International Practices in Investment Decision Making in Road Sector

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PREFACE

This report is written under the research project entitled “Investment Decision-making Framework for Civil Infrastructure Assets Management”. The project has commenced at the CRC for Construction Innovation at RMIT University, with the collaboration several public and private industry partners.

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EXECUTIVE SUMMARY

This document provides the findings of an international review of investment decision-making practices in road asset management. Efforts were concentrated on identifying the strategic objectives of agencies in road asset management, establishing and understanding criteria different organisations adopted and ascertaining the exact methodologies used by different countries and international organisations.

Road assets are powerful drivers of economic development and social equity. They also have significant impacts on the natural and man-made environment. The traditional definition of asset management is "A systematic process of maintaining, upgrading and operating physical assets cost effectively. It combines engineering principles with sound business practices and economic theory and it provides tools to facilitate a more organised, logical approach to decision-making" (US Dept. of Transportation, 1999). In recent years, the concept has been broadened to cover the complexity of decision making, based on a wider variety of policy considerations as well as social and environmental issues rather than is covered by Benefit-Cost analysis and pure technical considerations.

Current international practices are summarised in table 2. It was evident that Engineering-economic analysis methods are well advanced to support decision-making. A range of tools available supports performance predicting of road assets and associated cost/benefit in technical context.

The need for considering triple plus one bottom line of social, environmental and economic as well as political factors in decision-making is well understood by road agencies around the world. The techniques used to incorporate these however, are limited. Most countries adopt a scoring method, a goal achievement matrix or information collected from surveys. The greater uncertainty associated with these non-quantitative factors has generally not been taken into consideration. There is a gap between the capacities of the decision-making support systems and the requirements from decision-makers to make more rational and transparent decisions.

The challenges faced in developing an integrated decision making framework are both procedural and conceptual. In operational terms, the framework should be easy to be understood and employed. In philosophical terms, the framework should be able to deal with challenging issues, such as uncertainty, time frame, network effects, model changes, while integrating cost and non-cost values into the evaluation. The choice of evaluation techniques depends on the feature of the problem at hand, on the aims of the analysis, and on the underlying information base

At different management levels, the complexity in considering social, environmental, economic and political factor in decision-making is different. At higher the strategic planning level, more non-cost factors are involved. The complexity also varies based on the scope of the investment proposals. Road agencies traditionally place less emphasis on evaluation of maintenance works. In some cases, social equity, safety, environmental issues have been used in maintenance project selection. However, there is not a common base for the applications.

1. INTRODUCTION

In this report, a comprehensive review of international practices, which includes the practices in North American and European countries, and international organisations, such as the World Bank and Organisation of Economic Co-operation and Development (OECD), is presented. The sections appear in the order of three main components of a decision-making framework: Section 2 goals/objectives, Section 3 decision-making criteria, and Section 4 evaluation methodology. A summary of findings is given in Section 5.

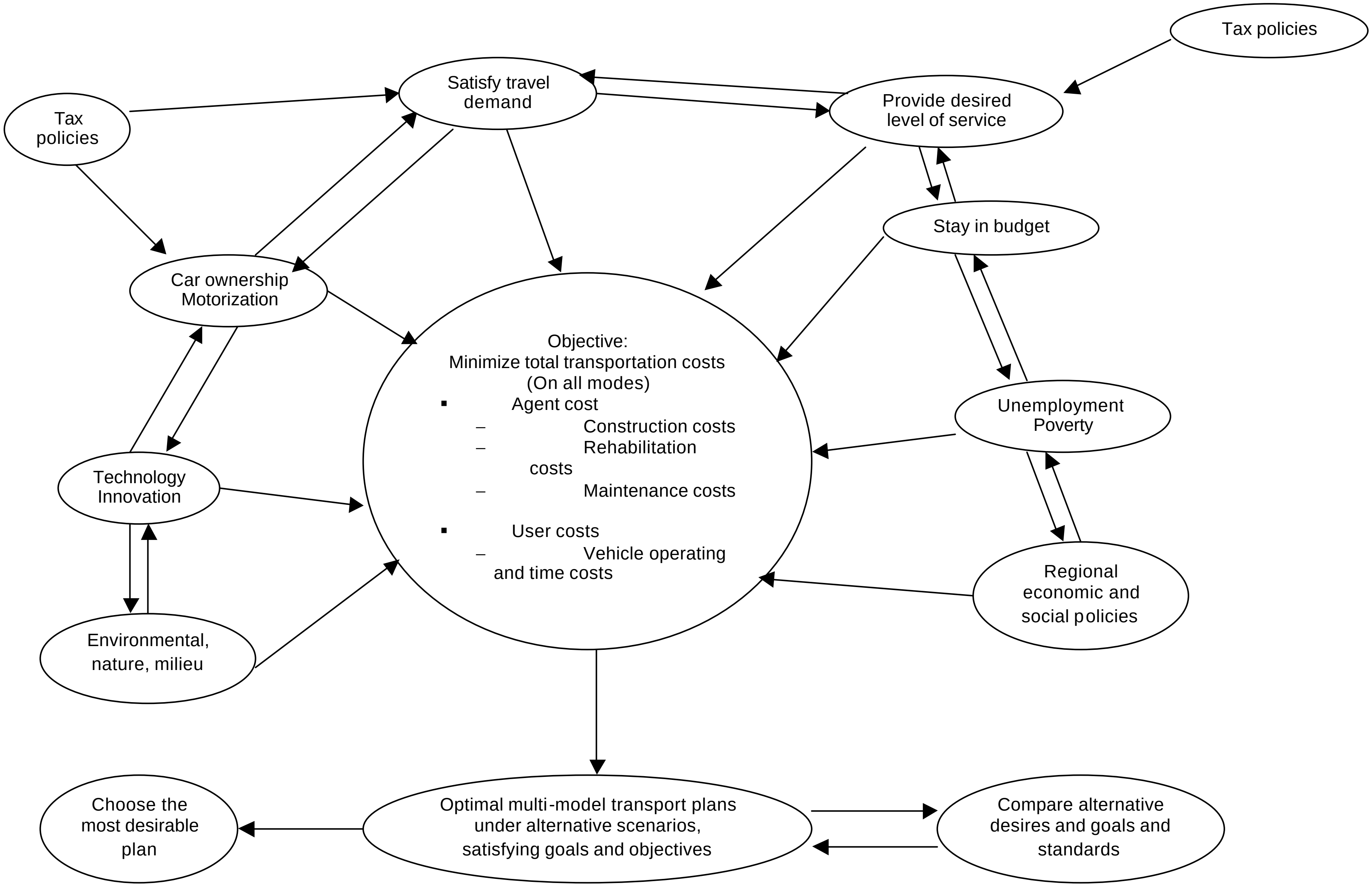
2. GOAL/OBJECTIVE OF CURRENT PRACTICES

This section discusses the goals and objectives of current practices in road sector. At present, road agencies have to consider a large number of issues in order to meet community expectations. However, traditionally, a single objective approach, engineering-economic analysis can be found in most of road authorities around the world (OECD 2001a & Sirajuddin 1997). This approach is established on the objective of **minimizing total road system cost**, including agency cost (construction, rehabilitation, and maintenance) and user costs (vehicle operating and time costs, pollution cost, and accident costs), within constraints as to characteristics and standards, and funding. In the current practice, social and environmental impacts are simplified to a certain extent that only issues such as air pollution, accident costs, and timesaving etc are considered. These issues are considered either quantitatively by some agencies by converting these impacts into monetary means or in a qualitative manner.

2.1 Organization for Economic Co-operation and Development (OECD)

The Working Group of Organisation for Economic Co-operation and Development (OECD 2002) investigated current evaluation practices for transportation planning in OECD countries. The objective of OCED is to minimize the total transportation costs on all modes. These transportation costs include agencies costs and user costs. Agencies costs include construction, rehabilitation and maintenance costs. User costs include vehicle operation and time costs, pollution and accident costs. The study found that some innovative evaluation frameworks for transportation infrastructure investment are being developed in many road agencies. Based on a globe wide investigation, the group concluded that investment decision-making in transport infrastructure could not be supported by solely a single objective decision-making approach such as Benefit-Cost Analysis. Figure 1 presents constellation of often competing and contradictory forces and demands which the decision makers face (OCED 1994).

Figure 1 Decision-making considerations in road rehabilitation and maintenance



(OECD 1994)

2.2 Finland

In addition to the common goals mentioned in Section 2.1, Finland has considered the data reliability in the evaluation process. According to Jansson (1999), Ministry of Transportation and Communication, of Finland conducted a comprehensive impact evaluation for proposed E18 highway. The study assessed traffic development, development alternatives and environmental impacts of the alternatives. The task force formulated four road and railway investment alternatives with different transport policies. Starting with a traffic impact study, the evaluation identifies the impacts on the national economy, regional and urban structure, the natural and cultural environment, well being, groundwater protection, energy use, emissions and traffic safety. Similar Impact evaluations for transportation infrastructure investment planning were conducted in Denmark, Norway, and Sweden. The lessons gained from these studies are:

- At the strategic level, a crucial question for decision-makers is balancing the objectives of: mobility, safety, environment and economy.

- Although there are different levels in strategic planning, it is not really hierarchical. The process is iterative, moving back and forth between levels and stages.

- Data reliability is one of the main concerns in the evaluation process. Data cost also tend to increase radically, while the results, as the number of factors increase, seem to lose their focus.

2.3 Canada

Transport Canada (2001) has adopted four principles that recognize sustainable development as among the highest of departmental priorities, and defined how the department will apply the concept of sustainable development to the transportation sector. The principles cover social, economical, environmental and managerial aspects, which are explained in details below. Transport Canada is committed to applying these principles to its policies, programs and operations so that decisions will better reflect the goal of sustainable transportation. While these principles are similar to the common goals set by other countries, Canada is more specific in defining different objectives.

SOCIAL PRINCIPLES
Safety and Health: Transportation systems should first be designed and operated in a way that protects the safety of all people. In addition to Transport Canada's commitment to prevent accidents, the department will strive to reduce the negative health impacts of transportation.

Access and Choice: Transportation systems should provide people with reasonable access to other people, places, goods and services. The department will promote a more diverse transportation system, including access to innovative alternatives (i.e. information technologies).

Quality of Life: Transportation is a key ingredient in the quality of life of Canadians. The department recognizes that transportation policies have a direct effect on people and that it must consider the characteristics of different communities and regions across the country.

ECONOMIC PRINCIPLES
Efficiency: Transport Canada will use policies, programs and innovative approaches to support the productivity and competitiveness of Canada's transportation system and its contribution to the national economy. The department will explore ways of promoting efficient travel behaviour and sustainable transportation options.

Cost Internalisation: The department recognizes the merit of "full cost pricing," whereby the costs of transportation reflect, to the extent possible, their full economic, social and environmental impacts. The department will assess barriers to sustainable transportation practices to better understand the full impact of its decisions

Affordability: Transportation systems should be affordable. The department will promote sustained strategic investment in transportation through new partnerships, innovative financing and a clear identification of priorities. In seeking cost-effective solutions, it will promote options that include demand management and that foster an appropriate mix of modal alternatives.

ENVIRONMENTAL PRINCIPLES

Pollution Prevention: Transport Canada will work to ensure that transportation needs are met in a way that avoids or minimizes the creation of pollutants and waste, and that reduces the overall risk to human health and the environment.

Protection and Conservation: The department will apply sound environmental protection and conservation practices. It will support transportation systems that make efficient use of land and natural resources, preserve vital habitats and maintain biodiversity.

Environmental Stewardship: The department will continually refine its environmental management system so that its internal operations support sustainable development. As both custodian and landlord, it will consider the potential environmental impacts of new initiatives, and will apply risk management and due diligence practices consistently to its real property assets.

MANAGEMENT PRINCIPLES

Leadership and Integration: Transport Canada recognizes sustainable development as among the highest of departmental priorities and accepts its responsibility to become a leader in sustainable transportation. The department will set priorities and responsibilities, allocate resources, and apply tools to integrate sustainable development into its policies, programs and operations.

Precautionary Principle: Where there are threats of serious or irreversible damage to the environment, the department will not use a lack of full scientific certainty as a reason for postponing cost-effective measures to prevent environmental degradation.

Consultation and Public Participation: The department will inform and engage employees, stakeholders and communities in its decision-making process as appropriate, and encourage them to participate in achieving the goal of sustainable transportation.

Accountability: The department will annually measure and report its progress in achieving its sustainable development objectives and targets. To this end, it will develop and refine sustainable transportation indicators.

3. DECISION-MAKING CRITERIA

Decision-making criteria represent and measure the performance in relation to the investment objectives. In a single objective decision-making approach, road agencies traditionally use economic or network condition indicators, such as Net Present Value (NPV), Benefit-Cost Ratio (BCR), Internal Return of Rate, Roughness, Pavement Condition Rating (PCR), and Present Serviceability Index (PSI) as evaluation criterion. With the use of multicriteria decision-making in road sectors, other criteria, which are related to social, environmental and political considerations, are adopted by road agencies.

3.1 The World Bank

According to Gwilliam (2000), in World Bank, besides the common engineering economic analysis which is widely applied in other countries and government agencies, three major "intangibles" factors, such as operation cost savings, accident cost savings and environmental impacts are also under consideration in Bank's project evaluation process.

In World Bank's evaluation process, benefit estimation is to calculate the **aggregate benefits** using standard national vehicle operating cost and benefit valuation conventions for such "intangibles" as time and pain and grief costs of accidents or loss of life, if available. Where such national standards are not available, operating cost values is constructed synthetically using the World Bank Highway Development and Management System (HDM) operating cost model parameters and time values follow default value recommendations by the World Bank infrastructure note.

For the evaluation of time saving, the Bank provides a sector guidance note, which recommends the estimation of local values, but also suggests some default principles of evaluation in the absence of such local values.

The evaluation of accident cost savings has been even more controversial and there is no explicit Bank guidance on this issue. Instead the Bank is assisting its client countries to make effective use of their own resources to accept within the evaluation of projects for Bank funding; valuation of accident savings at whatever valuation is currently adopted internally in the country.

Environmental impacts are somewhat similarly treated. All projects are pre-classified according to whether they have zero, small or large environmental impact. Those with non-zero impacts are required to have environmental impact assessments, and to contain mitigating measures to counter any adverse effects. This mandatory requirement covers the more obvious, immediate, consequences of projects. It does not, however, deal with more subtle effects, either positive or negative, associated with traffic generation or modal shift effects. It is rarely conducted to include such environmental effects within the central economic evaluation, except in cases, which are primarily viewed as environmental projects partly because of the absence of adequate data on the physical impacts of specific interventions, as well as the absence of evaluation conventions.

3.2 The United States

In USA, Legislation and public awareness challenged the traditional planning methodologies of transportation agencies. Transportation planners have to find out a solution to evaluate the investment impacts on congestion, pollution and safety. Donaghy and Schintler (1998) presented a dynamic transportation network model which optimises combinations of traffic demand management measures, lane widening, highway maintenance for achieving desired peak-period congestion levels, reducing vehicle mile travelled (VMT) and volatile organic compound (VOC) emissions. Therefore, traffic management and environmental control could be reflected in agency's budget allocation process.

Virginia Department of Transportation (Frohwein & Lambert 1999) considered crash-risk reduction, performance gain, and cost in selecting road improvement projects. Crash-risk reduction was calculated as the number of crashes avoided per year at the project site. Performance gain was quantified by the vehicle minutes of travel time saved in the peak hour, and cost in dollar is determined as the sum of preliminary engineering, right-of-way and construction cost. Other factors, such as environmental and political concerns also appeared in the decision-making process, but the detailed procedure was not mentioned in the paper.

3.3 Organisation for Economic Co-operation and Development

Based on a global wide investigation, the Working Group of Organisation for Economic Co-operation and Development (OECD 2002) suggested that following criteria could be used in road infrastructure investment decision-making (Table 1).

Table 1 Factors Considered in Road Infrastructure Investment Decision-making

Traditional BCA*	**Complementary Analysis**
User benefit	Transport network effects
Travel time	Reduced travel
Vehicle operating cost	Model shift
Safety	Reliability
	Quality of service
	Socio-economic spill over
	Accessibility
	Employment
	Efficiency & output
	Social inclusion
	Land use effect
	Environment impacts
	Air pollution
	Noise
	Lack of aesthetic quality

**BCA – Benefit Cost Analysis (OECD 2002)*

3.4 United Kingdom

In Northern Ireland, the road network is playing a vital role in promoting economic growth where 99% of freight moves by the roads. According to the corporate plan 2001-2004 & Business plan 2001-2002 of Road Service of Northern Ireland, all major road improvement schemes are assessed under the following 5 criteria:

- Integration- ensuring all decisions are taken in the context of an integrated transport policy;
- Safety- improving road safety for all road users;
- Economy- supporting sustainable economic activity in appropriate locations and getting good value for money;
- Environment- protecting the built and natural environment; and
- Accessibility- improving access to everyday facilities for those without a car and reducing community severance.

University of Birmingham, United Kingdom, developed an integrated road maintenance management system which is able to establish medium to long term rolling programmes based on existing road condition and economically justifiable serviceability standards, adjusted to cater for socio-political preferences (Costello & Snaith 2001). This last lead to a process whereby standards defined through the newly developed multicriteria analysis model (MCA) included political and social preferences in addition to economic considerations.

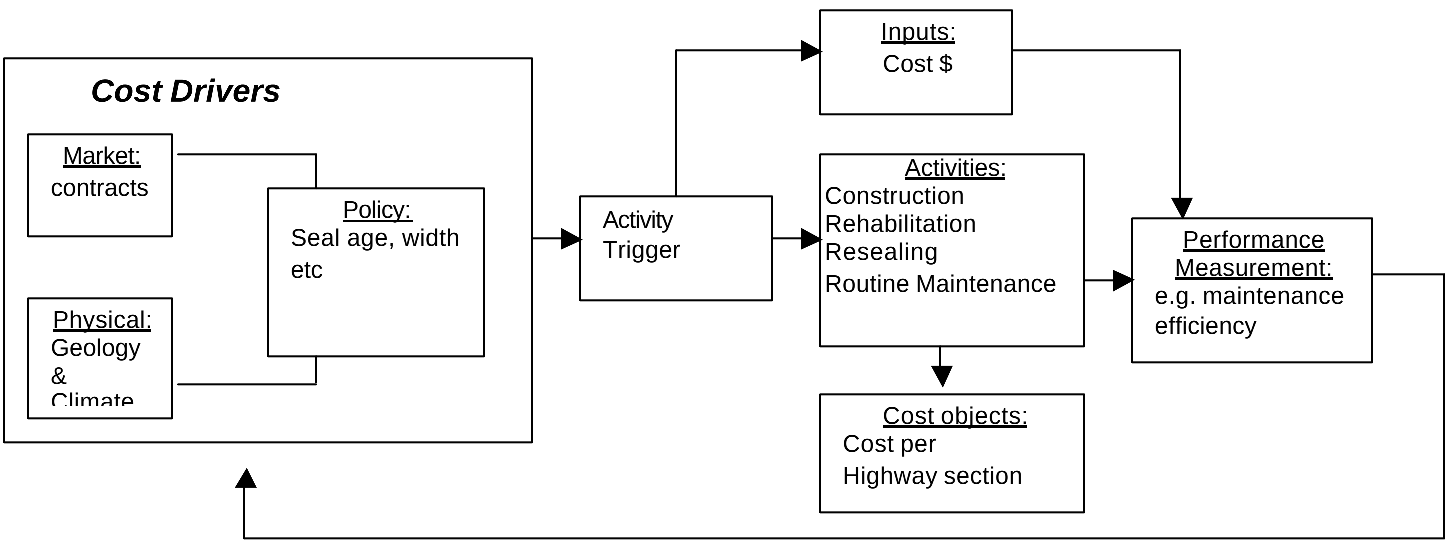
3.5 Slovakia

Slovakian researchers (Mikolaj & Celko 2001) developed an integrated road management system – Road Network Management System, which includes two parts. First part – Road Network Investment Plan, is based on national standard, road network characteristics, transportation characteristics, road parameters, assessment of environment and vehicle operating cost. A strategic plan for investment is modelled based on this information. The second part – Pavement Management System, is to create optimal rehabilitation budget. The authors proposed two possibilities to assess environmental impacts resulted from the investment. The first is used at project level, 25 indicators, such as a quality of water/ underground, air, noise, humidity, biology, forests, agriculture, bio-corridors, population etc. The second – a part of computer system, consist of noise calculation and emission from vehicle operations.

3.6 New Zealand

Based on the New Zealand conditions, Rouse and Putterill (2000) suggested focusing on the nature and extent of the impact of environmental cost drivers on costs of highway maintenance. The proposed cost management framework for highway maintenance is given in Figure 2. The study suggested that by linking a cost driver framework with engineering theory, and using geographic information systems (GIS) methodology, it has been possible to demonstrate that the physical geological environment has a significant effect on the cost of highway maintenance activity.

Figure 2 Cost Management Frameworks for Highway Maintenance

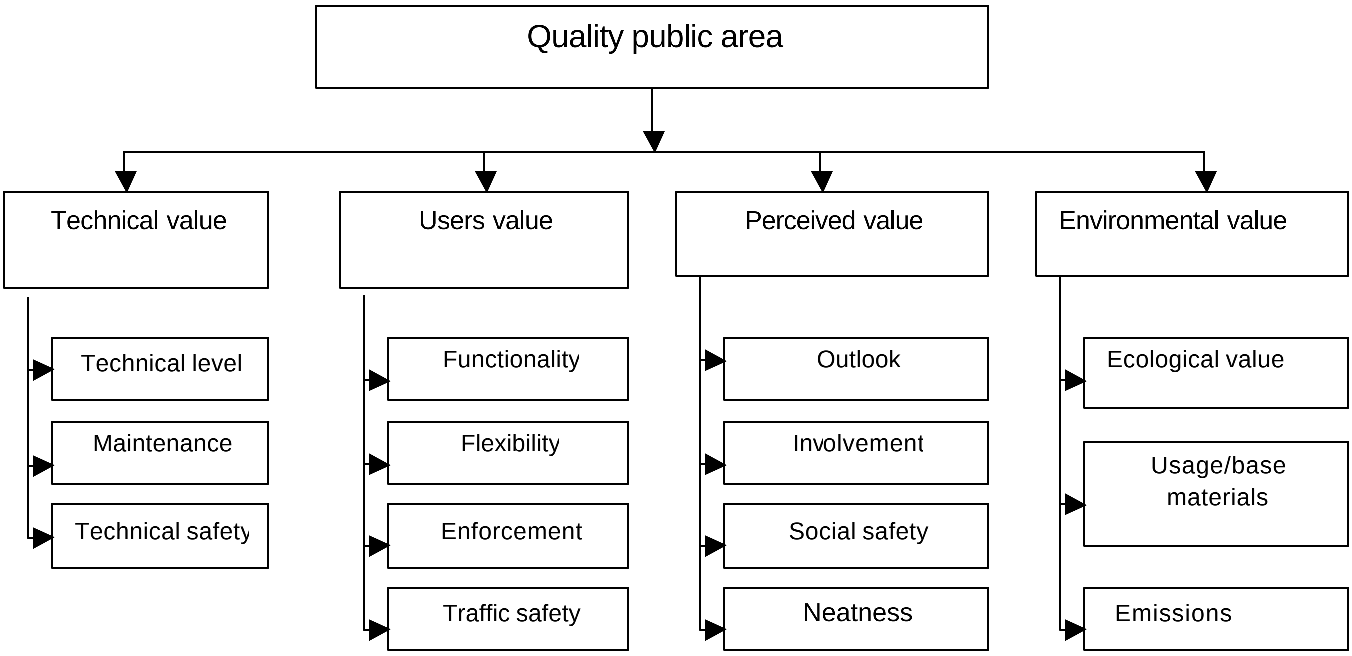


(Rouse & Putterill 2000)

3.7 Netherlands

Based on Dutch practices, researchers (Schut *et al* 2001) proposed a concept of Integrated Management Public Space to accommodate increased public involvement in road maintenance decision-making (see Figure 3). The system provides a platform for communication between decision-makers, stakeholders and public. Through Multi-Criteria Analysis (MCA), priorities from the policy makers, pavement managers and public can be translated to maintenance priorities.

Figure 3 Netherlands Integrated Management Public Space



(Schut et al 2001)

4. EVALUATION METHODOLOGY (INCLUDES FUND ALLOCATION)

Evaluation tools are key components of a decision-making framework, which provide the ability to articulate the impact of choosing one alternative over another through 'what if' analysis. We may classify these tools into four categories in decision-making literatures (Vreeker et al 2002):

- *Engineering–economic analysis*: based on Benefit-Cost Analysis (BCA) or Cost-effectiveness principles (Zimmerman *et al*. 2000 & Najafi & Paredes 2001);
- *Utility theory approach*: based on prior ranking of decision maker's preferences using Multi-Criteria Analysis (MCA) (El-gayar & Leung 2001, Frohwein *et al* 1999);
- *Learning approach*: based on an interactive or cyclical articulation of decision makers' views (Haapalinna 2002);
- *Collective approach*: based on multi-person negotiation or voting procedure (Zopounidis & Doumpos 2002 & Ghasemzadeh & Archer 2000).

Engineering–economic analysis are powerful tools for investment decision-making from economic perspective. While the decision involves conflicting goals, Multi-Criteria Analysis (MCA) is more suitable. Due to the complex nature of decision-making, there is not a single method that can satisfy all decision-making problems. The choice of evaluation technique depends on the feature of the problem at hand, on the aims of the analysis, and on the underlying information base.

Due to the limited practices on *learning approach* and *collective approach*, only literature review for BCA and MCA are presented in the following section.

4.1 Engineering-Economic analysis

Traditionally, the standard framework for evaluating infrastructure investments from economic perspective is Benefit-Cost Analysis (BCA) and Cost-Effectiveness Analysis (OECD 1994 & FHWA 1999). The theoretical basis of BCA was laid in the middle of 19th century. In the second part of the 20th century, this meaningful and practical approach has become popular and widespread in project evaluation. This approach can be employed to assess all direct and indirect (converted into dollars, e.g., cost of accident in HDM-4 model (PIARC 2002) benefits and costs of a given set of choice possibilities. Through the analysis, the most favourable option, from a monetary perspective, can be identified in a straightforward way.

However, researchers (Vreeker et al 2002) identified some intrinsic shortcomings and practical limitations of BCA:

- *Accuracy of information*: It has been very difficult to assess all indirect impacts, for example, long-term effect of infrastructure on biodiversity.
- *Distributional equity*: This effect is generally omitted in a BCA. However, it is an important consideration in infrastructure investment decision-making (Cox 1997 & De Silva & Tatam 1996).
- *Discount rate*: The value of a discount rate is not an unambiguous parameter, but it is essential for a socio-political decision (John *et al* 2002).
- *Lifetime of the project:* The lifetime is not only a technology issue, but also dependent on the emergence of alternative competing projects.

In addition, OECD report (2002) addressed the limitation of using BCA in transportation planning. The main reservations include the facts that BCA:

- Understates the economic development benefit of certain investment;
- Favours some groups of users to the detriment of others (bias resulting from BCA reliance on willingness-to-pay as a measure of opportunity cost);
- Fails to incorporate all the external effects of projects (e.g. environment impacts, social effects); and
- Fails to deal with distributional effects (e.g. impacts on deprived areas).

However, Austroad (1997) conducted a study on economic effects of the investment in road infrastructure. The report concluded that these criticisms are the products of the practice rather than of the theory of Benefit-Cost analysis. Most could be rectified if the analysts have the necessary resources to determine the project benefits.

4.2 Multi-Criteria analysis

After the popularity of BCA(Benefit Cost Analysis) and related engineering-economic evaluation techniques, such as Cost-Effectiveness Analysis and Life-Cycle Cost Analysis (Bull 1993 & Martin & Taylor 1994), there was an increasing popularity of Multi-Criteria Analysis (MCA), which is capable of dealing with the multiple dimensions of evaluation problems. These techniques aim to solve conflicting social, environmental, political and economic issues in modern decision-making.

MCA means different things to different people. Based on an extensive literature review, Lee (1997) classified MCA into five approaches:

- *Analytic Hierarchy Process (AHP)* uses hierarchy structures to represent a decision-making problem and then develop priorities for alternatives based on the decision-maker's judgments throughout the decision-making process (Saaty 1990, Greiner 2001).

- *Compromise Programming (CP)* determines solutions whose criteria values are close to given ideal criteria values, according to some measure of distance. This approach assumes that any planner seeks a solution as close as possible to the ideal point (vector) comprising of ideal values for all relevant objectives (El-gayar & Leung 2001).

- *Goal Programming (GP)* optimises multiple goals simultaneously by minimising the deviations among the desired levels of targets and the actual goal values through the addition of positive and negative deviation variables permitting either under or over achievement of each goal (Taplin *et al* 1996).

- *Multi-Attribute Utility Theory* (MAUT) consists of assessing and fitting utility functions and then using the functions and probabilities to come with priorities of alternatives (Prato 2000). The priorities are then investigated using sensitivity analysis. This approach is generally used for problems having stochastic outcomes.

- *Multi-Criteria Optimisation Model* (MCOM) solves problems which have multiple goals with multiple criteria. The solution is generally processed without assessing a utility function since the value functions are defined as a deterministic problem.

MCA has been widely used in strategic development of transport planning (Tsamboulas & Mikroudis 2000, Janssen 2001, Brand 2001), airport extension evaluation (Vreeker *et al* 2002), building maintenance planning (Costa & Oliveira 2002) and costal region management (Wind & Kok 2002).

4.3 Use of Engineering-Economic analysis in road sector

4.3.1 Switzerland

According to Güller (2000), Swiss project evaluation practice uses several assessment methods, such as:

- *Traffic model applications:* In general this is only done to predict traffic flows and accessibility ratios.

- *Econometric modelling:* There are a variety of efforts to predict global and spatial distribution effects of transport projects, but few of them are able to convince political decision makers.

- *Expert knowledge:* Which allows for a more or less systematic thinking through of causal paths and also for knowledge gained by statistical analysis or comparative analysis (see next category: case studies).

- *Case studies:* Politicians are inclined to attribute most attention to comparison with other cases where spatial effects of transport projects have become visible. They hereby rely on a mixture of expert knowledge and direct contacts with fellow politicians involved in the other case. The advantage for the decision makers is that they use similar sources of knowledge as is accessible to their potential political adversaries.

- *Experiments & surveys:* These methods are mainly applied if one wants to test out public opinion and the effects of measures on traffic flows. They are not able to simulate long-term changes of spatial structures.

It is found that besides engineering and economic considerations, some efforts and arrangements have been conducted to investigate the impacts of some non-monetary factors, such as political influence. It is also found that the practice in this area is still at its preliminary stage and there is no systematic methodology available for industry practice.

4.3.2 Netherlands

Based on Dutch practices, Schut *et al* (2001) suggested a 'Dedicated Road Fund' approach, which rolls on a five-year basis, to finance maintenance. Fund for capital work is separated from maintenance fund. The core of the approach is that estimation of the budget is based on the length of the network and designed service life of its components. The maintenance fund for programmed, routine, and rehabilitation operations are decided by:

- *Programmed maintenance:* The yearly budget is based on life cycle strategy. The budget must sustain in the road fund every year.

- *Routine maintenance:* The budget is related to programmed maintenance. When the needed budget based on lifecycle are defined, the budgets for routine maintenance can be defined and sustained yearly.

- *Rehabilitation:* The budget based on the average costs for the pavements per square meter per year in the life span of the pavement. The cost based on a major treatment at the end of the lifecycle to update the pavement. With the information about the area in the PMS for the different pavements the budget for rehabilitation is defined. The budget is also to be sustained in the road fund.

According to Eijgenraam (2000), in respect of large projects, a broad welfare-economical approach should be used. This implies that social *Benefit-Cost analysis (BCA)* must be used as the appraisal method for government investments.

Various methods are available for evaluating indirect impacts. It is advisable to employ an approach, which accommodates a number of research forms. This creates a total picture of the possible range of indirect impacts based on a variety of research methods. Indirect impacts are often evaluated by using the following methods:

- Macro-production function;
- Case studies;
- Targeted fieldwork;
- Models.

By using the *macro-production function*, the impacts on the national economy of the total investment in infrastructure of a country can be estimated. A lot of experience has been gained by this, both within and outside the Netherlands. Unfortunately the results vary substantially so that no clear picture emerges. Furthermore, it is not always clear in these analyses to what extent high investments are the cause or (also) the result of economic growth (causality). This method is only suitable for analysing total (macro) investments and not for evaluating a specific project.

Case studies can be used to draw lessons from comparable projects, for example, in other countries. Since situations and projects are not exactly the same in different countries, this does not provide an exact picture of the proposal being evaluated. Nevertheless, such a study can make a useful contribution when estimating the order of magnitude of impacts (by means of statistical indicators).

A third method to determine indirect impacts is *targeted fieldwork*: surveys and interviews. This method does not make any comparisons with the past, but looks explicitly at the expectations for the future (which may deviate from the past). A problem with this method is that the statements from respondents in surveys and interviews do not always correspond with their actual behaviour.

Finally, *models* can be used. These can be used to determine the impact of the project on the economy as a whole, including an overall estimate of the indirect welfare effects. Netherlands Bureau of Economic Policy Analysis (CPB)'s Athena model for example, may be used. It is used for short-term forecasts, medium- and long-term scenario building and for policy analysis. The model's ability to show changes in the production pattern makes it particularly appropriate for exploring long-term scenarios and for policy variants with different impacts upon individual branches. The direct impacts and the results of case studies and surveys can be used as input when using models to calculate impacts. This could partially solve the problem of a model not being detailed enough to avoid drawing ambiguous conclusions. In order to examine spatial-economical impacts, consideration could be given to constructing a spatial general equilibrium model.

It is found that in Netherlands the current practice includes the analyses of engineering economic factors as well as social and political issues. The existing difficulties are how to implement it to the project level for the social and political evaluations.

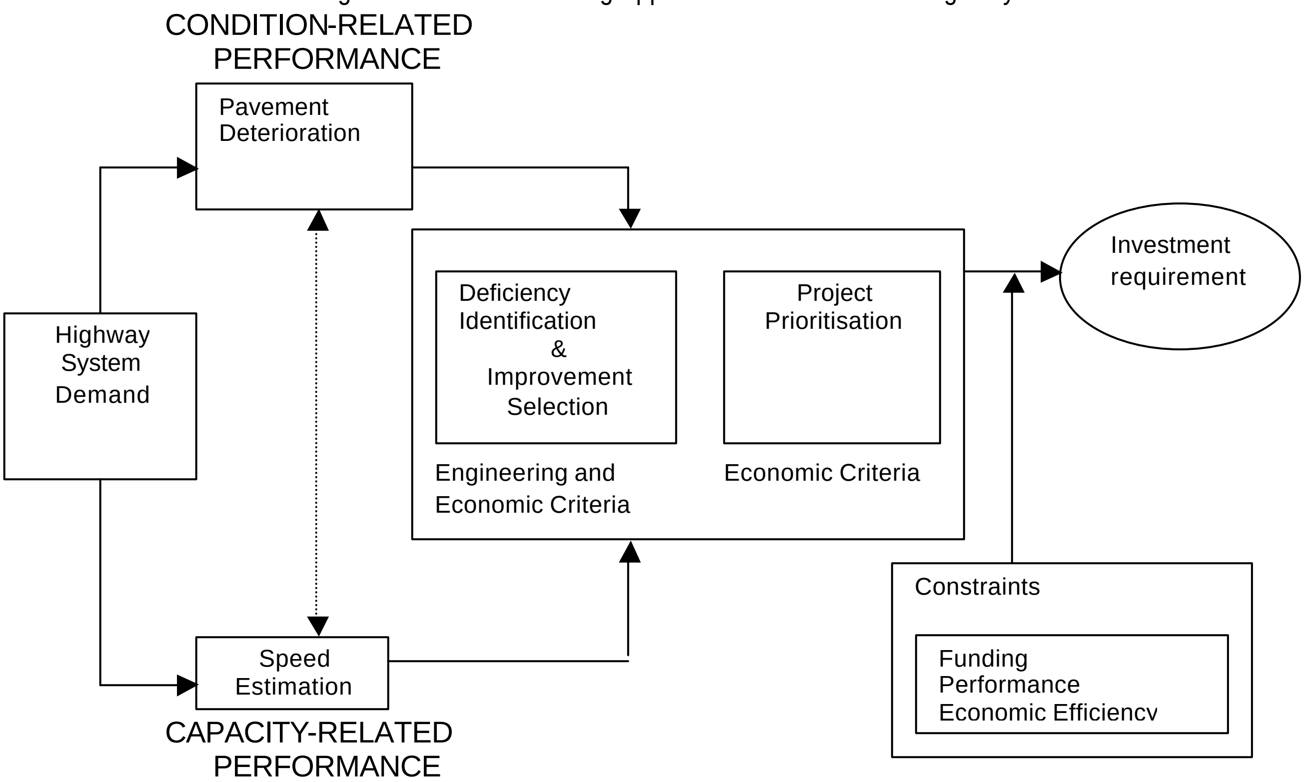
4.3.3 Finland

An integrated network level management model was established in Europe (Männistö et al 2001). The model adopted Markov technique, which is a probabilistic approach assuming that the future condition of a pavement is based on its existing condition, to predict the deterioration of pavements and bridges. Linear programming models are used in optimising long-term and short-term network condition and the distribution of the maintenance activities. The model relies on a condition classes approach to distribute budget between pavements and bridges, and also between different sub-networks. The sub-network of pavements and bridges are categories into homogenous groups based on road class, pavement type, bridge main material, climate and environment. Different condition parameters are applied for pavement and bridge. All condition parameters are classified into three condition classes: good, fair, and poor. Generally, this approach is based on a conventional Markov approach. The innovative idea is that it integrates pavement and bridge condition optimisation.

4.3.4 United Sates (FHWA)

Amekudzi (1999) summarised the general modelling approach for USA national highway investment in the last three decades, as shown in Figure 4. The approach is basically a discrete link-by link (or section-by-section) analysis, which can be used to simulate the impact of the usage on the pavement condition, identify deficient highway sections, select appropriate types of highway improvement projects for deficient sections, estimate the level of investment and prioritise projects according to their marginal benefits and cost. From 90's, environmental factors have been incorporated into the benefit-cost calculus, reflecting a growing intent to internalise costs from the environmental impacts of highways. According to Amekudzi (1999), the highway Economic Requirement Systems (HERS), which represents the state of the practice of national highway investment analysis, is a deterministic, dynamic, discrete, empirical, non-linear and non-monotonic model that performs policy-level benefit/cost analysis to develop investment requirement estimates for different scenarios of highway system performance.

Figure 4 General Modelling Approach for USA National Highway Investment



(Amekudzi 1999)

In May 2000, Federal Highway Administration (FHWA) issued investment estimates for highways for the years 1998 through 2017. To determine the estimates, FHWA used data from a statistically drawn national sample of 125,000 highway segments as well as information from the states on forecasts such as travel growth. FHWA officials reviewed the data submitted by the states and asked the states to correct serious flaws and improve some data submissions. FHWA used a computer model to simulate the effects of infrastructure improvements on a sample of highway sections and used a benefit-cost analysis to identify economically justified highway improvements. While FHWA's model analyses these sample highway sections individually, the model is designed to provide estimates of investment requirements valid at the national level and does not provide improvement recommendations for individual highway segments.

Montana Department of Transportation, USA, uses integrated performance programming to make trade-off decisions (McNeil 2001). The approach uses pavement, congestion, bridge, and safety management systems to develop a funding plan and support the capital program development. The pavement system uses an overall performance index based on various performance indicators. The bridge management system is PONTIS. The safety management systems use a safety management rating based on crash rate, severity, and number of crashes. The congestion management system is based on a level of service in rural areas and delay in urban areas. The systems are used to answer questions such as:

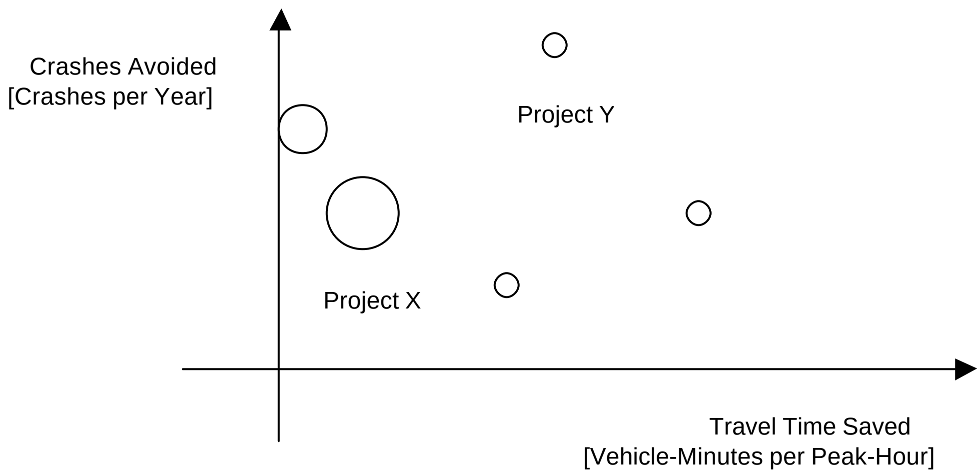
“What funding level is necessary to increase baseline performance by X% within the analysis period?” and “How many, where, and what kind of projects are needed to increase the baseline performance objective X% within the analysis period?” The result of the performance planning process is a funding plan that identifies investments by district. The plan also recognizes resource constraints and provides an opportunity for technical review and public comment.

Guignier and Madanat (1999) demonstrated a methodology, which performed joint optimisation of maintenance and improvements of a network. The study developed a Markov decision model for the joint optimisation. The budget allocation could be done between the two sets of activities and within each set. The model allowed the possibility of not exhausting the annual budget available each year, so that part of it could be spent more efficiently in later years. The authors conducted a case study based on some assumptions. The results showed that significant savings could be accrued by using such a joint optimisation approach in cross-category works.

4.4 Use of Multi-Criteria analysis in road sector

Frohwein and Lambert (1999) proposed a Multi-Criteria Decision-Making (MCDM) to aid the selection of road improvement projects for Virginia Department of Transportation, USA. Three factors - crash-risk reduction, performance improvement, and project cost are used as the criteria to aid the selection of competing projects. The author augured that decision could only be made by human; therefore, the approach did not assign any 'score' or 'priorities' to the projects. It used very simple chart to demonstrate information. In the project comparison chart, as shown in Figure 5, potential road improvement projects are depicted by circles whose area is proportional to the anticipated total cost in dollars. The horizontal and vertical positions of the circles in the chart are determined by the anticipated total travel time saved per peak hour in vehicle minutes and total number of crashes avoided per year. The chart can help decision makers to understand the trade-offs with respect to risk, performance and cost.

Figure 5 Project Comparison Chart



(Frohwein and Lambert, 1999)

5. FINDINGS

A comprehensive international literature review on investment decision-making in road sector was conducted (Table 2). Changes in decision-making concepts and processes are undergoing in many road agencies around the world. Multiple objective decision-making approaches can better accommodate social, environmental, economic, and political issues. Traditional engineering-economic evaluation is challenged by more advanced evaluation tools, such as Multi-Criteria evaluation.

Due to the complex nature of decision–making in road infrastructure investment, there is not a single method, which can solve all the problems. The choice of technique depends on the feature of the problem at hand, on the aims of the analysis, and on the underlying information base.

The main findings drawn from the literature review are as followings:

- Social, economic, environmental, political factors are currently considered in investment decision-making for road infrastructure asset management based on the personal judgment of the decision-makers, or a simple multi-criteria analysis.
- There is a gap between the capacities of the decision-making support systems and the requirements from decision-makers to make more rational and transparent decisions.
- The complexity in considering social, environmental, economic and political factor in decision-making varies at different management levels. At higher strategic planning level, more non-dollar factors are considered.
- The number of factors involved in decision-making varies based on the scope of the investment proposal. Traditionally, road agencies pay more attention on the evaluation of capital works. In some cases, social equity, safety, environmental issues have been considered in maintenance project selection. However, there is not a common base for the applications.
- Engineering-Economic Analysis forms one part of multiple objective decision-making.
- Various Multi-Criteria Decision Making tools are currently used in investment decision-making process for road infrastructure asset management. These are either in the form of a ranking or chart form, which provides information for decision makers.
- The choice of evaluation techniques depends on the feature of the problem at hand, on the aims of the analysis, and on the underlying information base.
- New indicators, which measure performance and investment outcomes based on agency goals of service delivery, government objectives, and community expectations, need to be developed.
- Project prioritisation should reflect community expectations, which can be collected through traditional surveys as well as use of new technology, such as Internet.

Table 2 Summary of International Literature Review

Countries, years	Current Practices in decision-making	Models and tools	Uncertainty and Risk assessment
Canada (2001)	• Benefit cost analysis • Preliminary consideration of social and environmental factors	• Engineering economic model • Simple forms of multi-criteria model	
Switzerland (2000)	• Benefit cost analysis • Expert knowledge, • Case studies, • Experiments & surveys	• Engineering economic model	
Netherlands (2000)	• Benefit cost analysis (BCA) with environmental and safety consideration	• Social economic model	Scenario assessment
UK (2001)	• Benefit cost analysis • Proposed decision-making framework for the consideration of social, political and environmental issues	• Engineering economic model	Scenario low and high assessment
Finland (1999)	• Benefit cost analysis • Preliminary framework for the consideration of social, political and environmental issues	• Engineering economic analysis • Simple forms of multi-criteria analyses	
Slovakia (2001)	• Benefit cost analysis • Limited qualitative Assessment for environmental impacts	• Engineering economic analysis • Simple forms of multi-criteria analyses	
Federal Highway Administration (2000)	• Benefit cost analysis • Recommendation for the consideration of user costs	• Engineering economic analysis	
Organisation of Economic Cooperation and Development (2002)	• Benefit cost analysis • Recommendation for the assessment of social, environmental impacts	• Socio-economic Benefit-Cost analysis • Multi-criteria analysis framework	
World Bank (2000)	• Benefit cost analysis • Recommendation for the assessment of environmental impacts	• Engineering economic analysis • HDM Series	• Sensitivity analysis of risk in economic evaluation
New Zealand (2000)	• Benefit cost analysis • Strategic factors, • Environmental factors and innovative features.	• Engineering economic model • Preliminary multi-criteria model	

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