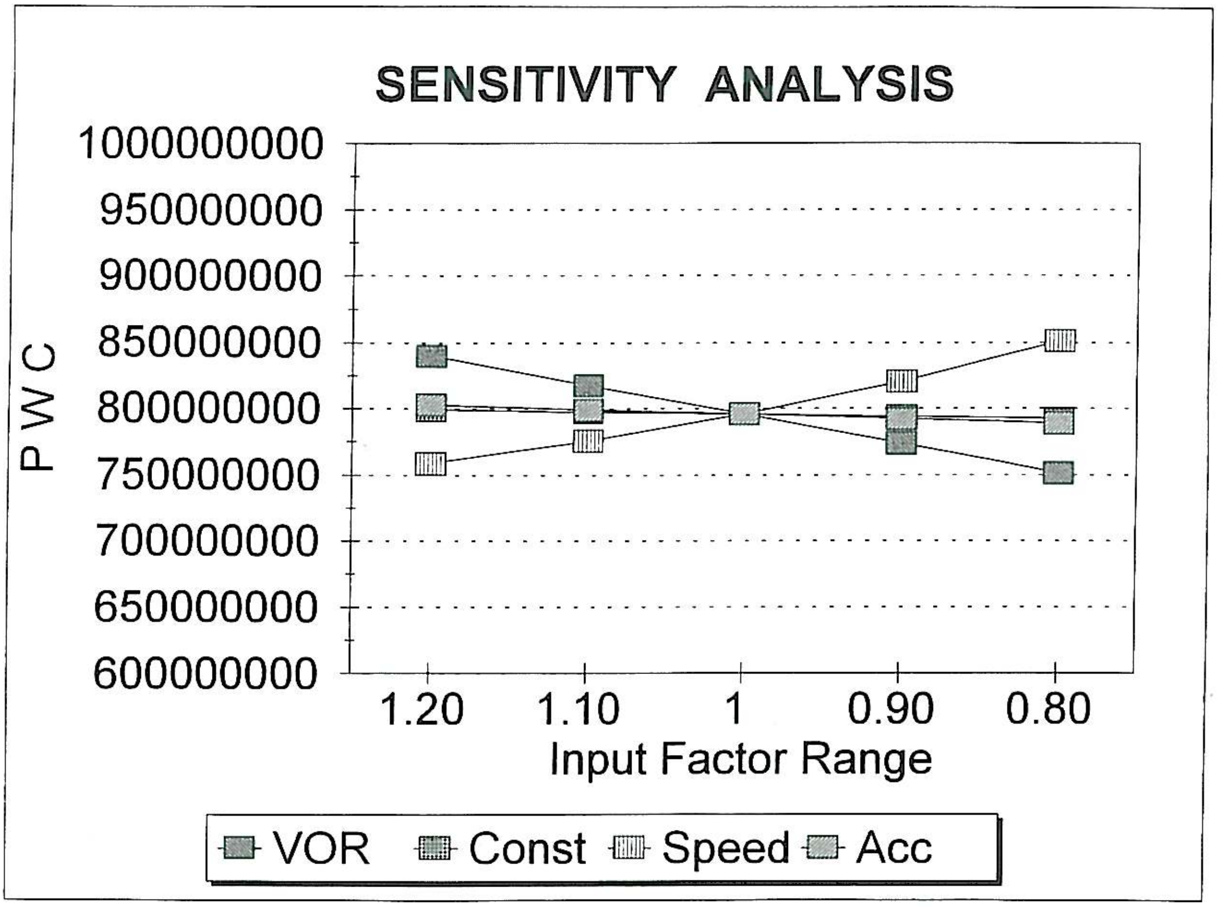
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0.90
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Input Factor Range
VOR
Const
Speed
Acc

APPENDIX H:

EXAMPLE OF OUTPUT FILE COSTCALC FOR PROJECT 2

COSTS

			Alt 0	Alt 1	Alt 2	Alt 3
MAINTENANCE		MAI	111,507	111,507	208,058	208,058
Fuel	Cars	Fc	3,348,965	2,964,941	319,803	2,922,287
	L D Vs	Fd	295,555	237,235	255,372	244,505
	L G Vs	Fl	785,840	677,814	647,916	676,377
	H G Vs	Fh	4,536,410	4,417,792	4,172,108	4,947,667
	Buses	Fb	1,165,463	926,816	912,042	902,340
Tyres	Cars	Tc	400,077	723,303	701,983	716,478
	L D Vs	Td	30,910	55,882	54,235	55,355
	L G Vs	Tl	194,984	350,972	386,289	394,104
	H G Vs	Th	1,641,656	2,959,606	3,410,409	3,473,957
	Buses	Tb	194,984	350,972	386,289	394,104

Oil						
	Cars	Oc	121,117	115,836	112,832	108,930
	L D Vs	Od	12,229	11,425	10,991	10,835
	L G Vs	Ol	20,654	19,839	18,377	18,595
	H G Vs	Oh	112,379	111,487	103,094	108,955
	Buses	Ob	29,652	27,842	25,982	25,912
Depeciation						
	Cars	Dc	11,059,918	11,296,786	9,848,540	10,132,312
	L D Vs	Dd	768,021	783,180	686,016	709,161
	L G Vs	Dl	1,727,569	1,736,017	1,513,023	1,563,328
	H G Vs	Dh	3,630,133	3,672,344	3,170,988	3,287,000
	Buses	Db	1,877,576	1,918,393	1,682,708	1,720,102

Maintenance					
Cars	Mc	3,917,434	3,826,331	3,705,722	3,588,875
L D Vs	Fd	439,591	427,465	418,461	394,390
L G Vs	Fl	688,493	688,493	642,358	634,618
H G Vs	Fh	2,870,338	2,870,338	2,668,270	2,648,935
Buses	Fb	726,540	710,213	688,041	665,605
VEHICLE OPERATING COSTS		40,596,490	41,881,322	36,541,850	40,344,727
Accidents					
fatal		2,845,676	2,845,676	2,607,006	2,607,006
serious		552,262	552,262	505,943	505,943
slight		219,523	219,523	201,112	201,112
damage		131,674	131,674	120,631	120,631
ACCIDENT COSTS		3,749,136	3,749,136	3,434,692	3,434,692
Time					
cars		3,159,836	3,009,368	2,631,652	2,517,233
L D Vs		220,612	209,581	182,860	174,548
L G Vs		203,641	193,459	168,794	161,122
H G Vs		739,697	698,603	606,326	576,010
buses		7,586,641	7,165,161	6,218,727	5,907,791
TIME COSTS		11,910,427	11,276,172	9,808,359	9,336,703

APPENDIX I:

EXAMPLE OF OUTPUT FILE MONTE CARLO FOR PROJECT 2

Present values of costs				B/C ratios									
686,402,549	696,502,982	629,321,677	672,736,525	-2.2582	3.6799	1.5347	4.6720E+15	4.9219E+15	3.7797E+15	4.4991E+15	0.3410	0.1120	0.0032
981,079,343	1,001,127,192	896,231,228	967,412,789	-5.4670	4.9835	1.5347	5.1223E+16	5.4975E+16	4.2201E+16	5.1802E+16	6.8902	0.9388	0.0032
677,827,872	689,742,511	623,316,934	669,284,454	-2.8434	3.5592	1.3342	5.9177E+15	5.9161E+15	4.5541E+15	4.9741E+15	0.0000	0.2074	0.0660
770,312,877	785,413,895	707,249,391	761,927,100	-3.8713	3.9607	1.3281	2.4207E+14	3.5175E+14	2.7054E+14	4.8909E+14	1.0592	0.0029	0.0692
763,872,806	775,418,783	696,591,336	745,640,699	-3.1383	4.5097	1.7926	8.3146E+13	7.6736E+13	3.3524E+13	3.3977E+13	0.0877	0.2452	0.0405
695,890,648	706,402,273	634,242,910	678,776,151	-3.2386	4.6178	1.8370	3.4649E+15	3.6309E+15	3.1989E+15	3.7253E+15	0.1572	0.3639	0.0604
705,508,295	717,737,730	647,993,359	695,450,371	-2.9450	3.7002	1.3935	2.4252E+15	2.3933E+15	1.8325E+15	1.9679E+15	0.0106	0.0988	0.0391
594,793,650	605,098,439	551,163,484	591,153,654	-2.0219	2.8621	1.1295	2.5587E+16	2.6102E+16	1.9499E+16	2.2099E+16	0.6727	1.3281	0.2132
691,076,536	701,092,947	633,317,221	676,669,586	-2.2311	3.7117	1.5637	4.0549E+15	4.2989E+15	3.3044E+15	3.9869E+15	0.3734	0.0917	0.0008
628,568,197	638,988,440	578,513,514	620,256,180	-2.3614	3.3500	1.3252	1.5923E+16	1.6300E+16	1.2609E+16	1.4294E+16	0.2311	0.4417	0.0708
718,774,797	732,173,738	660,894,643	710,534,506	-3.3222	3.7174	1.3224	1.2945E+15	1.1892E+15	8.9441E+14	8.5716E+14	0.2305	0.0883	0.0723
851,157,362	864,082,985	776,044,464	830,615,711	-3.1696	4.5264	1.8037	9.2935E+15	9.4915E+15	7.2664E+15	8.2454E+15	0.1072	0.2620	0.0451
732,888,259	743,594,187	667,309,412	713,499,509	-3.3169	4.8485	1.9482	4.7813E+14	5.3198E+14	5.5187E+14	6.9233E+14	0.2254	0.6955	0.1274
798,498,491	810,549,347	727,241,374	778,494,783	-3.3193	4.7171	1.8696	1.9135E+15	1.9264E+15	1.3279E+15	1.4964E+15	0.2277	0.4936	0.0775
742,574,264	753,106,182	678,912,906	725,178,979	-2.3974	3.9888	1.6806	1.4836E+14	1.8368E+14	1.4133E+14	2.1412E+14	0.1978	0.0007	0.0080
990,343,289	1,007,459,862	904,013,731	970,497,908	-4.0195	4.6846	1.7058	5.5502E+16	5.7985E+16	4.5460E+16	5.3216E+16	1.3863	0.4489	0.0131
702,547,855	716,928,978	649,327,763	699,893,486	-3.2173	3.2715	1.0944	2.7255E+15	2.4731E+15	1.7201E+15	1.5935E+15	0.1408	0.5522	0.2468
837,280,845	846,445,262	760,432,705	808,523,094	-1.9563	4.6079	2.1251	6.8106E+15	6.3659E+15	4.8485E+15	4.7213E+15	0.7848	0.3520	0.2850
766,109,675	777,297,934	702,005,402	750,196,789	-2.2810	3.7360	1.5660	1.2894E+14	1.1319E+14	1.2553E+14	1.0785E+14	0.3148	0.0776	0.0006
798,471,511	811,973,718	730,826,220	783,900,060	-3.3556	4.1758	1.5701	1.9112E+15	2.0534E+15	1.6020E+15	1.9438E+15	0.2636	0.0260	0.0004
743,122,766	754,841,253	680,277,794	728,668,006	-2.7802	3.9505	1.5655	1.3529E+14	1.3966E+14	1.1074E+14	1.2418E+14	0.0038	0.0041	0.0007
1,023,578,185	1,042,149,827	932,139,625	1,002,676,077	-4.9909	5.2929	1.8178	7.2266E+16	7.5895E+16	5.8244E+16	6.9098E+16	4.6170	1.6341	0.0513
866,278,116	881,570,962	791,436,634	850,406,323	-3.9332	4.5137	1.6210	1.2438E+16	1.3205E+16	1.0127E+16	1.2231E+16	1.1904	0.2491	0.0009
762,505,367	772,763,626	692,313,391	739,226,778	-3.1364	5.1192	2.1384	6.0078E+13	3.7268E+13	2.2864E+12	3.4218E+11	0.0866	1.2203	0.2994
864,884,772	877,966,921	788,381,530	843,754,257	-3.2200	4.5917	1.8267	1.2129E+16	1.2389E+16	9.5219E+15	1.0804E+16	0.1428	0.3331	0.0554
658,001,622	669,614,464	605,933,221	650,472,755	-2.7461	3.4445	1.2946	9.3611E+15	9.4176E+15	7.2026E+15	7.9815E+15	0.0092	0.3250	0.0880
805,621,489	819,042,052	736,814,199	790,242,258	-3.3292	4.2304	1.6017	2.5875E+15	2.7440E+15	2.1172E+15	2.5432E+15	0.2373	0.0466	0.0001
746,727,074	758,445,561	683,579,805	731,970,017	-2.7802	3.9647	1.5773	6.4438E+13	6.7459E+13	5.2150E+13	6.1493E+13	0.0038	0.0025	0.0002
730,948,781	743,507,495	670,586,219	719,601,256	-3.0512	3.8339	1.4440	5.6671E+14	5.3599E+14	4.0865E+14	4.0846E+14	0.0437	0.0326	0.0217
730,948,781	743,507,495	670,586,219	719,601,256	-3.0512	3.8339	1.4440	5.6671E+14	5.3599E+14	4.0865E+14	4.0846E+14	0.0437	0.0326	0.0217
719,389,245	727,725,201	656,332,583	698,435,298	-1.6890	3.9604	1.8198	1.2507E+15	1.5158E+15	1.1881E+15	1.7120E+15	1.3297	0.0029	0.0522
789,189,080	801,439,384	721,003,953	772,117,285	-2.9517	4.2012	1.6679	1.1857E+15	1.2097E+15	9.1220E+14	1.0436E+15	0.0120	0.0348	0.0059
620,664,005	630,438,566	575,532,701	615,324,046	-1.6276	2.7657	1.1741	1.7980E+16	1.8556E+16	1.3287E+16	1.5497E+16	1.4751	1.5597	0.1740
817,287,324	829,867,660	745,899,949	798,703,182	-3.0582	4.3515	1.7271	3.9104E+15	3.9953E+15	3.0359E+15	3.4682E+15	0.0467	0.1135	0.0185
801,869,463	815,290,025	733,236,564	786,664,622	-3.3292	4.2222	1.5949	2.2198E+15	2.3650E+15	1.8007E+15	2.1952E+15	0.2373	0.0431	0.0000
700,603,012	710,257,241	643,145,904	686,424,410	-1.8312	3.4523	1.5043	2.9324E+15	3.1811E+15	2.2710E+15	2.8502E+15	1.0221	0.3162	0.0076
895,777,052	909,219,236	815,484,517	872,700,771	-3.3362	4.7696	1.9028	1.9887E+16	2.0323E+16	1.5546E+16	1.7659E+16	0.2441	0.5701	0.0971
739,518,458	751,236,945	676,975,783	725,365,995	-2.7802	3.9363	1.5537	2.3213E+14	2.3784E+14	1.9115E+14	2.0868E+14	0.0038	0.0061	0.0014
750,331,382	762,049,869	686,881,816	735,272,028	-2.7802	3.9789	1.5892	1.9563E+13	2.1243E+13	1.5363E+13	2.0609E+13	0.0038	0.0013	0.0000
756,295,229	765,794,865	688,246,453	733,549,408	-2.4049	4.5498	1.9888	2.3742E+12	7.4654E+11	6.5274E+12	3.9217E+13	0.1912	0.2864	0.1580
672,054,367	682,911,005	617,351,824	661,329,015	-2.5021	3.5682	1.4196	6.8393E+15	7.0137E+15	5.3948E+15	6.1595E+15	0.1156	0.1993	0.0295
766,109,675	776,987,934	699,875,402	747,640,789	-2.5091	4.1096	1.7226	1.2894E+14	1.0669E+14	8.2339E+13	6.1294E+13	0.1109	0.0090	0.0172
742,075,222	749,402,905	675,502,522	716,855,447	-1.3638	4.1255	1.9867	1.6076E+14	2.9777E+14	2.3405E+14	5.2699E+14	2.1855	0.0123	0.1564
787,000,436	798,336,156	718,463,495	767,942,926	-2.6567	4.2177	1.7456	1.0398E+15	1.0034E+15	7.6520E+14	7.9136E+14	0.0344	0.0413	0.0238
746,727,074	758,755,561	685,709,805	734,526,017	-2.5274	3.6042	1.4340	6.4438E+13	6.2463E+13	2.5924E+13	2.7939E+13	0.0990	0.1684	0.0247
638,949,645	646,423,752	584,821,385	622,511,079	-1.4110	3.5412	1.6431	1.3411E+16	1.4456E+16	1.1232E+16	1.3759E+16	2.0481	0.2241	0.0027
833,426,048	845,166,156	759,223,736	811,402,144	-2.7871	4.4837	1.8617	6.1892E+15	6.1634E+15	4.6816E+15	5.1252E+15	0.0030	0.2200	0.0731
743,122,766	755,151,253	682,407,794	731,224,006	-2.5274	3.5913	1.4232	1.3529E+14	1.3243E+14	7.0451E+13	7.3749E+13	0.0990	0.1791	0.0282
594,793,650	604,788,439	549,033,484	588,597,654	-2.2241	3.1484	1.2424	2.5587E+16	2.6202E+16	2.0098E+16	2.2866E+16	0.3819	0.7503	0.1217
640,046,605	648,360,940	587,568,299	625,882,818	-1.6820	3.4638	1.5541	1.3158E+16	1.3994E+16	1.0657E+16	1.2980E+16	1.3458	0.3034	0.0014
763,435,320	773,102,521	698,438,296	743,989,719	-1.8350	3.7741	1.6916	7.5359E+13	4.1520E+13	5.8323E+13	1.7456E+13	1.0144	0.0578	0.0101
597,677,096	607,671,886	551,675,093	591,239,263	-2.2241	3.1597	1.2519	2.4673E+16	2.5277E+16	1.9356E+16	2.2074E+16	0.3819	0.7308	0.1152
715,170,489	728,569,430	657,592,632	707,232,495	-3.3222	3.7032	1.3106	1.5669E+15	1.4508E+15	1.1028E+15	1.0614E+15	0.2305	0.0970	0.0788
834,804,401	848,600,854	762,577,633	817,796,462	-3.4505	4.3909	1.6654	6.4080E+15	6.7145E+15	5.1518E+15	6.0816E+15	0.3701	0.1416	0.0055
746,727,074	758,445,561	683,579,805	731,970,017	-2.7802	3.9647	1.5773	6.4438E+13	6.7459E+13	5.2150E+13	6.1493E+13	0.0038	0.0025	0.0002
724,216,143	735,014,601	659,461,669	705,463,608	-3.3542	4.8001	1.9171	9.3258E+14	1.0014E+15	9.8217E+14	1.1798E+15	0.2622	0.6171	0.1062
749,166,699	761,962,802	686,644,663	736,782,934	-3.1278	3.9353	1.4845	3.1222E+13	2.2053E+13	1.7278E+13	9.1736E+12	0.0816	0.0063	0.0114
746,727,074	758,445,561	683,579,805	731,970,017	-2.7802	3.9647	1.5773	6.4438E+13	6.7459E+13	5.2150E+13	6.1493E+13	0.0038	0.0025	0.0002
666,482,854	679,180,507	614,285,290	660,835,088	-3.0960	3.4506	1.2210	7.7919E+15	7.6525E+15	5.8547E+15	6.2373E+15	0.0645	0.3181	0.1371